State of Ohio
Environmental Protection Agency

Division of Surface Water

Total Maximum Daily Loads for the Mad River Watershed

Mad River in autumn at County Line Road

Final Report
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Ted Strickland, Governor
Chris Korleski, Director

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The U.S. Geological Survey completed the loading analysis for the Mad River watershed under a 319 grant. The USGS work was published as Open File Report 2006-5183 in 2006.

Many full- and part-time staff participated in field monitoring; chemistry analyses were provided by the Ohio EPA Division of Environmental Services.

Acknowledgment is also given to the property owners that allowed Ohio EPA personnel access to the Mad River and its tributaries.

EXECUTIVE SUMMARY

The Mad River watershed drains approximately 657 mi^2 and flows into the Great Miami River in Dayton, Ohio. The watershed is located in west-central Ohio in the counties of Logan, Champaign, Clark, Miami, Greene, and Montgomery. Urban areas in the watershed include Dayton, Fairborn, Springfield, Urbana and West Liberty. The Ohio Environmental Protection Agency evaluated the biological health and water quality of the watershed in 2003 and determined that several stream segments in the Mad River watershed do not support designated aquatic life uses or the recreational use.

Loading analyses[1] were completed for fecal coliform, nitrate, habitat and sediment (or bedload) in the watershed. Fecal coliform impaired the primary contact recreation use. Fecal coliform can be reduced through the elimination of cattle access to streams, the elimination of failing home sewage treatment systems, and the use of agricultural BMPs to filter nutrients and bacteria from surface runoff. Nitrate was elevated in ground water, including aquifers used for drinking water. Because of nitrate's soluble nature, the elevated concentrations can be reduced through reductions in nitrate loading to streams via surface runoff and ground water infiltration.

Habitat was the most common cause of impairment identified in the Mad River watershed. Habitat was evaluated through the Qualitative Habitat Evaluation Index. Habitat and sediment analysis are included in Section 2.2. An analysis of all areas is included in Appendix A. An example of a nitrate TMDL calculation is included in Appendix B.

Recommendations regarding improvements to water quality in the Mad River watershed are discussed in detail in Chapter 3.

[1] The U.S. Geological Survey completed loading analysis for fecal coliform and nitrate. Ohio EPA completed the loading analyses for habitat and sediment and adapted the USGS work into this TMDL document.

1.0 INTRODUCTION

The Mad River watershed (Figure 1) drains approximately 657 mi^2 and flows into the Great Miami River in Dayton, Ohio. The watershed is located in west-central Ohio in the counties of Logan, Champaign, Clark, Miami, Greene, and Montgomery. Urban areas in the watershed include Dayton, Fairborn, Springfield, Urbana and West Liberty.

The Ohio Environmental Protection Agency (Ohio EPA) evaluated the biological health and water quality of the watershed and determined that several stream segments in the Mad River watershed do not support designated aquatic life uses for Warmwater Habitat (WWH), Modified Warmwater Habitat (MWH) or Coldwater Habitat (CWH), or the Primary Contact Recreational use. Additional physical habitat impairments were determined using the Quality Habitat Evaluation Index (QHEI) scores (Rankin, 1989), which measure the overall habitat and ecosystem health. Table 1 summarizes the impairment causes and sources within each Assessment Unit (AU).

The Mad River and some of its tributaries were found to be impaired by fecal coliform bacteria. Other causes of impairment include nutrient and organic enrichment resulting from agricultural activities, urban runoff, or wastewater treatment plants. Habitat alteration because of channelization also has degraded several stream segments in the watershed (Ohio EPA, 2005).

Ambient biological, water column chemical and sediment sampling was conducted in the Mad River basin from June to October 2003. The study area included over 61 miles of the Mad River beginning in the headwaters and extending to near the confluence with the Great Miami River. Subwatersheds within the study area included Macochee Creek, Kings Creek, Nettle Creek, Buck Creek and Mud Run. Eighty-five (79.4%) of the sites fully met current or recommended aquatic life use. Sixteen (14.5%) of the sites partially met and six (5.6%) of the sites were not attaining their designated or recommended use. Three sites were located on watercourses that went dry. Consequently, an aquatic life use was not ascribed pending the development of headwater habitat designations, assessment protocols, and biocriteria.

The United States Geological Survey (USGS) completed a loading analysis of bacteria and nitrates for the Mad River watershed under a 319(h) grant from Ohio EPA. The USGS work was published as Open File Report 2006-5183 (Reutter *et al.*, 2006). Ohio EPA adapted the USGS loading work and added analyses of sediment and habitat to produce this TMDL document.

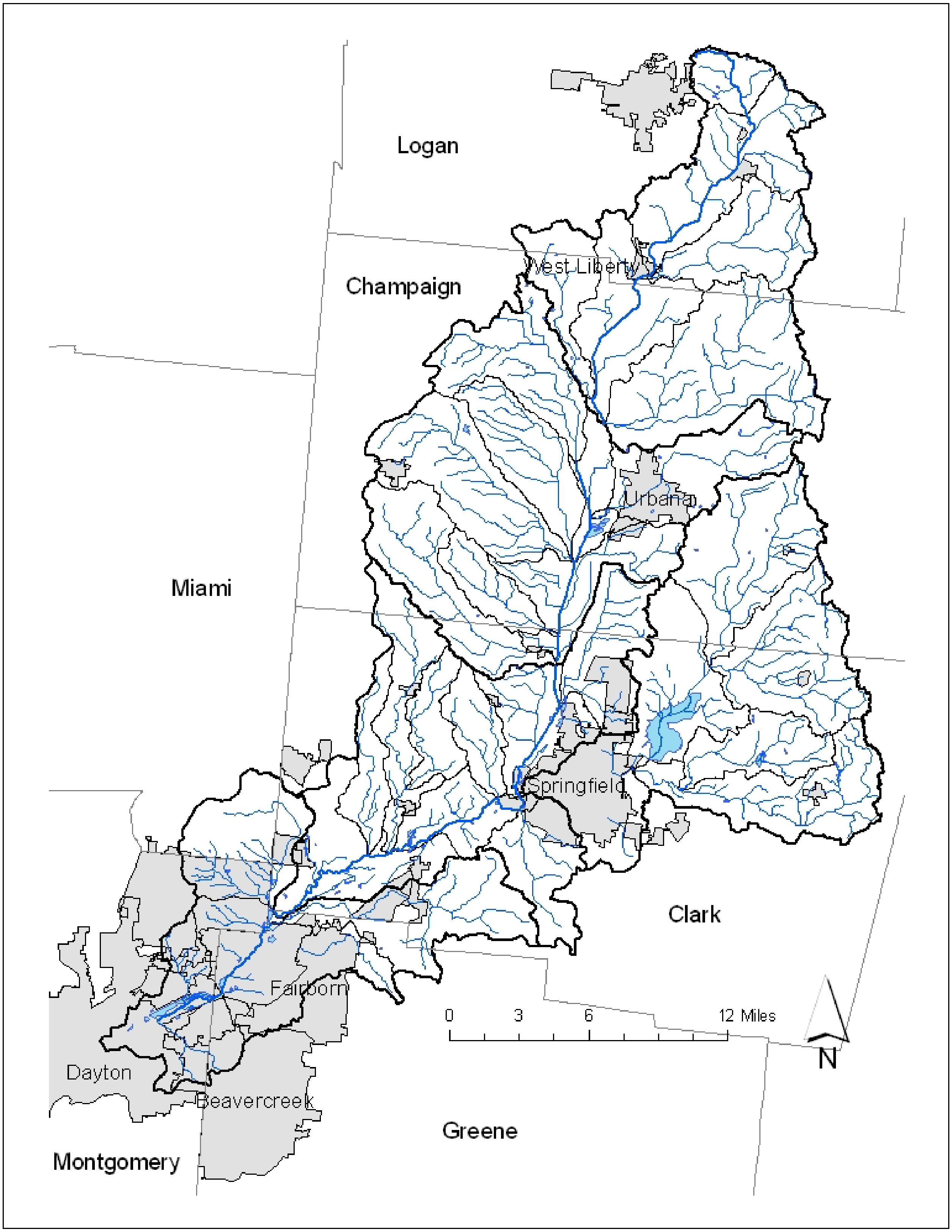

Figure 1. Boundaries of the Mad River watershed.

1.1 The Clean Water Act Requirement to Address Impaired Waters

The Clean Water Act (CWA) Section 303(d) requires States, Territories, and authorized Tribes to list and prioritize waters for which technology-based limits alone do not ensure attainment of water quality standards. Lists of these impaired waters (the Section 303(d) lists) are made available to the public for comment, then submitted to the U.S. Environmental Protection Agency (U.S. EPA) for approval in even-numbered years. Further, the CWA and U.S. EPA regulations require that Total Maximum Daily Loads (TMDLs) be developed for all waters on the Section 303(d) lists. The Ohio EPA identified the Mad River watershed (assessment units 05080001 150, 05080001 160, 05080001 170, 05080001 180, and 05080001 190) as impaired on the 2008 303(d) list (available at http://epa.ohio.gov/dsw/tmdl/2008IntReport/2008OhioIntegratedReport.aspx).

In the simplest terms, a TMDL can be thought of as a cleanup plan for a watershed that is not meeting water quality standards. A TMDL is defined as a calculation of the maximum amount of a pollutant that a waterbody can receive and still meet water quality standards and an allocation of that quantity among the sources of the pollutant. Ultimately, the goal of Ohio's TMDL process is full attainment of Water Quality Standards (WQS), which would subsequently lead to the removal of the waterbodies from the 303(d) list. Table 1 summarizes how the impairments identified in the Mad River watershed are addressed in this TMDL report.

Table 1. Summary of impairment causes and actions taken for the Mad River watershed.

Assessment Unit	Narrative Description	Causes of Impairment (Ohio EPA, 2006)	Action Taken
05080001 150 *Priority points: 8*	Mad River (headwaters to downstream Kings Creek)	Direct habitat alterations	TMDLs for habitat and nitrate
		Bacteria (recreation use)	Not addressed
05080001 160 *Priority points: 7*	Mad River (downstream Kings Creek to downstream Chapman Creek)	Organic enrichment/ dissolved oxygen (DO)	Not addressed[1]
		Nutrients	TMDL for nitrate
		Metals	Not addressed
		Priority organics	Not addressed
		Direct habitat alterations	TMDL for habitat
		Siltation	TMDL for sediment
		Bacteria (recreation use)	Not addressed
05080001 170 *Priority points: 8*	Buck Creek	Direct habitat alterations	TMDL for habitat
		Flow alteration	TMDLs for habitat and nitrate
		Bacteria (recreation use)	TMDL for fecal coliform
05080001 180 *Priority points: 9*	Mad River (downstream Chapman Creek to upstream Mud Creek); excluding Buck Cr. and Mad R. mainstem	Direct habitat alterations	TMDL for habitat
		Unionized ammonia	Not addressed
		Organic enrichment/DO	Not addressed
		Metals	Not addressed
		Priority organics	Not addressed
		Flow alteration	TMDL for habitat
		Bacteria (recreation use)	TMDL for fecal coliform
05080001 190 *Priority points: 8*	Mad River (upstream Mud Creek to mouth); excluding Mad R. mainstem	Organic enrichment/DO	Not addressed
		Direct habitat alterations	TMDL for habitat
		Flow alteration	TMDL for habitat
		Bacteria (recreation use)	Not addressed
Mainstem *Priority points: 8*	Mad River mainstem (large river assessment unit)	Flow alteration	TMDL for habitat
		Bacteria (recreation use)	Not addressed

[1] An SSO to the Village of St. Paris was noted during the 2003 watershed survey. In December 2003, an upgrade to a lift station was completed that eliminated the overflow pipe that bypassed the entire treatment process. Ohio EPA completed a dissolved oxygen survey downstream of the previous SSO in 2006 and found no violations of dissolved oxygen or other chemical parameters, indicating a permit-based resolution to this source of organic enrichment.

1.2 Public Involvement

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

A meeting was held in November 17, 2005 at which two presentations were given to the Upper Mad River Steering Committee about the Mad River TMDL project. The first presentation described the chemical and biological results of the field sampling survey of 2003. The second presentation gave an overview of the TMDL program in Ohio and summarized the results of the loading analysis by USGS. A second meeting was hosted by Beavercreek-Wenrick Greenway Community Land Trust (B-W Greenway) on February 16, 2006, similar in nature to the meeting given in November. The audience was from the middle geographic region of the Mad River watershed. A third meeting was held with the Lower Mad River Watershed group May 19, 2006. A presentation at this meeting discussed the 2003 sampling results as well as some of the major challenges and general solutions in the watershed.

Consistent with Ohio=s current Continuous Planning Process, the draft TMDL report was available for public comment from September 24 through October 26, 2009. A copy of the draft report was available on Ohio EPA=s Web page (http://www.epa.ohio.gov/dsw/tmdl/index.aspx). No public comments were received.

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

1.3 Organization of the Report

As mentioned above, ambient biological, water column chemical and sediment sampling was conducted in the Mad River basin from June to October 2003. Results of that study are published in the *Biological and Water Quality Study of the Mad River Basin, 2003* (Ohio EPA 2005).

In 2004, USGS obtained a Section 319(h) grant through the Ohio EPA to conduct a loading analysis for fecal coliform and nitrate in the Mad River basin. The USGS report (Reutter *et al.*, 2006), including a watershed description and model set-up and results, is included in Attachment 1. A summary of those results, including load allocations and wasteload allocations, is included in Chapter 2 of this report. Recommendations for improving water quality are included in Chapter 3. The QHEI analysis, including TMDLs for sediment and habitat, is included in Appendix A. An example of a nitrate TMDL calculation is included in Appendix B.

2.0 TOTAL MAXIMUM DAILY LOADS

Ohio EPA has assigned beneficial uses to the streams in the Mad River watershed. Beneficial uses are one component of Ohio's water quality standards, as summarized in Table 2. The coldwater habitat, warmwater habitat and modified warmwater habitat aquatic life uses are assigned to various streams within the Mad River watershed. The primary contact recreation use is assigned to all streams within the watershed. The large river assessment unit is designated as warmwater habitat for aquatic life and primary contact for recreation. There is one public drinking water supply in the watershed (Dayton at river miles 5.2 and 5.6 of the Mad River mainstem), but there were insufficient data to determine attainment status for the 2008 Integrated Report. Most designated streams are designated agricultural and industrial water supplies as well.

Ohio EPA established and checked the status of the beneficial uses in the Mad River watershed during the assessment of 2003. Where waters are not attaining their assigned use, a loading analysis to set total maximum daily loads (TMDLs) is necessary. USGS completed part of the loading analysis using the model Hydrological Simulation Program-Fortran (HSPF) to simulate nitrate and fecal coliform loading in the Mad River watershed. Ohio EPA completed habitat and sediment TMDLs for the watershed.

Table 2. Summary of the components and examples of Ohio's WQS.

<table>
<tr><th>WQS Components</th><th>Examples of:</th><th>Description</th></tr>
<tr><td>Beneficial Use Designation</td><td>1. Water supply uses
· Public drinking
· Agricultural
· Industrial

2. Recreational Uses:
· Beaches (Bathing waters)
· Swimming (Primary Contact)
· Wading (Secondary Contact)

3. Aquatic life habitat uses (partial list):
· Exceptional Warmwater (EWH)
· Warmwater (WWH)
· Modified Warmwater (MWH)
· Limited Resource Water (LRW)</td><td>Designated uses reflect how the water is potentially used by humans and how well it supports a biological community. Every waterbody in Ohio has a designated use or uses; however, not all uses apply to all waters (they are waterbody-specific).

Each use designation has an individual set of numeric criteria associated with it, which are necessary to protect the use designation. For example, a waterbody that was designated as a drinking water supply and could support exceptional biology would have more stringent (lower) allowable concentrations of pollutants than would the average stream.

Recreational uses indicate whether the water can potentially be used for swimming or if it may only be suitable for wading.</td></tr>
<tr><td rowspan="4">Numeric Criteria</td><td>1. Chemical</td><td>Represents the concentration of a pollutant that can be in the water and still protect the designated use of the waterbody. Laboratory studies of organism's sensitivity to concentrations of chemicals exposed over varying time periods form the basis for these.</td></tr>
<tr><td>2. Biological
Measures of fish health:
· Index of Biotic Integrity
· Modified Index of Well Being
Measure of macroinvertebrate health:
· Invertebrate Community Index</td><td>Indicates the health of the in-stream biological community by using these 3 indices (measuring sticks). The numeric biological criteria (biocriteria) were developed using a large database of reference sites.</td></tr>
<tr><td>3. Whole Effluent Toxicity (WET)</td><td>Measures the harmful effect of an effluent on living organisms (using toxicity tests).</td></tr>
<tr><td>4. Bacteriological</td><td>Represents the level of bacteria protective of the potential recreational use.</td></tr>
<tr><td>Narrative Criteria (also known as "free froms")</td><td colspan="2">General water quality criteria that apply to all surface waters. These criteria state that all waters shall be free from sludge, floating debris, oil and scum, color and odor producing materials, substances that are harmful to human, animal or aquatic life, and nutrients in concentrations that may cause algal blooms.</td></tr>
<tr><td>Antidegradation Policy</td><td colspan="2">This policy establishes situations under which the director may allow new or increased discharges of pollutants, and requires those seeking to discharge additional pollutants to demonstrate an important social or economic need. Includes State Resource Water Use Designation. Refer to http://www.epa.ohio.gov/dsw/wqs/index.aspx for more information.</td></tr>
</table>

2.1 Fecal Coliform and Nitrate

Reutter *et al.* (2006; Table 19) identified HUC14s in which fecal coliform reductions were necessary. They applied calibrated model loads to determine the maximum 30-day average of fecal coliform between 1999 and 2003. Any HUC14 in which at least one 30-day average exceeded the standard of 1,000 cfu per 100 mL was identified as needing a reduction. Ohio EPA, in order to determine load reductions using USGS data from Table 17 of Reutter *et al.* (2006), utilized existing loads segregated by source across a recreation season. Loads allocated to WWTPs were based on the average design flow and the permit limit. This analysis identified three HUC14s that needed load reductions instead of the original nine that USGS identified. The remaining six HUC14s identified by USGS will not receive TMDLs, though they would be prime candidates for protective actions, as discussed in Chapter 3.

There are numerous point source dischargers located within the Mad River watershed, as shown in Table 3. Thirty-two dischargers were included in the model. Only four of those are located in HUC14s in which reductions in fecal coliform are needed and one in a HUC14 in which nitrate reductions are needed, so wasteload allocations are made only for those five (Table 4).

Table 3. Dischargers with NPDES permits in the Mad River watershed (as of December 2009).

HUC14 (05080001)	Facility	Ohio EPA Permit No.	Type of Permit[1]	Flow (MGD)[2]
180 020	A&R Reck Sunset Terrace MHP	1PV00118	P	0.01
170 040	Beaver Valley Resorts	1PX00042	P	0.022
190 040	BP Products North America Dayton Terminal	1GU00299	G	Storm water[3]
190 040	BP Products North America Dayton Terminal	1IN00147	I	0.1
170 060	BP Springfield Bulk Plant	1IN00256	I	Storm water[3]
170 040	Bridgewood MHP	1PV00112	P	0.0075
170 050	Brookside Village MHP	1PV00097	P	0.04
170 060	Cascade Corp	1IS00020	I	0.576
170 020	Catawba SD	1PA00020	P	0.0225
190 020	CEMEX Inc	1IN00211	I	0.8
180 070	Chateau Estates MHP	1PV00056	P	0.035
180 030	Clearview MHP	1PV00098	P	NPR[4]
180 010	Crown Mini Mart	1GU00246	G	0.00002
190 040	Dayton WTP Ottawa	1GW00001	G	0.4
190 040	DP & L Co Office Bldg	1IB00022	I	Storm water[3]
180 030	Edgewood MHP	1PV00100	P	0.01
180 030	Enon Heights MHP	1PV00106	P	0.0135
180 030	Enon Sand and Gravel LLC	1IJ00062	I	Storm water[3]
180 080	Enon WTP	1IX00032	I	0.01
180 080	Fairborn Sand & Gravel	1IJ00026	I	Storm water[3]
190 020	Fairborn Water Reclamation Center	1PD00002	P	6
190 040	Flowserve Corp Service and Repair Division	1IN00034	I	Storm water[3]
170 040	Fuel Mart No 764	1PZ00092	P	Storm water[3]
160 040	Graham High School	1PT00088	P	0.009
190 030	Greenon HS	1PT00014	P	0.016
170 040	Harmony Estates MHP	1PV00007	P	0.05

HUC14 (05080001)	Facility	Ohio EPA Permit No.	Type of Permit[1]	Flow (MGD)[2]
180 020	Harvest Square MHP	1PV00082	P	0.03
190 020	Huber Mobile Home Court	1PV00088	P	0.0235
190 030	Hustead Elem Sch	1PT00069	P	0.01
150 020	Indian Hills MHP	1PV00108	P	0.0075
160 030	International Fiber Corp	1IH00020	I	1.25
180 020	International Truck and Engine Corp	1IN00022	I	0.1
190 010	JGR Properties Inc Sunshine MHP	1PV00019	P	0.015
160 030	Johnson Welded Products Inc	1IS00000	I	0.075
150 010	Kamp-A-Lott Campground	1PZ00109	P	0.012
150 020	Kirkmont Center	1PZ00069	P	0.01
180 020	KTK Industrial Park WWTP	1PZ00003	P	0.017
180 030	Moyno Inc	1IS00019	I	Storm water[3]
160 030	Neenah Paper FR LLC	1IA00003	I	NPR[4]
170 040	Northeastern HS	1PT00033	P	0.015
160 030	ORBIS Corp	1IN00093	I	0.48
170 060	OS Kelly Co Compressed Metallurgical Products	1IS00023	I	<0.005
180 080	Pleasant Valley Est MHP	1PV00105	P	0.052
180 040	Possum Primary and Middle School	1PT00121	P	0.011
150 010	Rockin Ridge Resort	1PR00101	P	0.0075
180 050	Rockway Primary Middle School	1PT00118	P	0.006
180 020	Rolling Hills MHP STP	1PV00047	P	0.046
180 050	Rolling Terrace MHP	1PV00058	P	0.03
160 040	Saint Paris WWTP	1PB00029	P	0.5
170 040	South Vienna STP	1PA00021	P	0.0772
180 080	Southwest WWTP	1PK00013	P	2
180 040	Springfield Beckley Municipal Airport	1PS00009	P	0.07
180 030	Springfield Waste Water Treatment	1PE00007	P	25
180 030	Tecumseh Court MHP	1PV00126	P	0.0078
170 040	Tomorrows Stars Resort Inc	1PX00043	P	0.018
160 060	Urbana Local Elem Sch	1PT00100	P	0.006
160 010	Urbana WPCF	1PD00011	P	3
160 010	Urbana WTP	1IY00300	I	0.036
190 040	US Dept of the Air Force	1IO00001	I	0.0266
160 060	Valley View MHP	1PY00002	P	0.01
150 040	West Liberty Salem School	1PT00066	P	0.021
150 040	West Liberty STP	1PC00012	P	0.5
190 020	Wright Patterson AFB	1IN00156	I	1.15

1 Three types of NPDES permits are listed: P (individual permit); I (industrial permit); G (general permit).
2 MGD = million gallons per day
3 “Storm water” under design flow indicates that the permit covers discharges associated with storm water; discharge quantity is dependent on storm events.
4 NPR = “no permit required”; these facilities are no longer operation, therefore no permit is required.

Table 4. Summary of NPDES discharger wasteload allocations in the Mad River watershed.

HUC14 (05080001)	Name of Discharger	Permit Number	Design Flow (MGD)	Permit Limit[1]	WLA
170 020	Village of Catawba WWTP	1PA00020	0.0225	N/A	18.36[2]
180 030	Springfield WWTP	1PE00007	25.0	1,000	946,352.50[3]
180 030	Clearview MHP[4]	1PV00098	0.015	1,000	567.81[3]
180 030	Enon Heights MHP	1PV00106	0.0135	1,000	511.03[3]
180 040	Springfield-Beckley Municipal Airport	1PS00009	0.07	1,000	2,649.79[3]

1 For fecal coliform, units are colony forming units / 100 milliliters.
2 Units are pounds per day.
3 Units are millions of colonies per day.
4 The WWTP at Clearview MHP is no longer operating. The “no permit required” was issued in July 2008.

Within each 14-digit hydrologic unit, total load and wasteload allocations were made for five sources (wastewater treatment plants, combined sewer overflows, municipal separate storm sewer systems, cattle in streams and failed septic systems) and overall nonpoint sources (distributed between eight different land uses).

The U.S. EPA Bacteria Indicator Tool (BIT) is employed as data manager for inputs of fecal coliform bacteria into HSPF, the model employed by USGS to develop load and wasteload allocations. BIT treats both failing home sewage treatment systems (HSTS) and (beef) cattle in the stream as point sources; thus fecal matter is not deposited on the land surface for subsequent accumulation and washoff events. However, these two bacteria sources function as nonpoint sources because exact locations of their effluent are regional or pervasive in nature. Statistics regarding rates of HSTS failure or number of beef cattle per subwatershed are generally estimated on a regional scale (such as by county); therefore, they often function as nonpoint sources on a watershed scale. Bacteria from other livestock waste (e.g., sheep, horse, or “grazing” beef cattle) within BIT are deposited on the land surface and subjected to washoff and accumulation.

Therefore, from a TMDL perspective, it is most logical to include these two sources in the nonpoint source category and assign them a load allocation. Ohio EPA divided wasteload allocations among the specific point source dischargers utilized in the model for those HUCs where reductions were needed.

Nitrate and fecal coliform load allocations and wasteload allocations are summarized in Tables 5 through 11. In these tables, “LA” represents load allocation, “WLA” represents wasteload allocation, “TMDL” represents total maximum daily load, “MOS” represents margin of safety, “HSTS” represents home sewage treatment systems, and “MS4” represents municipal separate storm sewer systems. Figure 2 displays each HUC14 in which reductions are needed and the locations of NPDES dischargers that are receiving fecal coliform WLAs. A step-by-step example of how nitrate TMDLs were calculated is included in Appendix B.

Wasteload allocations to MS4s were not made in the USGS report. MS4s are permitted entities and therefore considered to be point sources. However, the discharge from an MS4 comes from urban land washoff. Therefore, the percent of MS4 within each HUC14 was calculated and that percent multiplied by the total allocation to nonpoint sources (which, in the USGS report, included urban land uses). The difference was taken to obtain the new nonpoint source allocation. Where CSOs overlapped area covered in the MS4, the area covered by the CSO was subtracted from the MS4 area. In HUCs where TMDLs were calculated, MS4s received wasteload allocations (as subtracted from nonpoint source load allocations).

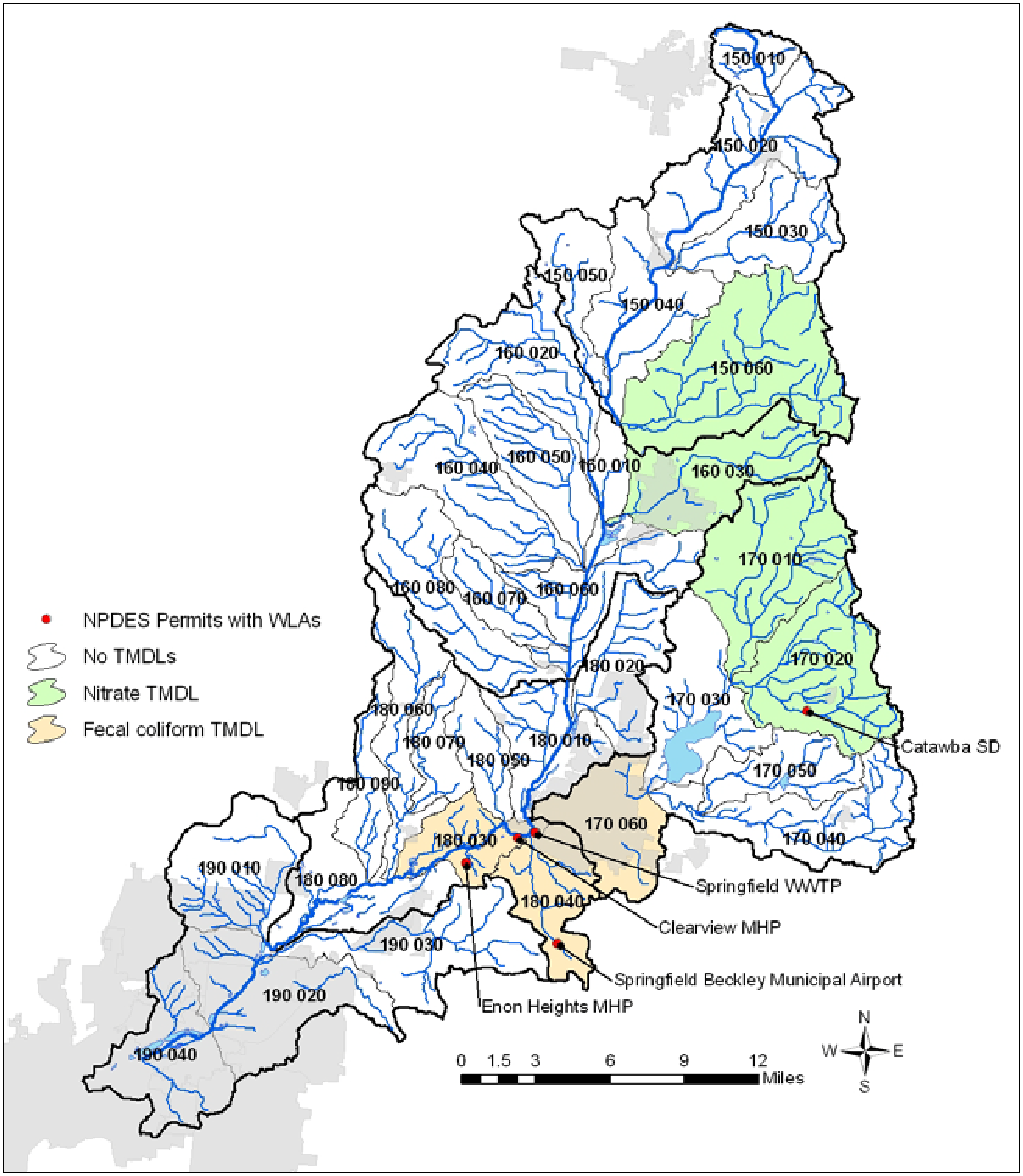

Figure 2. Subwatersheds in which TMDLs for nitrate or fecal coliform were calculated.

Table 5. TMDLs for assessment unit 05080001 150 060.

Kings Creek 05080001 150 060		Load (pounds/day)
Pollutant	**TMDL Component**	
Nitrate	Current Load	1,863.01
	TMDL = LA + WLA + MOS	1,205.48
	LA (Total)	1193.73
	LA: Nonpoint source runoff	1193.73
	LA: Failed HSTS	0
	LA: Cattle in streams	0
	WLA: MS4 (Urbana)	11.75
	TMDL Reduction (%)	35.3%

Table 6. TMDLs for assessment unit 05080001 160 030.

Dugan Run 05080001 160 030		Load (pounds/day)
Pollutant	**TMDL Component**	
Nitrate	Current Load	931.51
	TMDL = LA + WLA + MOS	602.74
	LA	463.90
	LA: Nonpoint source runoff	463.90
	LA: Failed HSTS	0
	LA: Cattle in streams	0
	WLA: MS4 (Urbana)	138.84
	TMDL Reduction (%)	35.3%

Table 7. TMDLs for assessment unit 05080001 170 010.

Buck Creek (above East Fork Buck Creek) 05080001 170 010		Load (pounds/day)
Pollutant	**TMDL Component**	
Nitrate	Current Load	1,698.63
	TMDL = LA + WLA + MOS	1,123.29
	LA	1,122.90
	LA: Nonpoint source runoff	1,122.90
	LA: Failed HSTS	0
	LA: Cattle in streams	0
	WLA: MS4 (Urbana)	0.39
	TMDL Reduction (%)	33.9%

Table 8. TMDLs for assessment unit 05080001 170 020.

East Fork Buck Creek 05080001 170 020		Load (pounds/day)
Pollutant	**TMDL Component**	
Nitrate	Current Load	1,452.05
	TMDL = LA + WLA + MOS	977.26
	LA	958.90
	LA: Nonpoint source runoff	958.90
	LA: Failed HSTS	0
	LA: Cattle in streams	0
	WLA: Village of Catawba WWTP	18.36
	TMDL Reduction (%)	32.7%

Table 9. TMDLs for assessment unit 05080001 170 060.

Buck Creek (below Beaver Creek to Mad River) 05080001 170 060		Load (million colonies/day)
Pollutant	**TMDL Component**	
Fecal Coliform	Current Load	11,309,523.81
	TMDL = LA + WLA + MOS	687,179.03
	LA	13,081.03
	LA: Nonpoint source runoff	13,081.03
	LA: Failed HSTS	0
	LA: Cattle in streams	0
	WLA: MS4 (Springfield)	5,975.34
	WLA: CSO (Springfield)	599,404.76
	TMDL Reduction (%)	93.9%

Table 10. TMDLs for assessment unit 05080001 180 030.

Mad River (below Buck Creek to above Donnels Creek [except Mill Creek and Rock Run); excluding Mad River mainstem 05080001 180 030		Load (million colonies/day)
Pollutant	**TMDL Component**	
Fecal Coliform	Current Load	10,714,285.71
	TMDL = LA + WLA + MOS	3,835,128.19
	LA	55,179.42
	LA: Nonpoint source runoff	55,179.42
	LA: Failed HSTS	0
	LA: Cattle in streams	0
	WLA: Springfield WWTP	946,352.50
	WLA: Clearview MHP	567.81
	WLA: Enon Heights MHP	511.03
	WLA: MS4 (Springfield)	16,384.56
	WLA: CSO (Springfield)	2,432,619.05
	TMDL Reduction (%)	64.2%

Table 11. TMDLs for assessment unit 05080001 180 040.

Mill Creek 05080001 180 040		Load (million colonies/day)
Pollutant	**TMDL Component**	
Fecal Coliform	Current Load	559,523.81
	TMDL = LA + WLA + MOS	453,975.62
	LA	64,070.17
	LA: Nonpoint source runoff	64,070.17
	LA: Failed HSTS	0
	LA: Cattle in streams	0
	WLA: Springfield-Beckley Municipal Airport	2,649.79
	WLA: MS4 (Springfield)	33,045.80
	WLA: CSO (Springfield)	308,812.50
	TMDL Reduction (%)	18.9%

2.1.1 Margin of Safety

As stated in the USGS report (Reutter *et al.*, 2006), a margin of safety was incorporated implicitly into the model from two model inputs: high failure rate of home sewage treatment systems and WWTP flow volumes were set to design flow. In addition, Ohio EPA included an explicit margin of safety of 10% in fecal coliform TMDLs. Further information is available on page 60 of the USGS report.

2.1.2 Allowance for Future Growth

There is little projected growth for the Mad River watershed, and in fact population declined in Dayton and Springfield from 1990 to 2000 (U.S. Census Bureau, www.census.gov). Therefore, no allowance for future growth was made in the calculations of the TMDL.

2.1.3 Seasonality and Critical Conditions

The following text, from Reutter *et al.* (2006), describes why seasonal variation is not important for the loading analysis:

> Seasonal variability in nitrate concentrations was neither indicated by the model nor evident from the observed data from the Mad River at St. Paris Pike streamflow gage. The absence of variability is likely caused by the large ground water component of streamflow, which delivers a relatively constant load of nitrate to the streams in the Mad River Basin. Seasonal variability in fecal coliform concentrations was not addressed in this study because the model was calibrated for the recreation season only (May 1st through October 15th).

The highest concentrations of pathogens are typically observed in the Mad River during winter months when primary contact recreation is unlikely to occur (Figures 11a, 11b and 12; Reutter, *et al.*, 2006). Addressing fecal coliform during the recreation season (May 1st through October 15th) addresses the critical conditions for that parameter (*i.e.*, the time when recreation is most likely to occur in streams).

2.2 Habitat and Sediment

Habitat alteration is a cause of impairment throughout the Mad River watershed. Poor habitat quality is an environmental condition, rather than a pollutant load, so development of a load-based TMDL to address this cause of impairment is not possible. However, the Qualitative Habitat Evaluation Index (QHEI) is a tool that provides a numeric value that is assigned to a particular stream segment based on the quality of its habitat. The QHEI evaluates six general aspects of physical habitat that include channel substrate, in-stream cover, riparian characteristics, channel condition, pool/riffle quality, and gradient and drainage area.

The numeric value assigned to a stream segment through the QHEI is qualitatively derived, but it is based on the presence and absence and relative abundance of unambiguous habitat features. QHEI scores can range from 12 to 100. The appropriate QHEI habitat target score is determined by statistical analysis of Ohio's statewide database of paired QHEI and Index of Biotic Integrity (IBI) scores. Simple linear and exponential regressions and frequency analyses of combined and individual components of QHEI metrics in relation to the IBI have been examined. The regressions indicate that the QHEI is significantly correlated with the IBI. QHEI scores greater than 75 indicate excellent stream habitat; scores between 60 and 75 indicate good habitat quality; and scores less than 45 demonstrate habitat not conducive to warm water habitat (WWH) (Ohio EPA, 1999). The Warmwater Habitat use designation QHEI target is 60. In addition, since habitat is strongly correlated with the IBI biocriteria, the QHEI provides a target and format to evaluate how habitat issues and impairments affect attainment of the aquatic life use designations. Degraded habitat has been identified as a contributing cause of non-attainment in several stream segments within the TMDL area. Targets for habitat characteristics for the Mad River watershed are presented in Table 13 and have been taken from the technical report entitled *Association Between Nutrients, Habitat, and the Aquatic Biota in Ohio Rivers and Streams* (Ohio EPA, 1999). Ohio EPA QHEI data are presented in Appendix A. Additional discussion of the Ohio EPA's QHEI methodology can be found in *The Qualitative Habitat Evaluation Index (QHEI): Rationale, Methods, and Application* (Rankin, 1989) Web link: http://www.epa.ohio.gov/dsw/bioassess/BioCriteriaProtAqLife.aspx - see QHEI section), and the 2006 updated manual found at the Web link: http://www.epa.ohio.gov/portals/35/documents/QHEIManualJune2006.pdf.

The analysis of the QHEI components as they relate to IBI scores led to the development of a list of attributes that are associated with degraded communities. These attributes are modifications of natural habitat and are listed in Table 12. Modified attributes are further divided into high influence and moderate influence attributes based on the statistical strength of the relationships. The presence of these attributes can strongly influence the aquatic biology, and the QHEI score itself may not reflect this effect. Since other, less influential habitat components are present, a QHEI score can be above 60 though habitat is impaired. Because of this, an accumulation of four modified attributes corresponds to fewer than 50% of sites achieving a WWH target IBI score of 40. High influence modified attributes are particularly detrimental. The presence of one is likely to result in impairment, and two will likely preclude a site from achieving an IBI of 40. The QHEI score of 60 or greater is correlated with IBIs of 40 or greater. These three factors appear to have about an equal weight. A complete habitat TMDL needs to reflect both a good QHEI score and the relative absence of these modified attributes (Ohio EPA, 1999).

The habitat TMDL equation presented in Table 13 reflects the relationship between the QHEI score, modified attributes and aquatic community performance. The TMDL is based upon a total score of three (3) and is the sum of three component scores each worth one point.

Table 12. QHEI modified attributes.

QHEI Categories	Modified Attributes	
	High Influence	Moderate Influence
QHEI Score	- Channelized or no recovery - Silt/muck substrate - Low sinuosity - Sparse/no cover - Maximum pool depth < 40 cm (wadeable streams only)	- Recovering channel - Sand substrate (boat sites) - Hardpan substrate origin - Fair/poor development - Only 1-2 cover types - No fast current - High/mod embeddedness - Ext/mod riffle embeddedness - No riffle

Table 13. Targets for the habitat TMDL.

Scores for the TMDL							
QHEI score ≥ 60	+1	One or less of the high influence attributes present	+1	Four or less of the modified attributes present (high and moderate influence together)	+1	=	3

Flow Alteration
Habitat alteration can result in flow alteration, which is a listed cause of impairment in the Mad River watershed. Under certain circumstances flow alteration can be viewed as the hydrological consequences of habitat alteration. For example, in an agricultural setting, channelization of streams to facilitate drainage often exacerbates hydrological extremes; high flows get higher and low flows get lower. The high flows contribute to entrainment of excess sediment in the stream system, and the low flows exhibit low dissolved oxygen and high temperatures (U.S. EPA, 2003). For stream assessment areas where flow alteration is identified as the cause of impairment, the habitat QHEI is carried out in this report.

Sediment
In the Mad River watershed, one assessment area has sedimentation listed as a cause of impairment in addition to habitat alteration. In order to address this, numeric targets for sediment are also based upon the QHEI metrics. The QHEI substrate, riparian characteristic, and channel metrics all evaluate stream attributes related to sediment. Each of these factors influences the degree to which sediment affects a stream, and cumulatively serves as its numeric target.

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

The individual components of the sediment TMDL are QHEI metric scores for substrate, channel and riparian. These metric target scores are based on the same associations made between QHEI and IBI results as explained in the habitat TMDL above (Ohio EPA, 1999). Table 14 shows the minimum scores expected for the sediment TMDL.

Table 14. Targets for the sediment TMDL.

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

2.2.1 Results

Figures 3 and 4 show the QHEI scores for all sites in the watershed grouped by attainments status. The figures show that all but a small number of the fully attaining sites have QHEI scores above the target. The majority of sites that are impaired have QHEI scores less than 60. This demonstrates the importance the quality of the habitat has on attaining water quality standards in Ohio.

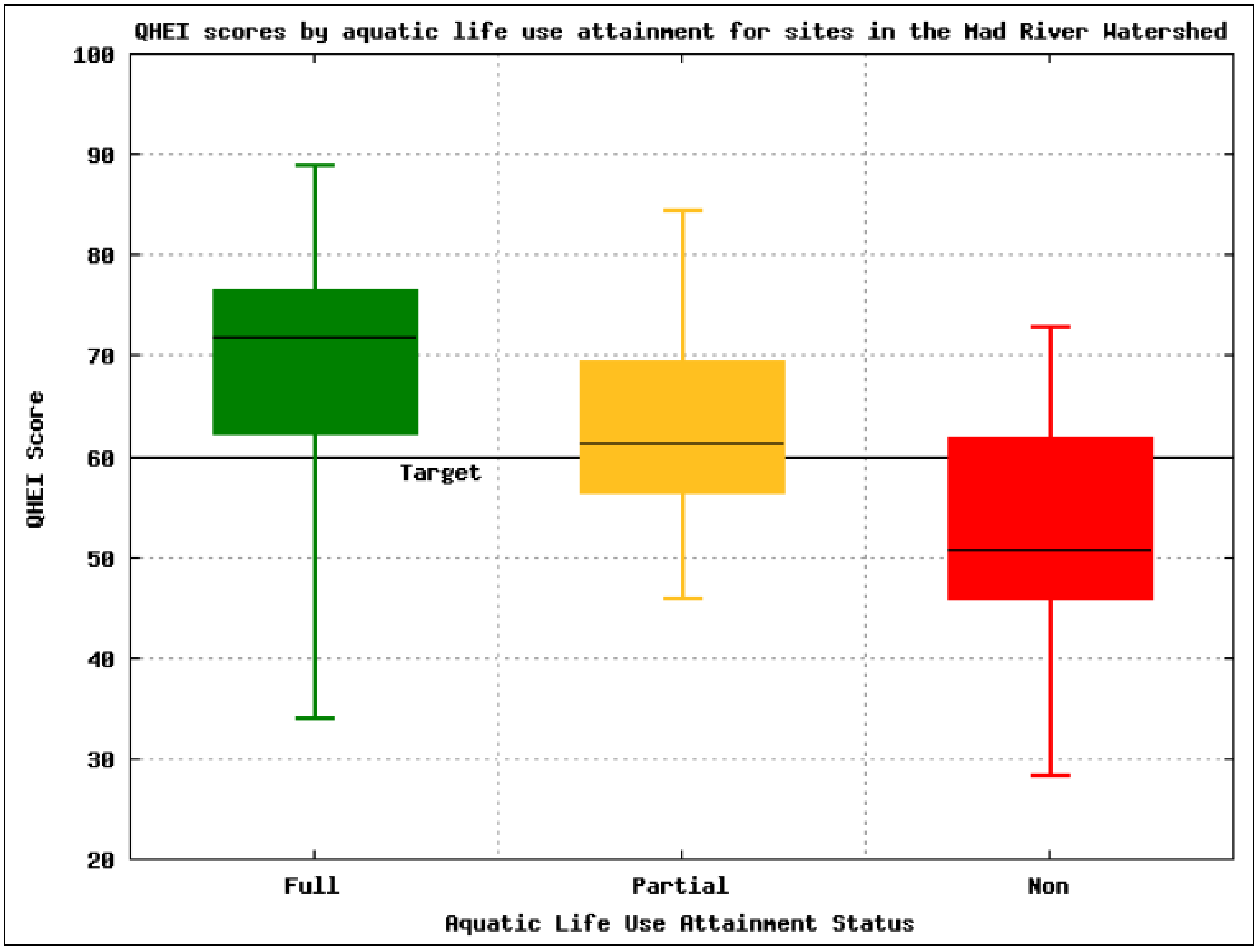

Figure 3. Comparison of habitat quality and biological response.

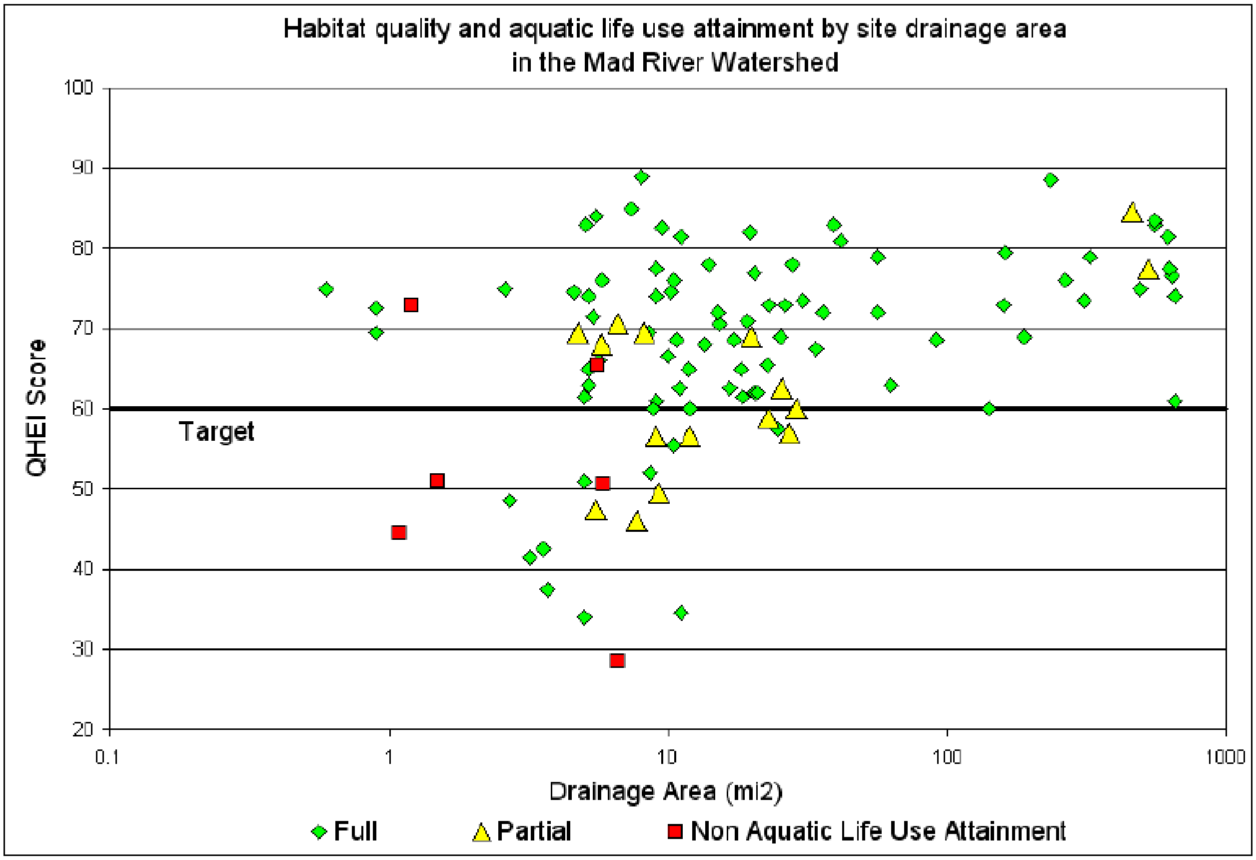

Figure 4. Comparison of habitat quality and biological response distributed by drainage area of sampling site.

The habitat and sediment TMDL results are summarized in Table 15. The sediment and habitat allocations are site-specific; only sites impaired in aquatic life use are shown. Applicable targets per component are shown in the header row of the table. The information presented in the body of the table is organized by stream and site river mile. The existing scores for each category and the total existing bedload (sediment) and habit score is defined. The percent deviation the actual bedload score from the allowable sediment score is shown followed by the main impaired QHEI category of the three used in determining the bedload score. The existing total habitat score per site can be compared to the allowable habitat score to make the same deviation determination. This table shows what components of the habitat need improvement and to what degree, and it can be used to guide management decisions and implementation activities.

Table 15. Sediment and habitat TMDLs for sites impaired in aquatic life use in the Mad River watershed.

		Sediment TMDL						Habitat TMDL						
	Use	Allocations			TMDL			Allocations			Subscore			TMDL
TMDL Targets	*WWH*	*≥13*	*≥14*	*≥5*	*≥32*			*≥60 = 1 pt*	*<2 = 1 pt*	*<5 = 1 pt*				*3 pts*
Existing Scores Stream/River (Use) *indicates aquatic life use is not being supported*	**River Mile**	QHEI Categories: Substrate	Channel	Riparian	Total Bedload Score	% Deviation from Target	Main Impaired Category if any	QHEI Score	# of High Influence Attributes	Total # of Modified Attributes	QHEI	High Influence	# Modified Attributes	Total Habitat Score
Mad River below Macochee Cr. to above Kings Cr. [except Glady Cr.] 05080001 150 040														
Macochee Ditch (CWH)[1]	0.7	6	10.5	3.5	20	38%	substrate	46	3	7	0	0	0	0
Kings Creek 05080001 150 060														
Kings Creek (CWH)[1]	3.9	13	10	4	27	16%	channel	60	2	7	1	0	0	1
Muddy Creek 05080001 160 020														
Muddy Creek (CWH)[1]	6.3	14	6.5	3	23.5	27%	channel	56.5	2	5	0	0	0	0
Dugan Run 05080001 160 030														
Dugan Run (WWH)[2]	1.2	16.5	11	5.5	33	---	channel	59	1	7	0	1	0	1
Nettle Creek [except Anderson Cr.] 05080001 160 040														
Nettle Creek (CWH)[3]	2.8	13	13	4	30	6%	riparian	69	0	3	1	1	1	3
Trib. to Nettle Creek (RM 8.80) (WWH)[2]	2.7	14	6	4.5	24.5	23%	channel	44.5	4	9	0	0	0	0
	2.6	13.5	16	9.5	39	---	---	73	1	5	1	1	0	2
Mad River below Nettle Cr. to above Chapman Cr. [except Storms Cr.] 05080001 160 060														
Stony Creek (WWH)[4]	0.7	11	10	4	25	22%	channel	51	3	9	0	0	0	0

Table 15 (cont.). Sediment and habitat TMDLs for sites impaired in aquatic life use in the Mad River watershed.

		Sediment TMDL						**Habitat TMDL**						
TMDL Targets	**Use**	Allocations			TMDL			Allocations			Subscore			TMDL
	WWH	*≥13*	*≥14*	*≥5*	*≥32*			*≥60 = 1 pt*	*<2 = 1 pt*	*<5 = 1 pt*				*3 pts*
Existing Scores Stream/River (Use) *indicates aquatic life use is not being supported*	**River Mile**	QHEI Categories: Substrate	QHEI Categories: Channel	QHEI Categories: Riparian	Total Bedload Score	% Deviation from Target	Main Impaired Category if any	QHEI Score	# of High Influence Attributes	Total # of Modified Attributes	QHEI	High Influence	# Modified Attributes	Total Habitat Score
Chapman Creek 05080001 160 080														
Chapman Creek (CWH)[4]	10.1	17	12.5	7	36.5	---	channel	68	2	4	1	0	1	2
Buck Creek below E. Fk. to above Beaver Cr. 05080001 170 030														
Buck Creek (WWH)[1]	6.4	15.5	10	4.5	30	6%	channel	69.5	2	4	1	0	1	2
Mad River below Chapman Cr. to above Buck Cr. [except Moore Run] 05080001 180 010														
Pondy Creek (WWH)[5]	1.1	16	6.5	5.5	28	13%	channel	47.5	4	7	0	0	0	0
Moore Run 05080001 180 020														
Moore Run (WWH)[1, 2]	4.1 [1]	1	5.5	4.5	11	66%	substrate	28.5	5	10	0	0	0	0
	2.5 [2]	3.5	8	5	16.5	48%	substrate	49.5	4	8	0	0	0	0
Kenton Creek (WWH)[1]	0.7	16	10.5	6	32.5	---	channel	69.5	2	4	1	0	1	2
Mud Creek 05080001 190 010														
Mud Creek (WWH)[4]	5.0	11.5	9	5	25.5	20%	channel	50.5	3	9	0	0	0	0
	2.5	14.5	9	4.5	28	13%	channel	56.5	3	7	0	0	0	0

Table 15 (cont.). Sediment and habitat TMDLs for sites impaired in aquatic life use in the Mad River watershed.

		Sediment TMDL						Habitat TMDL						
	Use	Allocations			TMDL			Allocations			Subscore			TMDL
TMDL Targets	*WWH*	*≥13*	*≥14*	*≥5*	*≥32*			*≥60 = 1 pt*	*<2 = 1 pt*	*<5 = 1 pt*				*3 pts*
Existing Scores Stream/River (Use) *indicates aquatic life use is not being supported*	**River Mile**	QHEI Categories			Total Bedload Score	% Deviation from Target	Main Impaired Category if any	QHEI Score	# of High Influence Attributes	Total # of Modified Attributes	QHEI	High Influence	# Modified Attributes	Total Habitat Score
Mud Run 05080001 190 030														
Mud Run (WWH)[1]	0.8	10	10	5	25	22%	channel	57	2	10	0	0	0	0
Trib. to Mud Run (RM 9.8) (WWH)[5]	0.7	14	16	7.5	37.5	---	---	65.5	1	2	1	1	1	3
Mad River below Huffman Dam to Great Miami River 05080001 190 040														
Lilly Creek (MWH)[6]	0.1	15	12.5	9	36.5	n/a	channel	70.5	0	5	---	---	---	n/a
Mad River below Donnels Cr. to above Mud Cr. [except Jackson Cr.] Large River Assessment Unit														
Mad River (WWH)[1]	17.5	17	11	5.5	33.5	---	channel	77.5	1	4	1	1	1	3

1 Aquatic life use is impaired by habitat and/or flow alterations.
2 Aquatic life use is impaired by habitat alterations among other causes (e.g., nutrients).
3 Aquatic life use is impaired by siltation (sand – possibly natural causes).
4 Aquatic life use is impaired by something other than habitat or sediment. However, bedload and/or habitat scores fall below targets.
5 Aquatic life use is impaired by natural conditions.
6 Aquatic life use is impaired by habitat, but no MWH targets have been developed, so a TMDL cannot be completed.

There is one site at which the field biologists, using field observations and best professional judgment, determined that habitat alterations were a cause of impairment, but the QHEI and sediment targets are fully met: Mad River at RM 25.5/25.8 (in HUC 05080001 180 030).

The sediment and habitat TMDL analyses were completed because habitat and/or sediment were listed as causes (Ohio EPA 2005) and the results of that analysis are presented in Appendix A. This situation illustrates that the QHEI tool, like all TMDL calculation methods, is imperfect. Sometimes one aspect of habitat is causing impairment because of its severity but the other habitat targets are met at a site. For example, on the Mad River at river mile 25.8, channelization was the main cause of partial attainment of aquatic life use. However, while the moderate influence attributes pertaining to siltation and channelization were noted, there were no high influence attributes and only three moderate influence attributes. In addition, there were a large number of warmwater attributes that were helping the stream, though they were insufficient to reach attainment. In this case, then, the habitat TMDL targets were met overall.

In addition, several sites were found to have habitat and sediment values below the target values but habitat and sediment were not identified as causes of impairment. The sites are listed below. However, because habitat and sediment values were also deficient, the analysis is included in Table 15.

HUC	Stream	RM	Cause
05080001 160 060	Stony Creek	0.7	Organic enrichment
05080001 160 080	Chapman Creek	10.1	Unknown; possible nutrient enrichment
05080001 190 010	Mud Creek	5.0 and 2.5	Organic enrichment/dissolved oxygen

3.0 WATER QUALITY IMPROVEMENT STRATEGY

This section provides a strategy for improving water resources in the Mad River watershed to the full attainment of applicable water quality standards (WQS). The actions recommended are aimed at reaching the water quality goals and load reductions discussed in this report and address the documented sources of impairment (Ohio EPA, 2005). Some recommendations rely on regulatory authority, while others are based on voluntarily action.

Several factors related to the recommended actions are addressed, including:

- Water quality problems addressed
- Effectiveness
- Relative costs
- Potential barriers to success
- Resources available for assistance
- Locations where activities should take place
- Participation needed for successful implementation
- Timeframe under which actions should occur

A process for validating that the recommended actions are effectively achieving the water quality goals is also provided. Details include a recommended monitoring strategy, conditions sufficient to warrant revising the existing recommendations, and a methodology for selecting alternative actions.

This remainder of this chapter is organized as follows:

- Implementation approach and rationale
- Recommendations for each of the sub-watersheds (assessment units)
- Reasonable Assurance that recommended actions are carried out
- Process for evaluation and revision of the water quality improvement strategy

3.1 Implementation Approach and Rationale

TMDLs are developed for ***fecal coliform*** to address impairment of recreational uses and also for ***nitrate, habitat and sediment*** to address impairment of aquatic life uses. Recreational use impairment is pervasive throughout most of the basin while aquatic life use impairment occurs more discretely on a segment by segment basis. The recommendations that follow provide a basic approach for addressing each of these causes of impairment and their respective sources. Also included are recommendations regarding habitat, stream geomorphology, floodplain connectivity, and storm water management that are intended to provide further enhancement and protection of aquatic life uses.

It is possible that some stream segments not surveyed are impaired by sources that have been identified in surveyed segments. A broad application across the watershed of some of the recommendations is likely to abate those sources as well.

The discussion in this section is organized according to the cause of impairment, providing a broad overview of what is necessary for meeting and maintaining water quality standards and often includes technical or scientific rationale. Recommendations being made for specific locations will be discussed in the following section, and a more detailed discussion regarding causes and sources of impairment can be found in the Biological and Water Quality Study for the Mad River Basin, 2003 (Ohio EPA, 2005).

A source-reduction scenario was modeled by USGS for both fecal coliform and nitrate. The scenario for reducing fecal coliform included the elimination of failing septic systems, the elimination of direct access of cattle to streams, the reduction of fecal coliform loads from CSOs by 95%, and ensuring compliance at WWTPs. The scenario for reducing nitrate included the elimination of failing septic systems, the elimination of direct access of cattle to streams, and a 30% reduction in nitrate runoff. These reductions for both scenarios would be applied watershed-wide.

3.1.1 Pathogens

Recreation use impairments in the rural part of the Mad River watershed (i.e., parts of Champaign and Clark counties) are primarily attributable to agricultural and pasture lands. Livestock farming is not intense in the watershed, but a number of operations are sources of impairment. Wildlife is believed to make a relatively small contribution to the pathogen load. In urban areas, primarily the City of Springfield, pathogen contamination is primarily the result of CSOs and SSOs. Wastewater treatment plants were also sources of pathogens. Of the total fecal coliform load in the Mad River basin, approximately 67% of the load was contributed by WWTPs and CSOs (Reutter *et al.*, 2006).

Significant work has been done in the last ten years to reduce fecal coliform loading in the watershed. In Clark County in particular, multiple older WWTPs have been taken off-line, connecting the areas serviced by those plants to regional sewer systems. Multiple WWTPs have been upgraded to better treat sewage. Several unsewered communities have been connected to sewer systems. Findings and orders have been issued in some instances where necessary. The Division of Surface Water's Permit Compliance Assistance Program has also been active in the watershed to help WWTPs improve operations at their facilities. Additionally, a schedule for implementing Phase I of the long-term control plan in Springfield is incorporated into their NPDES permit.

Combined Sewer Overflows / Sanitary Sewer Overflows
There was one SSO in the Village of St. Paris. A Permit to Install (PTI, No. 05-12751) was issued to the Village on August 5, 2003. The installation of a lift station took place shortly thereafter, so the chance of future SSOs has been reduced.

There are 59 CSOs in the City of Springfield that contribute to recreational use impairments. One WWTP system relief discharge exists in Springfield that discharges directly into the Mad River. The CSOs drain portions of four 14-digit HUCs (170 060, 180 010, 180 020, and 180 040). However, the outfalls to streams for the CSOs are located in HUCs 170 060, 180 030 and 180 040. Therefore, allocations (see chapter 2) are made for the latter three HUCs.

The City of Springfield has submitted a three-phase long-term control plan (LTCP) to the Ohio EPA for approval. Ohio EPA incorporated a schedule to complete projects from Phase I and II of the plan into the NPDES permit. Agreement could not be reached, however, regarding the remaining projects (mostly in Phase III). The projects in the NPDES permit include construction of express sewers, construction of a ballasted flocculation treatment unit at one outfall, and a CSO industrial user storage evaluation. The LTCP submittal has been referred to U.S. EPA for further action, and a Consent Decree is anticipated.

Home Sewage Treatments Systems

Addressing HSTS as a source of bacterial pollution is best served by eliminating reliance on these systems for treating human wastes. Connecting unsewered residences to centralized treatment systems is an effective and permanent way to eliminate this source of impairment. However, it is not practical to extend sanitary sewers to some of the problematic areas in the watershed because of prohibitive costs and the potential for environmental degradation during the installation of sewer lines. An effective alternative to centralization requires improving failed systems through upgrades or the installation of new systems. Installation of new systems must be in compliance with applicable regulations (OAC 3701-29). Ensuring that HSTS be properly maintained is important for preventing pollution problems in the future.

Any direct routing of septic lines to surface waters, such as by-passing leach fields and/or septic tanks, is an illegal practice (OAC 3701-29) and creates unhealthy and unsafe conditions. These types of connections should be identified and enforcement and/or other actions be taken to correct the situation. Local health departments are responsible for responding to complaints issued regarding illicit connections and are expected to be proactive in locating them (OAC 3701-29).

Livestock Production

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 the construction of adequate storage facilities and storm water controls. Manure that is land applied should be done so according to guidance from the Natural Resource Conservation Service (NRCS) and applicable standards (Standard 633) or a Comprehensive Nutrient Management Plan (CNMP) that is specific to a given operation. Manure discharges occurring through sub-surface drainage tiles following field application can often be avoided if drainage water management control structures are in place. NRCS conservation practices that are appropriate for abating this 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 may also be a viable way to utilize livestock waste and reduce the threat to water quality. The stabilization of the manure materials during the composting process and the proper handling and storage of this material reduces the risk of pollutant loading via storm water runoff. More information regarding composting can be found on the Ohio Composting and Manure Management Program's web site (http://www.oardc.ohio-state.edu/ocamm/).

Additionally, cattle have free access to streams in some portions of the Mad River watershed, contributing direct inputs of fecal coliform and nitrate to the system. Cattle should be fenced out the streams entirely, eliminating this source of pathogens and nitrate, according to NRCS practice 382 (Livestock Exclusion Fencing).

Agricultural Row Crops

Manure is applied as fertilizer primarily to corn in the Mad River basin, which makes up approximately 40% of the cropland in the watershed, in March and April. Manure is applied to winter wheat from August through November. Information regarding pathogens from manure application was used to assign accumulation rates and storage capacities to the agricultural lands during application periods for use in the model (Reutter *et al.*, 2006). Methods to reduce pathogen input via agricultural runoff are similar to those to reduce nitrate and are discussed in more detail in Section 3.1.2.

3.1.2 Nitrate

Nitrate was not noted by Ohio EPA biologists as a widespread cause of aquatic life use impairment in the Mad River watershed. However, ground water is known to show elevated levels of nitrate in parts of the watershed (Ohio DNR, 1996; Rowe *et al.*, 2004). The high infiltration rate of the sand and gravel aquifers in the Mad River watershed supports the strong ground water discharge/base flow component of the Mad River. The high infiltration rate of surface water to the local aquifers makes them sensitive to transportation of surface contaminants. The presence of elevated nitrate in aquifers, predominantly sourced from agricultural inputs in the Mad River watershed, documents this process. The 1996 Ohio DNR report *Identification of the Hydrologic System and Nonpoint Source Impacts in the Mad River Watershed* indicates the average nitrate concentration from the wells that were sampled for the study was 2.54 mg/L nitrate. Numerous wells post nitrate values of 4-9 mg/L in the 1993-1995 sampling with scattered results that exceed the nitrate maximum contaminant level (MCL) of 10 mg/L (results listed by address in Appendix C of the report referenced above).

In the summer of 2005, the Division of Drinking and Ground Waters (DDAGW) assisted Ohio DNR with water quality sampling in the Mad River watershed. Selected results for wells with elevated nitrate are provided below. The locations of these wells are indicated in Figure 5, showing the area due north of Urbana. The nitrate concentrations ranged from non-detect to 13.4 mg/L. These wells were oxidized to depths of more than 65-70 feet, but some of the private wells sampled were reduced with the result that nitrate was non-detect. The samples listed below exhibit nitrate concentrations greater than 9.0 mg/L. Elevated nitrate is clearly an issue of concern for the Mad River watershed aquifers.

Private Wells sample north of Urbana – June 2005

- DW2 – at fish farm - 9.38 mg/L
- DW7 – just east of fish farm - 9.44 mg/L
- DW9 – one-half mile east of Route 68 – 9.9 mg/L

Ohio DNR Multiport Monitoring Wells – Just north of Urbana

- CMT1 at south end of Urbana Airport west side of Route 68 – June 2005
- Sample ports from 32 to 66 feet (evenly spaced); nitrate concentrations ranged from 9.4 to 10.7 mg/L.
- CMT2 north end of runway, east side of Route 68 – July 2005
- Sample ports from 29 to 65 feet (evenly spaced); Nitrated concentrations ranged from 11.5 to 12.4 mg/L.
- Monitoring well (MW8) at this site sampled on June 28, 13.6 mg/L

Nitrate loads in the Mad River watershed come primarily from land application of manure and commercial fertilizer (Reutter *et al.*, 2006). Nitrate is highly soluble and enters streams in one of two ways: via surface runoff or via ground water seeps. The ground water in the Mad River watershed is quite shallow and in many places flows into the Mad River and its tributaries. Nitrate can easily infiltrate into ground water because of its high solubility, which provides a second means of entering streams. The model used by USGS (Reutter *et al.*, 2006) indicates that nonpoint sources contributed 74% of the nitrate load for the Mad River watershed. Other sources include failing HSTS and livestock manure, and abatement strategies for these sources of nitrate are identical to those discussed earlier (see Section 3.1.1). In the urban and developing areas of the watershed, polluted runoff from residential and commercial land uses is creating elevated nitrate loads. Because of the elevated nitrate levels in ground water used for drinking water and the contribution of surface runoff, cattle access to streams and failing HSTS, it was considered advisable to develop a target value for sources in the Mad River watershed that would be protective of the drinking water supplies. For purposes of this study, Ohio EPA established a target mean nitrate concentration of 5 mg/L in the Mad River watershed that corresponds to a public water supply "action alert" that is equal to 50 percent of the Maximum Contaminant Level for drinking water (Ohio Revised Code 3745-81-23). Based on this target value, USGS concluded from the analysis that four 14-digit HUCs needed nitrate reductions. Those reductions are displayed as load allocations in chapter 2 of this report.

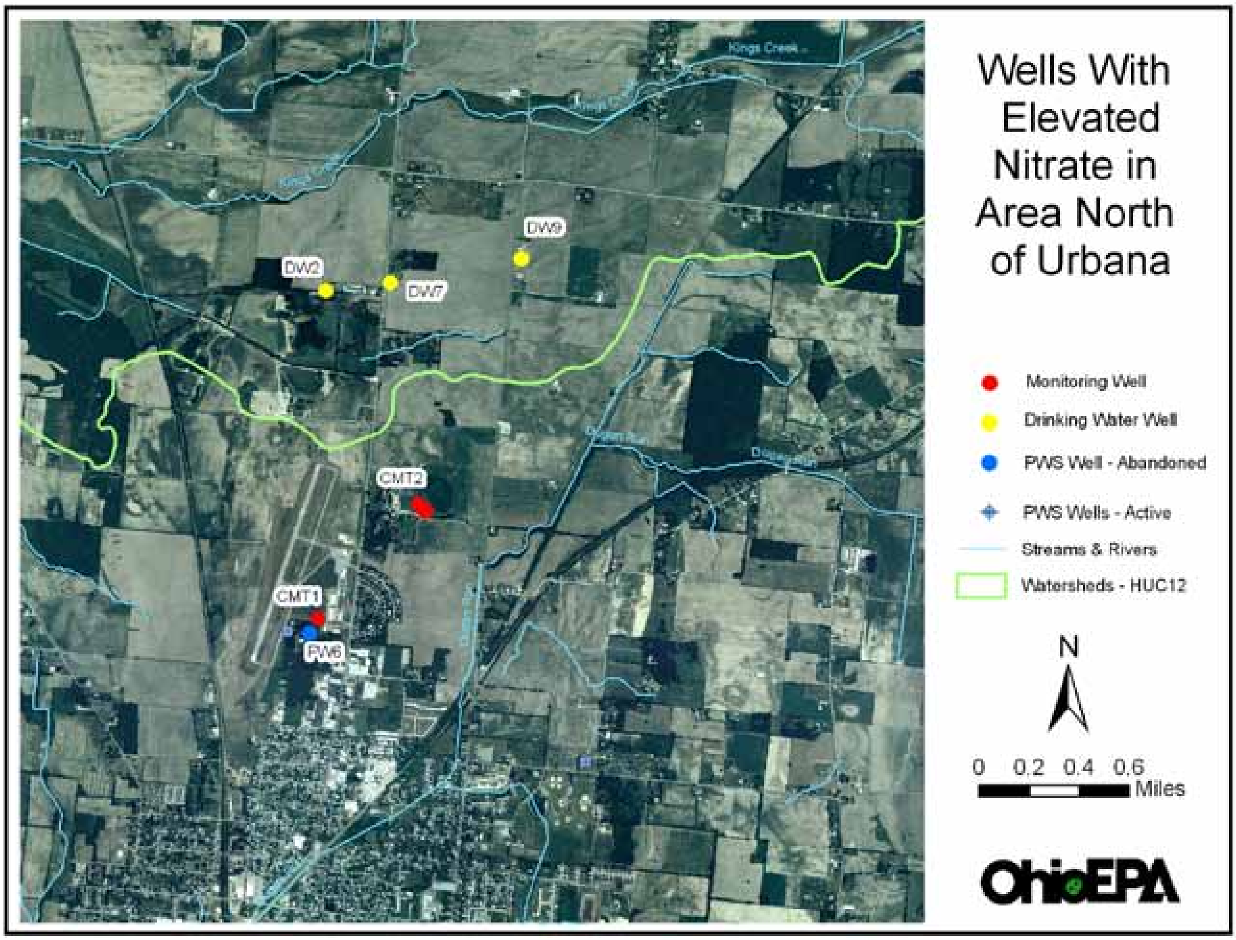

Figure 5. Well locations north of Urbana.

Point Source Discharges

No nitrate/nitrite reductions are required from point source dischargers because there are no point source dischargers in the four hydrologic units that require further nitrate load reductions. Monitoring for nitrate/nitrite and total phosphorus is recommended for those publicly owned treatment works that do not already collect those parameters and that have design flows greater than 25,000 gallons per day.

While not prevalent in the watershed, total phosphorus was identified as a parameter of concern in HUC 05080001 180 at the Navistar, Inc. (formerly International Truck and Engine) WWTP, which discharges to an unnamed tributary to Moore Run. Effluent data from 2005 through summer 2007 show an average discharge of 11.8 mg/L. Including a high concentration in July

2007 (386 mg/L associated with a primary pretreat and prime line cleanout event), the average over the last two years is 21.4 mg/L. In late 2007, Navistar was required to begin a study to identify sources of phosphorus and where there may be opportunities to reduce it. The plan is also required to identify what actions Navistar has taken or plans to take to reduce phosphorus in its discharge.

Sources from Agricultural Runoff and Drainage Infrastructure

Many management practices abate sediment and nutrient loading to surface waters from crop fields. Examples include vegetated buffer strips, grassed waterways, nutrient management, conservation tillage, conservation crop rotations, wetland restoration, and water table management. For decades conservation professionals have researched these practices, improved their effectiveness, and worked with private landowners to implement them. Programs currently funded under the Farm Bill provide cost share and dollar incentives for land set asides, and structural and management conservation practices.

Nutrient management might include NRCS practices such as manure management (practice 633); animal waste storage structures (practice 313); manure transfer practices (practice 634); and grass manure spreading strips (practice 635). A combination of these practices can often be most effective at managing the nutrients from manure and protecting water quality. A comprehensive nutrient management plan can aid substantially in considering “all of the resources (soil, water, air, plants, and animals) and the human concerns (economic and social) so as to make decisions that result in conservation plans that protect, conserve, and enhance the resources” (NRCS-NEDC-000019).

Vegetated buffer strips (e.g., riparian trees or grass filter strips) slow the velocity of overland surface flow allowing sediment particle to fall out of suspension. Buffers also increase infiltration of surface water because of better soil structure, macropores created by roots and soil invertebrates, and reduced surface crusting (Prichard, 1998). Greater infiltration reduces surface discharges and the associated sediment and nutrient loads (Prichard, 1998). However, the effectiveness of buffers decreases dramatically when small concentrated flow paths allow water to rapidly move across them. Such flow paths typically develop at low points along the fields/buffer border or where the vegetation of the buffer is disturbed. These situations should be corrected as they are identified by landowners, farm operators, and conservation professionals (e.g., NRCS/SWCD staff). Sub-surface drainage creates a by-pass to the buffer strips where there is no contact between the vegetation and the drainage water and flow is not slowed. However, water table management (e.g., NRCS practice 554) is a means to reduce the volume and/or rate of discharging sub-surface drainage water thereby counteracting the short circuiting that occurs through buffer strips.

Benefits of buffer strips that go beyond improving chemical water quality of surface runoff are related to channel stability, structural habitat, light availability, stream temperature, and food resources. Providing a stream buffer may reduce the need and/or importance for stream bank management and erosion control as crop losses would not be occurring. In some cases armoring stream banks to minimize erosion prevents the naturalization of the stream’s geomorphology (i.e., channel evolution) and perpetuates stream instability. Additionally, tree cover shades streams, which may limit algal growth and reduce stream temperatures. Temperature is inversely proportional to the stream’s capacity to hold dissolved oxygen, and high temperatures can severely impact aquatic life. Woody debris and detritus contributed to the stream system by riparian trees also have a significant role in the quality and diversity of habitat and food resources of the aquatic ecosystem (Ward, 1992; Wallace *et al.*, 1997; Baer *et* *al.*, 2001). These factors have a significant impact on the aquatic biological community and therefore the capacity for the system to attain its designated aquatic life use.

Sources from Urban and Residential Runoff

The relatively high volume of runoff generated in urban and high density residential areas increases the potential for pollution. Sediment and nutrient residues on surfaces that are impervious or poorly pervious (e.g., compacted lawns, gravel drives, etc.) are more easily transported in this higher volume of runoff and negligible attenuation of the loading occurs because of infiltration. Reducing imperviousness and improving on-site retention and infiltration can abate sediment and nutrient loading by reducing the runoff discharge.

Lawn care and yard maintenance that limits the application of nutrients and increases the likelihood of uptake and retention are recommended. This includes reducing the amount and/or frequency of fertilizer applications. The timing of application should be such that it is unlikely to immediately precede a runoff event (e.g., precipitation or irrigation). More stable alternatives to chemical fertilizers should be adopted such as organic based materials (e.g., composts and manures). Organic materials also provide carbon, which improves soil structure and increases permeability (i.e., leads to greater storm water infiltration).

The NRCS in collaboration with the National Association of Conservation Districts (NACD) and the Wildlife Habitat Council (WHC) developed a backyard conservation manual that highlights ten activities that collectively are designed to improve water and soil quality and wildlife habitat. This document can be found on the world-wide web at http://www.nrcs.usda.gov/feature/backyard/.

Assimilative Capacity

Increasing the assimilative capacity of the stream system itself is a viable means to help achieve water quality goals. Such an increase can help abate pollutant loads in the event that controls for landscape based and point sources are inadequate. One of the most important ways to increase the assimilative capacity of the system is to provide and/or preserve floodplain connection. Other means include ensuring high quality substrate (i.e., an adequate hyporheic zone) and appropriate channel morphology (e.g., sinuosity or width-depth relationships). A sufficient source of carbon is needed to support many of the organisms that are critical for in-stream biological processing; therefore, detritus from riparian trees and floodplains is important (Wallace *et al.*, 1997; Baer *et al.*, 2001; Crenshaw *et al.*, 2002).

3.1.3 Habitat

In the Mad River watershed, degraded stream habitat is primarily the result of channelization and ongoing maintenance activities carried out to improve water conveyance. These activities are related to agricultural drainage improvements; however, there is also channelization in urban areas where buildings and other infrastructure lie in close proximity to the streams. Most channelization is found on small to medium sized tributaries but also along some parts of the mainstem of the Mad River. Mainstem channelization occurred in the early part of the twentieth century and resulted in lowering the water table (draining much of the flood plain) and creating direct connections to ground water, which lowered the overall temperature of the river.

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., sub-surface drainage and channelization) as well as unintended impacts of farming (e.g., soil compaction and poor vegetative cover) increase storm flows. Efficient drainage also results in more extreme and more frequent low flow conditions. This diminishes the capacity of the system to assimilate pollutants and support diverse aquatic communities. In urban and developing areas, impervious surfaces create substantial increases in runoff, which increases channel erosion and decreases stability.

Other habitat impairments include impounded flows from dams and sedimentation. Sedimentation impairs substrate habitat and the aquatic communities, but discussion regarding its abatement will be reserved for Section 3.2.2. The following three sub-sections discuss habitat improvements that address channelization, stream instability, and impoundments, respectively.

Channelization

Channelization creates deeply incised and straight ditches or streams. This disconnects waterways from floodplains, which have damaging impacts on the quality of the system. Channelized streams change little along their length, lack features such as riffles and pools and have minimal variation in flow characteristics. This homogenous configuration reduces biological diversity (Hahn, 1982; Mathias and Moyle, 1992). Additionally, the in-stream cover important for diverse aquatic communities is often absent.

In the agricultural portions of the watershed, channelization enhances the drainage of agricultural land, which increases field accessibility and improves and/or protects crop growth (OSU, 1998 Bulletin 871-98 http://ohioline.osu.edu/b871/index.html). These practices are sanctioned through Ohio's drainage laws (ORC 6131 and OAC 1511) despite the deleterious effects on water resources. A challenge is to carry out actions that improve water quality while maintaining adequate drainage for profitable agriculture.

In terms of drainage related to agriculture, a primary function of a stream or ditch is to provide an outlet for sub-surface drainage infrastructure (i.e., drain tiles). This requires that the elevation of the channel bottom be far below (usually several feet) the elevation of the surrounding crop fields, which results in floodplain disconnections. Adequate outlets can be provided and habitat improvements achieved through stream restoration and a two-stage ditch approach.

The following three minor sub-sections discuss stream restoration, two-stage ditch management, and bio-engineering techniques as a means to improve habitat and water quality in channelized streams and ditches.

Stream Restoration

The recommended stream restoration will create or lead to the development of well connected floodplain areas, channel sinuosity, and also riffle and pool habitats where appropriate. The detention and temporary storage of high flows in created floodplains will likely mitigate downstream impacts associated with flooding. Stream restoration provides greater capacity to accommodate sub-surface drainage and enhances that use of the system. Although land drainage is not a goal of the Clean Water Act, this may provide some compensatory benefits that make landowners more willing to take this approach.

Restoration of agricultural ditches is not commonly done, but there are several such projects that are known to the Ohio EPA to have taken place in Ohio. One example occurred in the Bokes Creek watershed (www.oxbowriver.com/Web_Pages/Project_pages/P-Bokes-03.html). Early monitoring results at this site showed marked improvement in the resource (Steve Phillips, *personal communication*, 2005).

To provide the maximum benefit of stream restoration (i.e., suitable physical habitat), the location of potential projects should be considered from the perspective of the sub-basin scale or larger. Higher priority should be given to locations that facilitate upstream migration of high quality fish communities to areas with good habitat and adequate water quality. In essence, restored stream segments should bridge gaps between segments of high quality habitat. Generally speaking, downstream areas of degraded habitat should be addressed first in order to maximize continuous (or nearly continuous) high quality habitat, providing the greatest opportunity for upstream re-colonization by downstream source populations.

Additional information regarding natural channel design can be accessed at http://www.epa.gov/region4/water/watersheds/coordination/streamrestoration.html.

Two-stage approach

Stream restoration that employs natural channel design is superior to a two-stage ditch approach when strictly considering environmental benefits, but since stream restoration entails more earth moving and is considerably more expensive, a two-stage approach may be practical for addressing channelization on a large scale.

A two-stage ditch is similar to a typical drainage ditch (i.e., one-stage) but differs in some key ways. Two-stage ditches are wider at the top of their banks which increases the overall capacity of the ditch and out-of-bank flooding occurs less often. The bottom of a two-stage ditch has low elevation benches that are inundated during moderately high and higher flow events. The low flow channel is narrower than a typical ditch bottom and often develops a low-amplitude, sinusoidal pattern within the larger ditch. More information regarding two-stage ditches can be found at http://streams.osu.edu/naturalchannel.php. Figure 6 depicts a two-stage ditch.

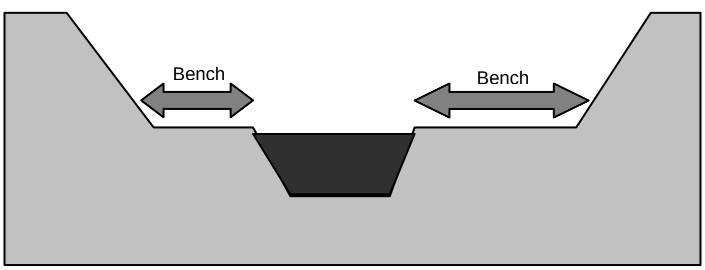

Figure 6. Graphical depiction of a two-stage ditch (left) and photo (right) taken in Wood Co., Ohio. Notice the slight meander pattern along the ditch bottom in the picture.

Two-stage channels yield modest improvements to stream habitat as compared to one-stage ditches. These benefits are realized because benches function to some degree like floodplains and the channels undergo more stable erosion and deposition processes. Bank erosion is less likely to occur because the toe (i.e., where the bank meets the channel bottom) is protected by vegetated bench deposits and flow depths are lower, which results in lower shear stress (where the stress is parallel or tangential to a face of the bank). Less bank erosion in these fairly unstable systems is beneficial to immediate and downstream reaches because in-stream sources of sediment are reduced.

Stream flow in the narrower low flow channel is more competent to move and redistribute fine sediment than wider channel bottoms typical of highly maintained ditches. Fine sediment is deposited and stored on the benches, which increases assimilative capacity of the system. Channel substrate has less fine material (i.e., is of higher quality) and habitat associated with channel sinuosity and riffle-pool development is likely to increase (Sablak, 2004), which adds habitat heterogeneity to these extremely homogenous systems. Two-stage channels may also have greater assimilative capacity for nutrients (Powell, 2004), which will be discussed in following sections.

Construction of a two-stage channel requires widening the ditch and/or creating the low-elevation benches. However, if conditions permit, two-stage ditches form on their own; in this case simply refraining from removing bench sediment (i.e., dipping) is nearly all that is necessary from a maintenance or management perspective. Simon and Hupp (1986) describe a model for channel evolution of incised streams in which the end result is analogous to a two-stage channel. Optimal conditions for two-stage channels to develop on their own are when the channel is overly wide for the amount of contributing drainage area, banks are steep, and riparian trees are absent.

The Ohio Department of Natural Resources is promoting over-wide ditch construction as a lower cost means for achieving two-stage form in ditches. The over-wide channel approach may avoid problems associated with errors in design and/or construction that result in inappropriate channel dimensions (i.e., does not facilitate desirable sediment transport processes). Over-wide channels also rely on fluvial deposits to form the benches, which are likely to have large contributions from upland soils that are richer in organic matter and have a greater potential for de-nitrification and other biological processing of pollutants.

Applying a two-stage channel approach to highly maintained ditches (e.g., streams designated as MWH) is likely to be a reasonably cost-effective way to improve these resources over a substantial percentage of the drainage network. Although cost analysis for three two-stage ditch construction projects show expenses to range from $5 to $25 per linear foot (Jeong, 2005, unpublished), when the two-stage approach is applied by leaving existing benches intact, costs may be lower than typical ditch maintenance that includes periodic re-construction. It is probable that a two-stage approach can be widely adopted at relatively low costs for landowners, county governments, and/or local organizations.

Important for the adoption of a two-stage approach is to effectively communicate the overall benefits to decision makers and designers who rely on familiar methods or ones they are comfortable using. Individuals who are particularly important to communicate with regarding a two-stage ditch approach include County Engineers and their staff, SWCD/NRCS personnel, and drainage contractors who conduct much of the design and construction work associated with drainage improvement. The benches that form in two-stage channels are often regarded as flow impedances that result in a reduction in the flow capacity of ditches. Ohio EPA is unaware of hydrologic analyses that support this idea but rather concurs that the capacity of the ditch to contain high flows increases if the ditch widens in forming the benches (http://streams.osu.edu/streams_pdf/2stage(ward).pdf).

Two-stage construction may be inappropriate for improving the stream biota and/or water quality when it is necessary to remove riparian trees in the process. Such consideration is particularly important when the channel demonstrates that it is recovering from past channelization. Two-stage ditches are clearly inappropriate when it results in a reduction in the amount of floodplain connectivity. This includes natural to moderately modified streams that have an intact connection to a floodplain and riparian areas. Such action would degrade the resource and the ameliorative effects of the benches will be far inferior to those of an established floodplain.

Bio-engineering Techniques
Bank stabilization and channel erosion controls that use hard engineering techniques (e.g., placement of concrete and/or rock) have little to no value in terms of aquatic habitat. Bio-engineering techniques promoted by the Ohio Department of Natural Resources (http://ohiodnr.com/water/pubs/fs_st/streamfs/tabid/4178/Default.aspx) use more natural materials and construction techniques that provide bank habitat structure. When bank erosion control is necessary, bio-engineering approaches should be promoted by local conservation authorities (e.g., NRCS and SWCD) and used by private and public entities as a means for abatement. However, it should be noted that channel erosion and lateral migration occurs naturally even in stable streams. If property loss is not an issue, abating bank erosion should be considered in light of whether it is occurring under stable stream conditions, and avoided if unnecessary.

Stream Stability
Stream stability is related to habitat quality and sedimentation in streams and can have a significant impact on stream biota. Areas of the basin that currently exhibit poor stream geomorphology (i.e., unstable) are associated with channelization in the agricultural portions of the watershed. Other areas include incised channels in the urban or urbanizing areas of the watershed.

Floodplains are important for maintaining stream stability and provide additional water quality benefits. For this reason, it is recommended that throughout the entire Mad River watershed, an effort should be made to maintain, create, or facilitate the enhancement of floodplains where possible.

Agricultural Areas
Ameliorating the impact of channelization can be achieved by methods discussed in the preceding sub-section (Channelization). Natural channel design and/or a two-stage ditch approach can reduce the severity of erosion processes and provide some storage of fine sediment. Additionally, the strong relationship between hydrology and stream stability and aquatic communities indicates that steps taken to stabilize watershed hydrology will be beneficial.

Activities related to agriculture may be substantially impacting watershed hydrology (Baker *et al.*, 2004) and the stability of stream channels. Baker *et al.* (2004) suggest that subsurface drainage in combination with reduced surface water retention (i.e., due to smoothing of the landscape and altering vegetation and soil properties) is increasing peak storm discharges. At the other extreme, more efficient drainage results in less infiltration and storage in the watershed, which leads to a reduction in baseflow (i.e., flows based on ground water contributions) during drier periods (Baker *et al.*, 2004; Robinson and Rycroft, 1999). The two phenomena result in an increase in the flashiness of the watershed, which is a measure of the rate and magnitude of changes in stream flow.

Although the causes of the observed increase in flashiness are not yet entirely known, activities that are likely to increase infiltration and reduce runoff should be pursued. In areas where drainage improvement practices are applied intensely, the use of infrastructure and management measures such as water table management and wetland detention are recommended.

Water table management (NRCS Practice Standard 554) is a means to reduce the discharge of sub-surface drainage water (http://ohioline.osu.edu/aex-fact/0321.html). Water table management requires the use of controlled drainage structures (e.g., Agri-Drain or Hancore types) that are installed within new or retrofitted to existing sub-surface tile systems. Drainage water passing through these structures must have adequate hydraulic head to rise to an elevation that is pre-set according to the height of the flashboard risers that are part of the structure. This system allows for management of the effective elevation of the drainage tile outlets. When this elevation is set high enough the effect is analogous to there being no sub-surface drainage infrastructure.

Benefits of water table management are reductions in annual drainage water discharges. These reductions have been estimated over several years of research to be approximately 40% (Fausey, 2004). Although Ohio EPA is unaware of comprehensive water budgets completed for water table management, it is reasonable to assume that a significant proportion returns to the stream as baseflow and interflow over a protracted timeframe (David Baker, *email*, 2006) or is otherwise taken up through evapo-transpiration. The extended period of discharge can also benefit the aquatic community by providing flow during critical drier periods.

The use of water table management may be limited in some areas. Topography dictates the area that can be controlled by a given structure because water table elevations greater than the top of the control structure are no longer influenced by it. This means that control of the water table depth is reduced when moving upslope from the control structure. Additional structures would often be needed within fields (i.e., as opposed to along the field margins) to be able to manage an entire sub-surface drainage system. Other factors that may limit use of water table management include the layout of the sub-surface drainage system and whether or not the pipes can be readily located.

A viable way to offset the problem of limited control associated with a given water table control structure is aligning the drain tiles of new sub-surface drainage systems along elevation contours. This decreases the slope of the drain tiles which allows drainage management infrastructure to have control over a larger area. Additionally, it is possible that significant benefits are realized even if it is only the lower portion of the sub-surface drainage system (i.e., near the outlet) that is controlled.

Wetlands provide detention capacity for runoff and increase infiltration. Numerous studies have shown that wetlands improve water quality and watershed hydrology as well as provide excellent wildlife habitat (Mitsch and Gosselink, 2000; Vellidis, 2003). Establishing wetlands often entails disabling a portion of the drainage infrastructure servicing that area and a relatively minor amount of earth work. The NRCS standards for wetland creation (NRCS Practice Standard 658) and wetland enhancement (NRCS Practice Standard 659) provide details regarding size and site condition considerations.

Depressions on the landscape with appropriate soils (i.e., hydric) are ideal locations for creating or enhancing wetlands, since it is likely that they were wetlands prior to land use conversions. In such cases, reversion to wetland is likely to require less effort and will have a greater probability of meeting the goals of the water resource improvements. The placement of wetlands adjacent to or near streams or ditches allows for treatment just prior to entering those waters, which may facilitate the treatment of a large volume of runoff caused by the wetland’s position in the drainage system.

Land use conversions from crop fields to grassland or forest also increases the retention and/or detention of rainwater. These land covers result in greater infiltration and a higher degree of storage through initial abstraction compared to row crops and/or barren ground and may help restore a more suitable hydrology. Such improvement may take several years to reach their full benefits, especially when land returns to forest cover. The Conservation Reserve Program (see Section 3.3.3) compensates producers for land set-asides.

<u>Developing Areas</u>
The conversion of forest and/or agriculture land uses to residential, commercial, and industrial uses can pose threats to stream stability. Numerous scientific studies show that increasing impervious cover in a watershed (i.e., through development) is commensurate with the degradation of water quality and biological communities (Booth, 2005; Brabec *et al.*, 2002; Roy *et al.*, 2003; Roy *et al.*, 2006; Morgan and Cushman, 2005).

This type of land use conversion substantially increases the volume of runoff, which is eventually routed to the stream system. Ultimately the sediment transport capacity of the system increases resulting in more channel erosion and instability (Booth, 2005). The resulting morphology provides poor habitat and may have a reduced capacity for nutrient assimilation (Walsh *et al.*, 2005). Higher runoff volume increases pollutant loading (e.g., nutrients, metals, salts, pesticides, sediment). Additionally stream temperatures can be raised when runoff is heated by impervious surfaces such as asphalt and concrete or while residing in detention basins. Increases in temperature reduce dissolved oxygen concentration and create stressful conditions for aquatic biota (Ward, 1992; Cossins and Bowler, 1987).

Controlling runoff associated with development typically consists of end-of-pipe measures such as storm water detention and retention. These controls abate flooding and reduce erosion, thus providing some water quality protection. However, studies show that water quality degradation occurs in developing watershed despite these controls due to the altered hydrologic regime (Brabec *et al.*, 2002; Booth, 2005).

A hydrologic regime that approximates that of 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 sub-surface flow paths, evapo-transpiration, 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 altogether 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 this (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 centralized systems that collect runoff over a broad area and 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/or 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. This is accomplished through appropriate planning, such as that used for Low Impact Development (LID). Low Impact Development is based on maximizing contiguous open space, protecting sensitive areas, namely floodplains and wetlands, and preserving existing vegetation (especially trees). A web-based resource for LID includes www.lowimpactdevelopment.org/. In a Low Impact Development, houses are located closer to one another, roadways are narrower, and bio-retention 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.

Watersheds that retain relatively large areas of forest are able to better mitigate the impacts of increasing imperviousness than those with little forest cover (Brabec *et al.*, 2006, Booth, 2005). The procurement of conservation easements and the establishment of parkland and nature preserves can help retain some of the existing forest cover as well as 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 and/or discrete on-site storm water management).

Storm water abatement techniques that are employed in commercial developments and on individual residences (i.e., that are not a part of a LID) will provide protections to water quality. In particular, parking lots often account for a very high proportion of the impervious surfaces in urban watersheds. According to the University of Connecticut Extension, impervious cover associated with automobile traffic accounts for a significant proportion of the total impervious cover in a given watershed (http://nemo.uconn.edu/).

At the scale of individual residences or businesses, 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 and/or temporary storage. Minimizing the extent of impervious surfaces by limiting their size or substituting them with permeable surfaces will also increase infiltration and detention for a given property. Outreach and education activities are likely to result in some increase in this type of voluntary action taken by watershed residents, but to what extent would be very difficult to predict. Outreach efforts that include landscape design and construction companies may also be beneficial as they can present options for enhanced storm water management to their prospective clients.

The current edition of the Rainwater and Development Guide that is posted on the ODNR website at http://ohiodnr.com/?TabId=9186 provides a great deal of information regarding storm water management. This resource highlights the goals, effectiveness, and limiting conditions for both planning and structural controls. The following topics are discussed:

- Reduction in impervious area
- Low Impact Development
- Conservation Development (similar to LID)
- Setbacks
- Water quality ponds
- Infiltration trenches
- Sand and organic filters
- Grass filters
- Bioretention area

Floodplains abate the impacts of development on stream systems. The reduction of the erosive power of storm flows, temporary flood storage, and sediment assimilation all act to mitigate the damage caused by increased runoff volume during flood events. Wetlands also provide storm water retention, increase infiltration and reduce the energy of surface flows (i.e., reduces erosion potential). These important environmental areas must be protected and preserved to the greatest reasonable extent.

Provisions for floodplain filling tend to vary across watersheds under county, township and municipality ordinances and zoning codes. Timely and adequate public notification of fill requests (permitting process) and opportunity for public hearings are recommended to ensure that permitting decisions are based on an adequate array of information, scientific as well as socio-economic.

Impoundments
There are a total of thirteen dams in the Mad River watershed. The largest is the impoundment at the C.J. Brown reservoir that is owned and operated by the U.S. Army Corps of Engineers for flood control, recreation, and low flow augmentation. There is an Ohio State Park located on this reservoir. The Miami Conservancy District owns the Huffman Dam between Fairborn and Dayton adjacent to the Wright Patterson Air Force base. This dam does not normally impound water, but at high flows it prevents downstream flooding by allowing water through its conduits at a fixed rate. A recreation area associated with the dam is administered by the Five Rivers MetroParks.

There are eleven lowhead dams in the watershed. Five are on the mainstem of the Mad River, four are on Buck Creek, and one each on Macochee Creek and Beaver Creek. A proposal to remove one lowhead dam in Champaign County failed to succeed because of local opposition. There is a proposal by the Springfield Conservancy District that would remove the four dams on Buck Creek and the one on Beaver Creek.

The primary benefits of dam removal are the increase in flow velocities and turbulence that corresponds to increased air entrainment and dissolved oxygen concentrations. Increased flow facilitates the movement of nutrients that are otherwise stagnated in a lentic type of condition when impoundments exist. Algae and associated biomass accumulate in these stagnate areas, creating poor water quality conditions (e.g., low dissolved oxygen). Habitat quality and diversity are impacted by impoundment and consequently impounded areas often can only support tolerant assemblages that have little biological diversity.

3.1.4 Summary

The diverse sources of impairment in the Mad River watershed related to two major land uses require a number of various implementation actions. The basic principles of providing floodplain connectivity, stable stream morphology and watershed hydrology that approximates natural conditions (i.e., there is adequate infiltration) are applicable to the agricultural, developing, and urban areas of the watershed. Likewise, stream buffers are appropriate for all land use types in the watershed.

Thirteen point sources received fecal coliform wasteload allocations based on permit limits. Home sewage treatment systems (HSTS) must be addressed in rural, urban, and developing areas. Overland sediment loading is primarily a concern in the agricultural areas and where residential and commercial development is rapid. Nutrient loading from agrochemicals and manure sources is primarily restricted to the upper and middle agricultural portions of the watershed and conservation and management practices promoted by NRCS are recommended to abate these sources. Residential, commercial and otherwise urban areas can reduce overland loading by reducing the application rate of fertilizers and improved timing. Reduction in runoff volume through on-site storm water management will also reduce loading from urban areas and improve watershed hydrology and consequently stream stability.

There is a wide range of BMPs available that can be used to achieve the load reductions identified through the TMDL analysis. Three BMPs that would like achieve high reductions of fecal coliform loading would be manure composting (Larney *et al.*, 2003), providing alternative water supplies for cattle (U.S. EPA, 2003), and excluding cattle from streams (U.S. EPA, 2003).

As discussed in Section 3.1.2, nitrate is highly soluble and is easily transported via surface overland flow. Therefore, nitrate is particularly susceptible to rain events during which large volumes of water run over land where nitrate has been applied in the form of manure or fertilizer. Practices such as use of grass filter strips, woody riparian buffers and controlled drainage would aid in controlling the amount of nitrate entering streams from runoff.

3.2 Recommended Implementation Actions by Assessment Unit

The USGS report (Reutter *et al.*, 2006) recommended a scenario by which most impairment could be eliminated through load reductions. This scenario includes both point source and nonpoint source load reductions.

In order to meet fecal coliform load reductions, all failing septic systems should be eliminated; all direct access of cattle to streams should be eliminated; loads from CSOs need to be reduced by 95 percent; and improvements need to be made to WWTPs that would eliminate all 30-day geometric mean exceedances of 1,000 cfu/100 mL in effluent. While the USGS report applied the source-reduction scenario described to all HUCs, it also identified only a few HUCs where these modifications were needed: 05080001 160 010, 170 040, 170 060, 180 030, 180 040, 180 070, 180 080, 190 020, and 190 140 (see Table 19, USGS report).

The source-reduction scenario for nitrate included the elimination of failing septic systems, the elimination of direct access to cattle to streams; and a 30 percent reduction in nitrate runoff. Only four 14-digit assessment units were identified as needing nitrate reductions in order to meet water quality targets; these included 05080001 150 060, 160 030, 170 010 and 170 020 (see Table 22, USGS report). After applying the source reduction scenario to these four HUCs, two still needed some further nitrate reduction (05080001 170 010 and 170 020).

3.2.1 Mad River (headwaters to downstream Kings Creek); 05080001 150

There are several specific recommendations regarding this assessment unit. In Macochee Ditch, agricultural channelization has altered habitat. Using fencing to restrict livestock access to the stream will improve habitat stability as well as reducing fecal coliform and nitrate. There is some riparian forestation in the lower stream stretches, so activities adjacent or near to the forested areas may extend the benefits of intact riparian areas further upstream.

The habitat of Kings Creek is also affected by agricultural channelization and would benefit from restricted livestock access to the streams. Nitrate also exceeded targets in this subwatershed, but the source-reduction scenario eliminated the necessary excess load.

3.2.2 Mad River (downstream Kings Creek to downstream Chapman Creek); 05080001 160

Habitat has been impaired in several subwatersheds in this assessment unit, including the watersheds of Muddy Creek, Dugan Run, Nettle Creek, and Chapman Creek. All streams are candidates for active stream restoration should funding be available for interested parties.

Dugan Run (160 030) has some development-related impairment around the City of Urbana. The City of Urbana was designated as a regulated small MS4 community in late 2006 and issued coverage under the general permit in June 2009. Additionally, in-stream structures might benefit the heterogeneity of habitat in the agriculturally-modified streams in order to create pools. In addition, the spillway at State Route 36 should be removed to allow the river to return to a more natural condition.

In the Nettle Creek subwatershed (160 040), siltation has impaired aquatic fish communities. The source of sediment is unknown and may be natural. However, reductions in sediment are possible. Sediments can be reduced by a variety of BMPs, including but not limited to grass swales, riparian buffer restoration, grazing land protection and use of cover crops. An unnamed tributary to Nettle Creek (river mile 8.80) has impaired macroinvertebrate communities in part because of habitat alterations through channelization. Restoring riparian buffers, preventing livestock access to the stream to prevent erosion, and where possible allowing over-wide or two-state ditches to form would all be potential methods to improve habitat.

Elevated metals and organic chemical contamination were documented in sediments in Dugan Run and the St. Paris tributary to Nettle creek. Contaminated sediments are noted as a cause of impairment in Dugan Run. In addition, floatable solids were noted downstream of the Village of St. Paris WWTP. Macroinvertebrates were impaired in the tributary to Nettle Creek and fish in Dugan Run. Improved operations at the WWTP combined with improvement in habitat, which increases assimilative capacity, will likely substantially contribute to a return to attainment of aquatic life use in these streams.

Muddy Creek has historically been channelized for agricultural purposes, and habitat for aquatic life is impaired. Habitat can be improved by a variety of methods, including allowing two-stage ditches to form; creating over-wide ditches; restoring riparian buffers; and reducing stream bank erosion by preventing livestock access to the stream.

In Stony Creek, the Lakewood Swim Club was contributing fecal coliform loads to the stream through a backwash effluent. The club was subsequently closed and the effluent eliminated. Further monitoring may be warranted to confirm recovery in this stream.

A fecal coliform reduction of 9 percent is needed in addition to the source-reduction scenario in the 14-digit subwatershed of the Mad River from below Kings Creek to above Nettle Creek (excluding Muddy Creek and Dugan Run; 05080001 160 010). Some BMPs that help to reduce fecal coliform loads are manure composting, grazing land protection and fencing cattle out of streams.

A nitrate reduction of 18 percent is needed in addition to the source-reduction scenario in the 14-digit subwatershed of Dugan Run (05080001 160 030). There is a swine livestock facility (currently applying for a permit with the Ohio Department of Agriculture) in the Dugan Run subwatershed that may be contributing some excess fecal coliform and/or nitrate. A comprehensive nutrient management plan would be useful to help direct efforts to reduce nitrate loads from this facility. Other BMPs that might reduce nitrate throughout the watershed include grass swales, riparian buffer restoration, grazing land protection and land preservation through conservation easements.

3.2.3 Buck Creek; 05080001 170

Two 14-digit subwatersheds of the Mad River, Beaver Creek except Sinking Creek (05080001 170 040) and Buck Creek below Beaver Creek to Mad River (05080001 170 060) need fecal coliform reductions of 79 and 73 percent, respectively, in addition to the source-reduction scenario in the USGS report (Reutter *et al.*, 2006). Some BMPs that help to reduce fecal coliform loads are manure composting, grazing land protection and use of filter strips along streams.

Two 14-digit subwatersheds of the Mad River, Buck Creek above East Fork Buck Creek (05080001 170 010) and East Fork Buck Creek (05080001 170 020) need nitrate reductions of 42 and 38 percent, respectively, in addition to the source-reduction scenario in the USGS report (Reutter *et al.*, 2006). Some BMPs that might reduce nitrate throughout the watershed include grass swales, riparian buffer restoration, grazing land protection and land preservation through conservation easements.

Habitat and flow alteration are causing some impairment in macroinvertebrate communities in Buck Creek downstream of the C.J. Brown Reservoir. Ammonia discharging from the reservoir is likely caused by nitrate entering the reservoir, which is converted to ammonia in the water. Nitrate reductions upstream of the reservoir are therefore likely to reduce ammonia outputs.

3.2.4 Mad River (downstream Chapman Creek to upstream Mud Creek; excluding Buck Creek and Mad River mainstem); 05080001 180

Four 14-digit subwatersheds of the Mad River—Mad River below Buck Creek to above Donnels Creek (05080001 180 030); Mill Creek (180 040); East Fork Donnels Creek (180 070); and Mad River below Donnels Creek to above Mud Creek, except Jackson Creek (180 080)—need fecal coliform reductions of 52, 41, 17 and 44 percent, respectively, in addition to the source-reduction scenario in the USGS report (Reutter *et al.*, 2006). Some BMPs that help to reduce fecal coliform loads are manure composting, grazing land protection and use of filter strips along streams.

Habitat alteration along the mainstem of the Mad River at river mile 25.8 has caused some impairment in the fish community. The mainstem may see improvement from upstream and tributary improvements. In addition, restoring riparian buffers and utilizing conservation easements along the mainstem may improve habitat for aquatic life.

Moore Run (05080001 180 020) at RM 4.1 was the only site in the assessment unit with both impacted fish and macroinvertebrate communities that resulted in nonattainment of the WWH use. The site was in a severely habitat-limited reach (QHEI = 28.5). Biological condition progressively improved at the two additional downstream sampling locations on Moore Run.

Both sites had moderately improved habitat and additional flow volume. The site at RM 2.5 had a silty muck substrate and thick growths of aquatic macrophytes. EPA personnel noted a petroleum odor and an oily sheen on the water surface. The fish community marginally met ecoregional expectations but the macroinvertebrate community was in only fair condition. Low dissolved oxygen readings and significant sediment contamination were documented in this reach of Moore Run. Storm water and process discharges at the Navistar, Inc. facility upstream are possible pollutant sources at this site (Ohio EPA, 2005). A compliance review from 2005 through August 2007 shows that this facility has had no permit limit violations. The facility currently has a compliance schedule for mercury, cadmium and silver. The facility is also at the beginning of a 12-month study to identify sources of phosphorus and where there may be opportunities to reduce it as much as the company is willing and able. Based on this information, it seems most likely that impairment is being caused by habitat impairment and phosphorus in effluent. Actions to reduce phosphorus may result from the 12-month study. Common habitat BMPs that may improve the condition of the stream include restoration of riparian buffers, elimination of livestock access to the streams, and formation of two-stage or over-wide ditches. In addition, this site on Moore Run may be a good candidate for low-level natural channel design that may restore natural fluvial processes in order to increase the assimilative capacity of the stream.

Partial attainment occurs in Pondy and Donnels creeks because of natural habitat impairment. In Pondy Creek, there are natural intermittent flows, and in Donnels Creek the water table is naturally lowered.

Both suburbanization and agriculture have affected the habitat of Kenton Creek. Broad use of grass filter strips is recommended to mitigate for agricultural impacts. Use of low impact development, restoring riparian buffers, and increasing pervious surface and stream set-backs can all mitigate for development impacts.

3.2.5 Mad River (upstream Mud Creek to mouth; excluding Mad River mainstem); 05080001 190

Two 14-digit subwatersheds of the Mad River, Mad River below Mud Creek to above Huffman Dam, except Mud Run (05080001 190 020) and Mad River below Huffman Dam to Great Miami River (05080001 190 040) need fecal coliform reductions of 33 and 17 percent, respectively, in addition to the source-reduction scenario in the USGS report (Reutter *et al.*, 2006). Some BMPs that help to reduce fecal coliform loads are manure composting, grazing land protection and use of filter strips along streams.

Some impairment from a small WWTP was noted in 2005 in Mud Creek. However, this plant (formerly belonging to the Gifford Apartments) has been abandoned and connected to Clark County Southwest Regional's WWTP as of June 28, 2006.

Mud Run had a somewhat impaired fish community at RM 0.8. The stream channel was channelized and some evidence of sediment impacts from the Southwestern Portland Cement landfill leachate was evident. An Ohio EPA Division of Emergency and Remedial Response study in 2003 showed some elevated chemical parameters from the landfill, but very little exceeded the water quality standards (Ohio EPA, 2003). Some pathogens were noted in an unnamed tributary to Mud Run. On June 2, 2004, Ohio EPA issued a PTI (No. 05-12916) to Greenon Local School District to upgrade Hustead Elementary School's WWTP. Construction was completed on August 24, 2004. The facility appears to be in general compliance with its NPDES permit. Additionally in this tributary, noted habitat impacts were likely caused by the practices of a former landfill. Improvement of intact floodplains and riparian vegetated areas may aid recovery.

Lilly Creek flows through an urban area and suffers from impacts common to urbanized streams, including alteration of the natural flow regime caused by hardening of the landscape and pollutants contained in storm water runoff and sediments. Additionally, a series of small eutrophic impoundments overflowed into Lilly Creek upstream from RM 0.1 and introduced an organic load and nutrients to the stream. The City of Riverside, adjacent to Dayton, is a small MS4 community, so it has a Phase II storm water permit. Re-development using alternative storm water management, such as bioretention, might improve some of the impacts from the urbanization of the watershed.

3.2.6 Mad River (mainstem); Large River Assessment Unit

Over time, agricultural channelization of the Mad River has lowered the water table and introduced increased ground water flow into the river. However, only one site did not fully attain WWH aquatic life use standards (RM 17.5). It is likely that improvements to upstream reaches (such as in-stream habitat structures as provided by Trout Unlimited) and tributaries, as discussed in previous subsections, will contribute sufficiently to improve the fish community at this site.

3.3 Reasonable Assurances

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

The following sections discuss organizations and programs that have an important role or can provide assistance for meeting the goals and recommendations of this TMDL. This section establishes why it is reasonable to be assured of successful implementation.

3.3.1 Ohio EPA

The several programs that Ohio EPA Division of Surface Water (DSW) administers are designed to control pollution from point sources and certain storm water discharges as well as provide assistance for abating nonpoint sources of pollution. Other divisions within the Ohio EPA provide assistance such as funding, technical assistance, and education for water resource related issues. Information regarding the specific programs within the Ohio EPA DSW can be found on the web at http://epa.ohio.gov/Default.aspx?alias=epa.ohio.gov/dsw, and information about the Division of Environmental and Financial Assistance (DEFA) at http://epa.ohio.gov/Default.aspx?alias=epa.ohio.gov/defa. What follows are programs within the agency that are especially important for the implementation of this TMDL.

NPDES Program
National Pollution Discharge Elimination System (NPDES) permits authorize the discharge of substances at levels that meet the more stringent of technology or water-quality-based effluent limits and establish requirements related to combined sewer overflows, pretreatment, and

sludge disposal. All entities that wish to discharge to the waters of the state must obtain a NPDES permit and both general and individual permits are available for coverage. Through the NPDES program (http://epa.ohio.gov/dsw/permits/permits.aspx), the Ohio EPA will use its authority to ensure that recommended effluent limits are applied to the appropriate permit holders within the Mad River watershed. Much of this work to ensure compliance has been ongoing in the watershed and multiple WWTPs have been connected to regional sewers and taken off-line, been upgraded and improved in operations. Ohio EPA staff in the NPDES Program can provide technical assistance for permitted entities when needed. Permits issued under the NPDES program must be consistent with the point source recommendations in a TMDL that has been approved by the U.S. EPA.

Combined Sewer Overflow Program
Ohio EPA implements CSO controls through provisions included in NPDES permits and by using orders and consent agreements when appropriate. The NPDES permits for CSO communities require the implementation of nine minimum control measures (http://cfpub1.epa.gov/npdes/cso/ninecontrols.cfm?program_id=5). Requirements to develop and implement Long Term Control Plans are also included where appropriate. Through the CSO program, the Ohio EPA will use its authority to ensure that recommended control activities are conducted by the permit holders within the Mad River watershed.

Storm Water Program
Ohio EPA implements the federal regulations for storm water dischargers (http://cfpub1.epa.gov/npdes/home.cfm?program_id=6). Both general and individual permits can be used for coverage of storm water effluent. Through the Storm Water Program, the Ohio EPA will ensure that the storm water permit related recommendations of this TMDL are applied.

Staff within the Storm Water Program provides technical assistance to permitted entities when needed. District Office staff within the Storm Water Program respond to and investigate complaints received by individuals and organizations.

401 Water Quality Certification Program
In Ohio, anyone wishing to discharge dredged or fill material into the waters of the United States, regardless of whether on private or public property, must obtain a Section 404 permit from the U.S. Army Corps of Engineers (Corps) and a Section 401 Water Quality Certification (WQC) from the state.

Stream and wetland mitigation is used as a condition for granting 401 certificates and is the means of ensuring that water resources do not experience a net decline in quality. When a wetland or stream segment is impacted, an appropriate mitigation is required such that there is no net loss of wetlands or unimpaired stream length. Restoration, creation, or other forms of enhancement is required at a level that depends upon the original quality of the resource.

Currently there are proposed rules changes to the 401 Program that are designed to provide a more scientific basis for determining appropriate criteria for 401 permit decisions (i.e., acceptance or denial) as well as mitigation stipulations for the respective projects (http://epa.ohio.gov/dsw/401/index.aspx). These rule changes are expected to be finalized in 2008. Ohio EPA staff will conduct reviews and issue permits to provide the most reasonable protections and improvements, where possible, of surface waters in the Mad River watershed.

Wetland Protection Program
House Bill 231 established a permanent permitting process for isolated wetlands. Reviewers in the 401 Water Quality Certification Section are responsible for the isolated wetland permits required by this state law. Ohio EPA staff will conduct reviews and issue permits to provide the most reasonable protections and improvements of surface waters in the Mad River watershed.

Enforcement Program
When Ohio EPA is unable to resolve continuing water quality problems because of violations of permitting rules or laws, the DSW may recommend that enforcement action be taken. The enforcement and compliance staffs work with Ohio EPA attorneys, as well as the Attorney General's Office to resolve these cases. Where possible, an added emphasis and priority is given to actions in sensitive watersheds. All completed enforcement actions are posted on the DSW web page.

208 Program (State Water Quality Management Plans)
Ohio EPA oversees the State Water Quality Management (WQM) Plan. The State WQM Plan is like an encyclopedia of information used to plot and direct actions that abate pollution and preserve clean water. A wide variety of issues is addressed and framed within the context of applicable law and regulations. The Mad River TMDL becomes a part of the State WQM Plan when it is approved by the U.S. EPA and the recommendations found herein align with and support the state's overall plan for clean waters. More importantly, the requirement and intention to review and update the State WQM Plan on an annual basis creates an avenue to apply adaptive management and make adjustments in these recommendations as necessary.

Nonpoint Source Program
The Ohio Nonpoint Source (NPS) program focuses on identifying and supporting implementation of management practices and measures that reduce pollutant loadings, control pollution from nonpoint sources and improve the overall quality of these waters. Ohio EPA receives federal Section 319(h) funding to implement a statewide nonpoint source program, including offering grants to address nonpoint sources of pollution. Staff from the NPS program work with state and local agencies, governments, watershed groups, and citizens.

In addressing sources of impairment related to agricultural activities, NPS staff will correspond with Ohio Department of Natural Resources (DNR) to promote best management practices (BMPs) as well as cost-share and incentive based conservation programs. In particular, Ohio EPA will support collaboration between the Ohio DNR and Farm Service Agency personnel and staff from local Soil and Water Conservation District (SWCD) and National Resource Conservation Service (NRCS) offices. NPS staff will also provide assistance to agencies and groups actively promoting conservation as well as direction to other appropriate resources within the Ohio EPA.

NPS staff will continue to work with the watershed groups that are active in the Mad River basin (see watershed groups below). Local NPS implementation is critical to achieving state environmental targets. Additionally, there is a reliance on watershed management plans to identify and outline actions to correct water quality problems caused by NPS pollution.

Section 319(h) grants are expected to be directed to projects that eliminate or reduce water quality impairments caused by nonpoint sources of pollution. Applicants may apply for a maximum of $500,000 for a three year period. Each project funded must provide an additional 40% matching share and the total federally funded share of project costs may not exceed 60%. Because a TMDL exists, grant proposals for work within the Mad River watershed will receive special consideration for funding. To date, over one million dollars have been awarded to the Mad River watershed for developing the USGS report (Reutter *et al.*, 2006) and other water quality projects in the watershed.

Division of Environmental and Financial Assistance
The Division of Environmental and Financial Assistance (DEFA) provides incentive financing, supports the development of effective projects, and encourages environmentally proactive behaviors through the Ohio Water Pollution Control Loan Fund (WPCLF). Municipal wastewater treatment improvements—sewage treatment facilities, interceptor sewers, sewage collection systems and storm sewer separation projects—are eligible for financing. Nonpoint pollution control projects that are eligible for financing include:

- Improvement or replacement of on-lot wastewater treatment systems
- Agricultural runoff control and best management practices
- Urban storm water runoff
- Septage receiving facilities
- Forestry best management practices

The Water Resource Restoration Sponsor Program (WRRSP) is a part of the WPCLF and directs funding toward stream protection and restoration projects. The primary focus of this program is to improve and protect stream habitat. Like Section 319 (h) grants, proposals for stream improvements within the Mad River watershed will receive special consideration.

3.3.2 Ohio Department of Natural Resources

The Ohio DNR works to protect land and water resources throughout Ohio. A specific objective in regards to water resources is to *"Lead in the development and implementation of stream and wetlands conservation initiatives, applying advanced science, technology and research to restore and protect stream and wetlands habitats."* This commitment attests that the Ohio DNR will be a reliable partner in addressing causes and sources of impairment in the Mad River watershed.

The following are programs and divisions within the Ohio DNR that are particularly instrumental in protecting and improving water resources within the Mad River watershed.

Pollution Abatement Program
Under Ohio's Pollution Abatement Rules (OAC 1501) the Ohio DNR is required to respond to written and non-written complaints regarding agricultural pollution. As defined by OAC 1501, agricultural pollution is the "failure to use management or conservation practices in farming or silvicultural operations to abate wind or water erosion of the soil or to abate the degradation of waters of the state by animal waste or soil sediment including substances attached thereto." In cooperation with SWCDs, an investigation is begun within five days of receipt of the complaint and a Pollution Investigation Report (PIR) is generated within ten days. Resource management specialists from Ohio DNR within the Division of Soil and Water Conservation (DSWC) typically become involved with pollution abatement cases in their respective areas of the state.

If it is determined necessary, an operation and management plan will be generated to abate the pollution. This plan is to be approved by the SWCD or Ohio DNR and implemented by the landowner. Cost-share funding may be available to assist producers in implementing the appropriate management practices to abate the pollution problems and such practices may be phased in if necessary. If a landowner fails to take corrective action within the required timeframe, the Chief of the Division of Soil and Water Conservation (Ohio DNR) may issue an order such that failure to comply is a first degree misdemeanor. This program safeguards against chronic problems that lead to the degradation of water quality.

SWCD Program

Ohio DNR-DSWC has a cooperative working agreement with the Soil and Water Conservation Districts throughout Ohio and the NRCS. According to the agreement Ohio DNR-DSWC is responsible to "provide leadership to Districts in strategic planning, technical assistance, fiscal management, staffing, and administering District programs." The Division also provides "training and technical assistance to District supervisors and personnel in their duties, responsibilities, and authorities." Program Specialists from Ohio DNR work with the SWCDs to identify program needs and training opportunities. Ohio DNR also ensures that program standards and technical specifications are available to SWCDs and NRCS personnel. State matching dollars from the Ohio DNR constitute roughly half of the annual operating budgets of SWCDs.

Through the partnership established by the working agreement and their history of collaboration, Ohio DNR can communicate the goals and recommendations highlighted in this TMDL to SWCDs and provide guidance to actively promote conservation efforts that are consistent with those goals.

Urban Storm Water Program

Ohio DNR staff provides technical expertise regarding storm water management and controls as well as administers urban storm water-related grants. The Urban Storm Water Program has been responsible for the development and maintenance of the Rainwater Manual for the State of Ohio which provides guidance regarding storm water management and sediment and erosion control measures.

Staff from the Urban Storm Water Program will be an important resource for communicating with the development community and promoting storm water management that is consistent with recommendations and goals of this TMDL report.

Division of Forestry

The mission of the Division of Forestry is to promote sustainable use and protection of forests on public and private lands. The division provides technical expertise and other forms of assistance regarding riparian forest establishment and protection.

Division of Wildlife

Through efforts to increase the amount of habitat for game birds and other forms of wildlife, private lands biologists actively promote the establishment of warm season grass in buffer strips and on cropland set-asides. Private lands biologists come into contact with private landowners and conservation groups to educate, and provide assistance regarding these types of habitat improvements.

3.3.3 Agricultural Services and Programs

Local SWCD, NRCS, and Farm Service Agency (FSA) offices often work to serve the county's agricultural community. Staffs from these offices establish working relationships with private landowners and operators within their county, which are often based on trust and cooperation.

SWCD and NRCS staffs are trained to provide sound conservation advice and technical assistance (based on standard practices) to landowners and operators as they manage and work the land. Sediment and erosion control and water quality protections make up a large component of the mission of their work. SWCD and NRCS activities also include outreach and education in order to promote stewardship and conservation of natural resources. SWCD and NRCS staffs also serve county residents not associated with agriculture and some districts have well developed urban conservation programs.

The close working relationships that SWCD and NRCS staffs typically maintain with local land owners and producers make them well suited for promoting both widely used conservation practices as well as some that are more innovative. In an initiative to produce a community water quality plan, the Clark County SWCD office wrote and submitted for endorsement a watershed protection project plan for the lower Mad River watershed. The plan contains multiple suggestions of activities that would improve water quality within the watershed. This plan was endorsed by both Ohio EPA and Ohio DNR. The plan includes Clark County and all of Buck Creek watershed, which extends into Champaign County. A plan for the upper Mad River watershed was drafted in 2005, but local complications prevented it from being submitted for endorsement.

Federal Farm Bill programs are administered by the local NRCS and FSA offices. NRCS is responsible for the Environmental Quality Incentives Program (EQIP), while FSA is responsible for set-aside programs such as the Conservation Reserve Program (CRP), Conservation Reserve Enhancement Program (CREP), and the Wetland Reserve Program (WRP).

Environmental Quality Incentives Program
EQIP is an incentive-based, voluntary program designed to increase the use of agriculturally-related best management and conservation practices. EQIP is available to operators throughout the entire Mad River watershed irrespective of whether they own or rent the land that they farm. Through this program operators receive cost share and/or incentive payments for employing conservation management practices. Contracts are five years in length.

Eligible conservation practices cover broad categories such as nutrient and pesticide management, conservation tillage, conservation crop rotation, cover cropping, manure management and storage, pesticide and fertilizer handling facilities, livestock fencing, pastureland management, and drainage water management among others. However, funding for these practices is competitive and limited to the allocations made to any respective county in Ohio. Each county in receives a minimum of $100,000 per year and may receive more depending on state priorities for that year. More information on this program is available on the NRCS website at www.nrcs.usda.gov.

Conservation Reserve Program and Wetland Reserve Program
The Conservation Reserve and Wetland Reserve Programs (CRP and WRP respectively) are set aside programs much like the CREP (see below), which is the enhanced version of CRP. The goals of these programs are to protect environmentally sensitive lands (e.g., highly erodible soils) and improve water quality and wildlife habitat.

Set aside programs are voluntary and incentive-based and provide compensation to farmers for establishing and maintaining buffers, wetlands, grasslands or woodlands on land that would otherwise be used for agricultural production. Compensation is restricted to the timeframe established in the contract agreement. Incentive payments for these two programs are lower than the enhanced versions (CREP and WREP), which are limited to areas that have been approved by the USDA for the additional funding. These programs can assist in creating land use changes that improve water resource quality in the Mad River watershed.

3.3.4 Extension and Development Services

Each county in Ohio has an extension agent dedicated to agricultural and natural resource issues. The primary purpose of extension is to disseminate up-to-date science and technology so it can be applied for the betterment of the environment and society. Like SWCD and NRCS staff, extension agents provide technical advice to landowners and operators and often develop strong relationships with the local community. Local extension agents are particularly well-suited for promoting innovative conservation measures that have not yet been established in the standard practices developed by NRCS.

The Mad River is in the area included in the Top of Ohio RC&D and that agency has been involved with some of the past projects, though there has not been much recent activity. The Champaign Extension office was the grant recipient for several of the grants when there was a coordinator in the watershed and supported the plan development in early stages.

3.3.5 Agricultural Organizations and Programs

Agricultural organizations are working to address water quality problems associated with traditional farming practices. The Ohio Farm Bureau Federation (OFBF) seeks to improve water quality through the employment of economically sound conservation management practices (http://www.ofbf.org/). In order to pursue this mission, OFBF initiated programs aimed at engaging producers in voluntary water quality protection and improvement efforts. At the local level most county Farm Bureaus have a chairperson of an Agricultural Ecology committee that is responsible to administer OFBF programs related to environmental quality. The Agricultural Ecology chairperson often works with the county's Organizational Director, who is a staff member of the OFBF, to implement program initiatives.

The Agricultural Watershed Awareness and Resource Evaluation program within the OFBF promotes water quality monitoring and education so that producers have more information when making decisions regarding their operations. OFBF has collaborated with other organizations through the Ohio Agricultural Environmental Assurance Alliance (OAEAA) in developing a self assessment program aimed at identifying source of water pollution on farms and developing strategies to abate those problems. OFBF also offers assistance to producers who are having difficulties in complying with environmental regulations.

The Ohio Livestock Coalition (OLC) developed the Livestock Environmental Assurance Program (LEAP). This program provides training to producers in employing best management practices to their livestock operations. The On Farm Assessment and Environmental Review (OFAER) is a national program similar to LEAP but provides a more comprehensive analysis. Livestock producers can request an evaluation of their operation that is conducted by a two-person assessment team. Following the assessment, OFAER participants receive a confidential report that highlights the specific areas on their operation that can be improved in terms of environmental soundness and has recommendations for such improvements. Both of the programs are available to persons operating farms in the Mad River watershed.

3.3.6 Local Health Departments

Under OAC 3701-29, local health departments are responsible for code enforcement, operational inspections, and nuisance investigations of household sewage treatment systems serving one, two, or three family dwellings. The Ohio Department of Health works with locals health departments and provides technical assistance and training. Ohio EPA will also work with local health departments to reduce HSTS failures.

The Champaign Health District serves nearly 40,000 people in Champaign County, including the City of Urbana. The Clark County Combined Health District, including Springfield, serves nearly 140,000 people. The Greene County Combined Health District serves just over 150,000 people, including Beavercreek and Fairborn. The Logan County Health District serves nearly 46,000 people. The Public Health: Dayton and Montgomery County serves nearly 550,000 people including Dayton and some of its suburbs. Each of these health districts has a program to help home owners become educated about HSTS and how to properly maintain them. The Logan County Health District allows constructed wetlands as an alternative to traditional HSTS.

3.3.7 Local Zoning and Regional Planning

Ohio EPA is aware of no local zoning or regional planning efforts, such as low impact development or stream setbacks, that would specifically target improvements in water quality.

3.3.8 Phase II Storm Water Communities

Phase II storm water communities must develop storm water management plans that include controls for the six minimum control measures outlined by the U.S. EPA (http://cfpub.epa.gov/npdes/stormwater/munic.cfm). Dayton has already implemented a storm water management plan (SWMP). Numerous other counties, townships and municipalities are regulated under the municipal separate storm sewer systems (MS4s) and have completed SWMPs. Those plans should be fully implemented by the spring of 2008. Below is a list of regulated entities:

- Clark County
- Montgomery County
- Springfield Township
- Bethel Township
- Greene Township
- City of Springfield
- City of Huber Heights
- City of Fairborn
- Wright Patterson Air Force Base
- Green County
- Moorefield Township
- German Township
- Mad River Township
- Bath Township
- Village of Enon
- City of Riverside
- City of Beavercreek

The City of Urbana was designated as a regulated small MS4 community in late 2006. They submitted a notice of intent and a storm water management plan in spring of 2007. Because the general permit is currently being renewed, Ohio EPA is holding Urbana's application and will issue the city initial general permit coverage under the renewal, which is expected in early 2008.

3.3.9 Local Watershed Groups

Multiple local groups are active in the Mad River watershed, including the Mad Men (Trout Unlimited), B-W Greenway Community Land Trust, the Lower Mad River Watershed Protection Group, Five Rivers MetroParks and the Miami Conservancy District.

The Mad River Steering Committee was incorporated in 1999 as a non-profit, charitable, tax exempt organization. It grew out of efforts that began in 1992 in cooperation between landowners, fishermen, and the Champaign SWCD. Initial discussions of watershed protection grew from contacts by fishermen concerned about water quality and access to the river. Previously there had been some conflicts over access to the river. Other local and state agencies (Logan SWCD, ODNR and Ohio EPA) were invited to participate in the discussions. The SWCDs and Ohio State University (OSU) Extension provided facilities, personnel, and leadership until a separate formal structure was formed. This group was ultimately incorporated as the steering committee. The Mad River Steering Committee included representatives from all of the organizations and agencies involved with the watershed.

The Steering Committee and OSU Extension cooperatively applied for Section 319 grants that allowed for employment of several watershed coordinators/extension agents with the purpose of promoting and implementing conservation practices within the watershed. Many educational programs were conducted as a result of the grants. Among the last efforts of the committee was to draft a watershed action plan (WAP) for the watershed. This project and the committee became inactive with the departure of the watershed coordinator in 2006.

Clark SWCD was not involved with the steering committee but was awarded a 319 grant to develop a WAP for the portions of the watershed in Clark County and southeast Champaign County. The grant also provided for implementation of agricultural and urban BMPs. The WAP was endorsed by ODNR and Ohio EPA in 2006.

In 2008, SWCD supervisors from Logan, Champaign, and Clark counties formed a Joint Board of Supervisors for the Mad River watershed within their counties. With support from ODNR Scenic Rivers, this board has been meeting monthly to develop a draft WAP for the entire watershed. This WAP includes the lower portion of the watershed in Clark County, which already has an endorsed WAP. At the time of this report, the draft WAP had been submitted to ODNR and Ohio EPA for endorsement.

From January 2003 through December 2005, collaboration amongst several groups and many volunteers produced the Mad River Watershed In-stream/Riparian Habitat Improvement Project Summary (http://www.tumadmen.org/html/summary_report.html). During this project, over two miles of stream habitat were restored. Four other projects were referenced at the above web page that include stream buffers with riparian tree plantings and in-stream and stream bank habitat improvements.

B-W Greenway is restoring and preserving several wetlands within the Mad River watershed, including the Hebble Creek wetland in Fairborn. This organization also promotes the installation of rain gardens by educating local home and land owners.

The Miami Conservancy District (MCD) is planning several projects in the Mad River watershed that will likely benefit water quality. The first is a plan to provide cost-share incentives to five communities and organizations to implement innovative local strategies to assist with NPDES Phase II storm water management requirements, water resource protection related to development, and water impairment issues. A Community Guidebook for Smart Watersheds will be developed based on project results. The Hidden Hills Detention Basin project in Fairborn has been completed. Its purpose is to decrease soil and nutrient runoff into the Hebble Creek that flows to the Mad River and was a joint effort between the City of Fairborn, the Greene County SWCD and the MCD. Finally, the City of Dayton will install storm sewer collection systems to prevent pollutants stored at a municipal maintenance facility from running into the Mad River. In addition to these projects, the MCD monitors water quality regularly within the basin through a volunteer monitoring program. An advisory committee administers a surface water quality credit trading program, which allows permitted dischargers to buy pollutant runoff credits from farmers who voluntarily reduce their runoff.

Five Rivers MetroParks actively pursues land accrual along the Mad River (in addition to other areas) to aid in conservation. Huffman Park is located on one side of the Mad River near Dayton and provides access to the public to see the river. Many recreational opportunities also exist at this park. Eastwood Metro Park is also located along the river in Dayton and provides recreational opportunities.

3.3.10 Easements and Land Reservation

B-W Greenway Community has an active monitoring program for easements and holds several easements. The MCD has worked to protect the floodplains of rivers and streams in the Great Miami River Watershed, including the Mad River. MCD manages more than 4,500 acres of protected floodplain land through various partnerships and programs. The City of Urbana has purchased conservation easements in order to protect a wellhead area.

3.3.11 Other Sources of Funding and Special Projects

Since 1994, six Clean Water Act Section 319 grants have been awarded in the Mad River watershed. In response to local concerns about nitrate contamination of ground water several grants have been focused or included activities related to this concern. ODNR’s Division of Water was awarded a grant to study the surface water/ground water interchange in the King’s Creek watershed. The Champaign SWCD was given a grant to demonstrate several conservation BMPs, volunteer water quality monitoring and education programs.

OSU Extension has been very active in the watershed and, along with the Steering Committee, was the recipient of two grants in which they provided fiscal management and watershed coordinator supervision. Activities conducted within these grants included: outreach and education, ground water protection through demonstrations of nutrient and manure management, filter strips, and riparian restoration. Included with one of the grants was support of in-stream habitat improvements that were installed by the Mad Men Chapter of Trout Unlimited. The last grant to OSU Extension ended with the departure of the last watershed coordinator.

Clark SWCD also received a grant for activities within their portion of the watershed. Among the tasks accomplished were: education and outreach, septic system pumping and inspection, erosion control, filter strips, tree buffers and creation of an urban wetland. Also included was development of a watershed action plan that was endorsed by ODNR and Ohio EPA.

Another grant was awarded to the U.S. Geological Survey for water quality modeling in support of this TMDL.

3.4 Process for Evaluation and Revision

The effectiveness of actions implemented based on the TMDL recommendations should be validated through ongoing monitoring and evaluation. Information derived from water quality analyses can guide changes to the implementation strategy to more effectively reach the TMDL goals. Additionally, monitoring is required to determine if and when formerly impaired segments meet applicable water quality standards (WQS).

This section of the report provides a general strategy for continued monitoring and evaluation and lists parties who can potentially carry out such work. It highlights past efforts and those planned to be carried out in the future by the Ohio EPA and others. It also outlines a process by which changes to the implementation strategy can be made if needed.

3.4.1 Evaluation and Analyses

Aquatic life and recreational uses are impaired in the watershed, so monitoring that evaluates the river system with respect to these uses is a priority to the Ohio EPA. The degree of impairment of aquatic life use is exclusively determined through the analysis of biological monitoring data. Recreational use impairment is determined through bacteria counts from water quality samples. Ambient conditions causing impairment include CSOs, WWTPs, cattle in the streams, failing home septic systems, and agricultural runoff. Improvements in these sources should improve aquatic life use and recreation use attainment.

A serious effort should be made to determine if and to what degree the recommended implementation actions have been carried out. This should occur within an appropriate timeframe following the completion of this TMDL report and occur prior to measuring the biological community, water quality or habitat.

Past and Ongoing Water Resource Evaluation
The Ohio EPA has conducted water quality surveys within the Mad River watershed in 1992 and in 2003 (Ohio EPA, 1994, 2005). The Ohio EPA is scheduled to perform biological, water quality, habitat, and sediment chemistry monitoring in all five assessment units in the basin in 2018 (Ohio EPA, 2006).

Past and continued monitoring in the watershed includes analysis of raw water from water treatment plants (WTPs), and ambient and effluent discharges from more than 60 NPDES permitted facilities. Raw water is monitored by the permittees. These data are included in the Discharge Monitoring Reports (DMRs) that are submitted to the Ohio EPA by these facilities.

Considerable research has been completed and published by the USGS. Several publications are available on their web site: http://www.usgs.gov/pubprod/.

Potential and Future Evaluation
Section 319(h) grants are available every year through Ohio EPA and can fund continuing monitoring as well as implementation actions. The close proximity of colleges and universities within the Mad River watershed increases the potential for collaboration and/or the availability of independently collected data regarding water resources in the watershed.

Recommended Approach for Gathering and Using Available Data
Early communications should take place between the Ohio EPA and any potential collaborators to discuss research interests and objectives. Through this, 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.

3.4.2 Revision to the Implementation Approach

An adaptive management approach will be taken in the Mad River watershed. Adaptive management is recognized as a viable strategy for managing natural resources (Baydack *et al.*, 1999) and this approach is applied on federally-owned lands. An adaptive management approach allows for changes in the management strategy if environmental indicators suggest that the current strategy is inadequate or ineffective. The recommendations put forth for the Mad River watershed largely center on elimination of failing septic systems; elimination of direct access to cattle to streams; load reductions from CSOs of 95 percent; improvements made to WWTPs that would eliminate all 30-day geometric mean exceedances of 1,000 col/100 mL in effluent; and a 30 percent reduction in nitrate runoff. If chemical water quality does not show improvement and/or water bodies are still not attaining water quality standards after the implementation plan has been carried out, then a TMDL revision would be initiated. The Ohio EPA would initiate the revision if no other parties wish to do so.

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Appendix A

QHEI Analysis for the Mad River

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A.1 Description of the QHEI

The QHEI is a quantitative expression of a qualitative, visual assessment of habitat in free flowing streams and was developed by the Ohio EPA to assess available habitat for fish communities (Rankin, 1989, 1994). The QHEI is a composite score of six physical habitat categories: 1) substrate, 2) in-stream cover, 3) channel morphology, 4) riparian zone and bank erosion, 5) pool/glide and riffle/run quality, and 6) gradient. Each of these categories are 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 is used by a trained evaluator while in the stream itself. Each of the components are evaluated on site, recorded on the form, the score totaled, and the data later analyzed in an electronic database. The evaluation form is available online at http://www.epa.state.oh.us/dsw/bioassess/QHEIFieldSheet062401.pdf

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 these 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 may have poorer physical habitat due to 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 indicated that the QHEI is significantly correlated with the IBI. Scores greater than 75 indicate excellent stream habitat, scores between 60 and 75 indicate good habitat quality, and scores less than 45 demonstrate habitat not conducive to WWH. Scores between 45 and 60 need separate evaluation by trained field staff to determine the potential aquatic life use for the stream.

All sites within the Mad River are either classified or recommended as coldwater or warmwater habitat (i.e., there are no exceptional warmwater habitat classifications). Since the IBI target for coldwater habitat is nearly identical to that for warmwater habitat, the warmwater QHEI target of 60 was used for this analysis. (WWH boat sites have an IBI target of 42 for boat sites, instead of 40 for CWH boat sites. The targets for headwater and wading sites are the same.)

The empirical nature of the QHEI and the data that underlie it provide measurable targets that are parallel concepts to a loading capacity for a pollutant. The components provide a way to evaluate whether habitat is a limiting factor for the fish community and which attributes are the likely stressors. The QHEI can assess both the source of the sediment (riparian corridor, bank stability) and the effects on the stream itself (i.e., the historic sediment deposition) and thus, has aspects of both a loading model and a receiving stream model. When used with biological indices, the numeric measurability of the index provides a means to monitor progress when implementing a TMDL and to validate that a target has been reached.

Current attainment levels of Mad River segments, along with QHEI scores and causes and sources of impairment, are given in the *Biological and Water Quality Study of the Mad River Basin, 2003* and are presented in Table A.1.

Figures 1 and 2 show the QHEI scores for all sites in the watershed grouped by attainments status. The figures show that all but a small number of the fully attaining sites have QHEI scores above the target. The majority of sites that are impaired have

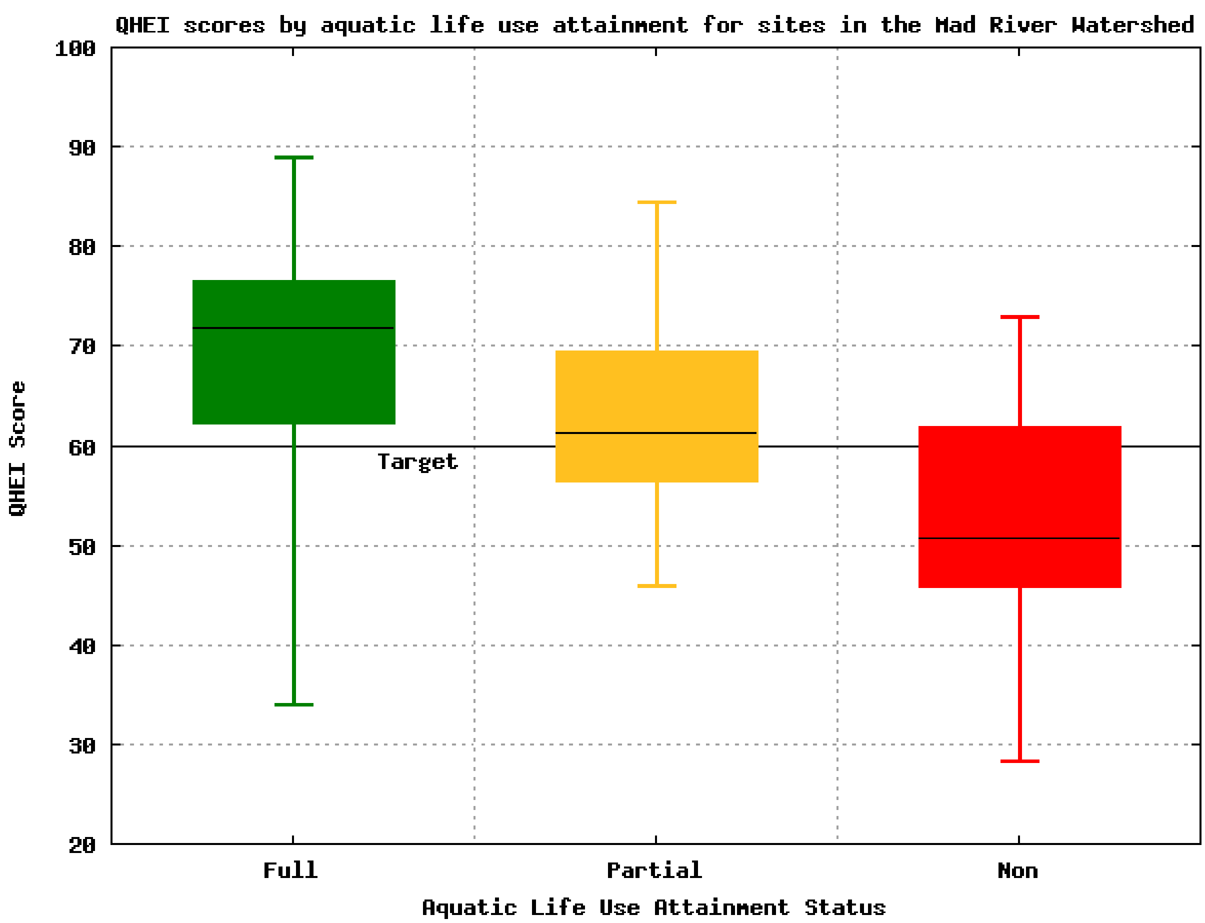

Figure 1. Comparison of habitat quality and biological response.

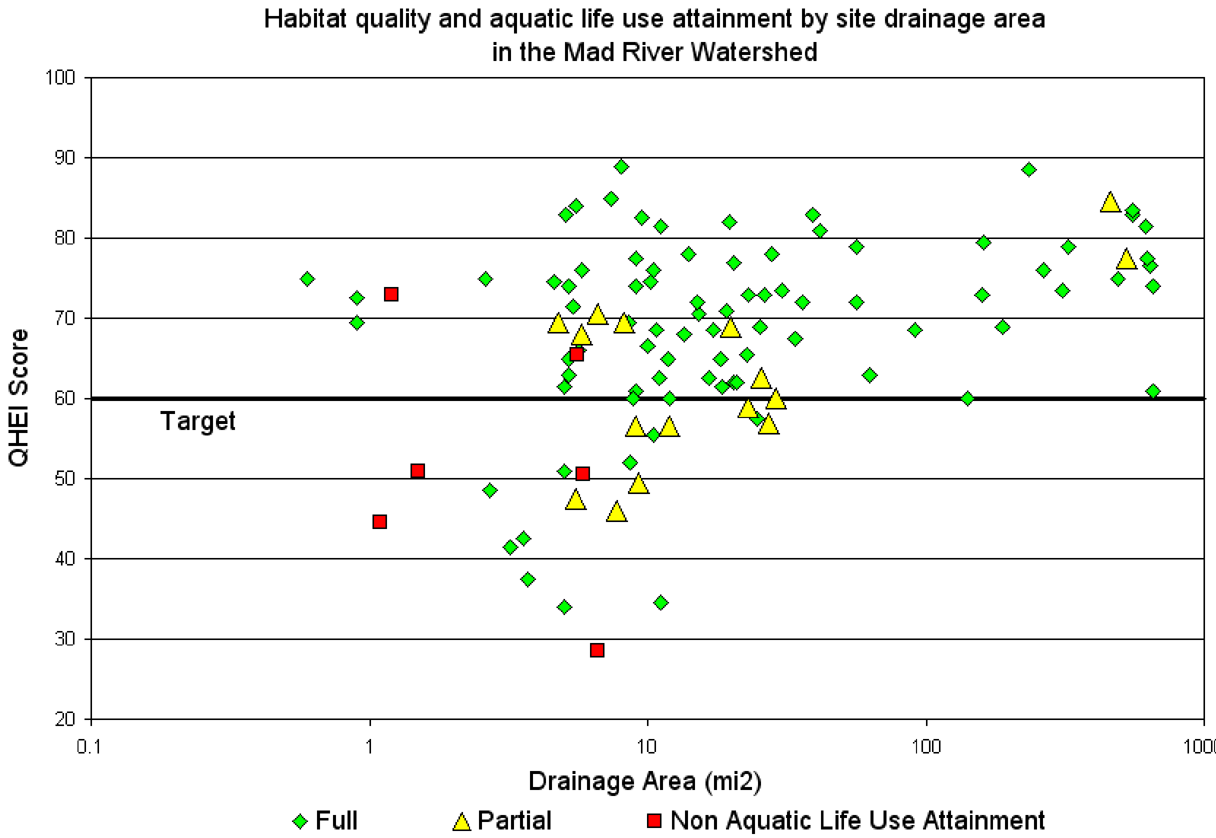

Figure 2. Comparison of habitat quality and biological response distributed by drainage area of sampling site.

QHEI scores less than 60. This demonstrates the importance the quality of the habitat has on attaining water quality standards in Ohio.

A.2 QHEI Habitat TMDL

The analysis of the QHEI components as they relate to IBI scores led to the development of a list of attributes that are associated with degraded communities. These attributes are modifications of natural habitat and are listed in Table A.2. These modified attributes were further divided into high influence or moderate influence attributes based on the statistical strength of the relationships. The presence of these attributes can strongly influence the aquatic biology and the QHEI score itself may not reflect this effect. This explains why habitat can be impaired even with a QHEI score above 60 (because other less influential habitat components are in place).

These three factors appear to have about an equal weight. An accumulation of four modified attributes corresponds to fewer than 50% of sites achieving a WWH target IBI score of 40. High influence modified attributes are particularly detrimental given that the presence of one is likely to result in impairment, and two will likely preclude a site from achieving an IBI of 40 (OEPA, 1999). The QHEI score of 60 or greater is correlated with IBIs of 40 or greater. A complete habitat TMDL needs to reflect both a good QHEI score and the relative presence of these modified attributes.

The habitat TMDL equation presented below reflects the relationship between the QHEI score, modified attributes, and aquatic community performance. It is based upon a total score of three (3), and is the sum of three component scores each worth one point.

Habitat TMDL = QHEI Score ≥ Target + Modified Attribute Score + High Influence Attribute Score
= 1 + 1 + 1
= 3

A.3 QHEI Bedload TMDL

The QHEI can also be used to evaluate the degree of bedload and the quality of the substrate at a particular site. The substrate, riparian characteristic, and channel metrics all evaluate stream attributes related to bedload. The substrate metric includes an assessment of streambed sediment quality, quantity, and origin. The riparian metric evaluates riparian width, quality, and bank erosion. The channel metric describes stream physical morphology including sinuosity and extent of development. Each of these factors influences the degree to which siltation affects a stream, and cumulatively serves as its numeric target.

The bedload TMDL equation which follows is a subset of those factors of the QHEI most directly related to sediment type, quality, build up, and source origin. The sediment TMDL is a score of 32 for WWH sites. The individual components of the bedload TMDL (QHEI scores for substrate, channel, and riparian) are allocated as described below and in Table 2.

Bedload TMDL = Substrate + Channel Morphology + Riparian Zone/Bank Erosion

For WWH ≥ 13 + 14 + 5
≥ 32

A.4 Results

Habitat assessment results are given in tables A.3 through A.8, and the QHEI TMDL results are summarized in tables A.9 through A.14. These are divided up by the five HUC11s with a separate section (LRAU 05080001 003) for the lower Mad River main stem. The bedload and habitat allocations are site specific, and all sites with a habitat assessment within the major watershed are presented in the table. The loading capacity and allocation tables follow and are organized by minor subwatershed. It is important to note that a site's attributes may contribute to downstream impairment (especially bedload) without the site itself being impaired.

The bedload and habitat TMDL tables show the applicable targets per component in the header row of the table. The information presented in the body of the table is grouped by each of the minor sub-watersheds from upstream to down, and it is organized by stream and site river mile. The existing scores for each category and the total existing bedload and habit score is defined. The percent deviation the actual bedload score is from the allowable bedload score is shown followed by the main impaired QHEI category of the three used in determining the bedload score. The existing total habitat score per site can be compared to the allowable habitat score to make the same deviation determination. This table shows what components of the habitat need improvement and to what degree, and it can be used to guide management decisions and implementation activities.

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Table A.1 Aquatic life use attainment status of the Mad River basin, June-October, 2003. The Index of Biotic Integrity (IBI), Modified Index of Well Being (MIwb) and Invertebrate Community Index (ICI) scores are based on the performance of fish (IBI, MIwb) and macroinvertebrate (ICI) communities. The Qualitative Habitat Evaluation Index (QHEI) is a measure of the ability of the physical habitat to support biological communities.

Stream River Mile, Invertebrate / Fish	Attainment Status[a]	IBI	MIwb	ICI / Narrative[b]	QHEI	Drainage Area	Causes[d]	Sources[e]
LRAU: 05080001 003 Mad River downstream Donnels Creek (RM 18.4) to mouth								
Mad River				*WWH*				
17.5 / 17.5	Partial	34*	8.4[ns]	G	77.5	527	Flow alteration	Agricultural related channelization
13.1 / 13.1	Full	41[ns]	9.2	G	83.5	554		
11.5 / 11.5	Full	38[ns]	9	46	83	554		
9.0 / 8.6	Full	40[ns]	9.2	G	81.5	617		
6.0 / 6.0	Full	43	8.7	40	77.5	622		
4.0 / 4.0	Full	52	10.1	42	76.5	642		
1.6 / 1.6	Full	52	9.7	G	74	654		
0.3 / 0.3	Full	50	9.5	G	61	657		

Table A.1 (con't)

Stream River Mile, Invertebrate / Fish	Attainment Status[a]	IBI	MIwb	ICI / Narrative[b]	QHEI	Drainage Area	Causes[d]	Sources[e]
WAU: 05080001 150 Upper Mad River								
Mad River				*CWH*				
61.3 / 61.2	Full	54	NA	G	85	7.4		
57.2 / 57.2	Full	40	NA	50	62	20.4		
53.2 / 53.2	Full	41	NA	46	67.5	34		
52.0 / 52.1	Full	41	NA	44	72	36		
51.1 / 51.1	Full	40	NA	48	79	56		
51.0 / 51.0	Full	41	NA	48	72	56		
49.1 / 49.1	Full	39[ns]	NA	52	63	63		
43.9 / 43.9	Full	42	NA	54	68.5	91		
Sugar Creek				*undesignated / CWH recommended*				
— / 1.0	(Full)	38[ns]	NA		42.5	3.6		
Peters Ditch				*undesignated / CWH recommended*				
— / 0.1	(Full)	42	NA		63	5.2		
Macochee Creek				*CWH*				
6.2 / 6.2	Full	56	NA	E	74	5.2		
3.7 / 3.7	Full	44	NA	VG	68	13.5		
3.0 / 3.0	Full	42	NA	46	78	14.1		

Table A.1 (con't)

Stream River Mile, Invertebrate / Fish	Attainment Status[a]	IBI	MIwb	ICI / Narrative[b]	QHEI	Drainage Area	Causes[d]	Sources[e]
WAU: 05080001 150 (continued)								
Macochee Creek				*CWH*				
1.4 / 1.4	Full	46	NA	G	62.5	16.6		
0.1 / 0.1	Full	44	NA	G	71	19.1		
Macochee Ditch				*CWH*				
3.4 / 3.4	Full	36[ns]	NA	MG[ns]	34	5		
0.7 / 0.7	Partial	30*	NA	G	46	7.8	Habitat alteration	Agricultural related channelization
Glady Creek				*CWH (verified)*				
3.6 / 4.2	Full	36[ns]	NA	MG[ns]	66.5	10		
Kings Creek				*CWH*				
6.1 / 6.1	Full	36[ns]	NA	MG[ns]	69.5	8.5		
3.9 / 3.9	Partial	35*	NA	38	60	29	Habitat alteration	Agricultural related channelization
0.1 / 0.1	Full	43	NA	44	81	41.8		
Trib. to Kings Creek (RM 4.99 / 3.18)				*undesignated / CWH recommended*				
1.0 / 1.0	Full	42	NA	VG	74.5	10.2		
Trib. to Kings Creek (RM 0.46)				*CWH*				
0.4 / 0.6	Full	36[ns]	NA	G	60	8.9		

Table A.1 (con't)

Stream River Mile, Invertebrate / Fish	Attainment Status[a]	IBI	MIwb	ICI / Narrative[b]	QHEI	Drainage Area	Causes[d]	Sources[e]
WAU: 05080001 160 Mad River / Nettle Creek								
Mad River				*CWH*				
41.6 / 41.6	Full	48	NA	56	73	160		
39.9 / 39.9	Full	41	NA	50	79.5	162		
38.4 / 38.4	Full	41	NA	46	69	188		
32.7 / 32.7	Full	36[ns]	NA	46	76	264		
Muddy Creek				*WWH existing / CWH recommended*				
6.3 / 6.3	Partial	34*	NA	G	56.5	12	Habitat alteration	Agricultural related channelization
0.4 / 0.5	Full	44	NA	48	65.5	22.8		
Spring Run				*CWH existing / WWH recommended*				
0.7 / 0.7	Full	52	NA	MG[ns]	37.5	3.7		
Dugan Run				*WWH*				
1.2 / 1.2	Partial	32*	7.1*	G	59	23	Habitat alteration, nutrients, enrichment / DO, metals, organics	Channelization, urban runoff, contaminated sediments
Nettle Creek				*CWH*				
8.2 / 8.2	Full	44	NA	40	89	8		
7.1 / 7.1	Full	46	NA	MG[ns]	60	12		

Table A.1 (con't)

Stream River Mile, Invertebrate / Fish	Attainment Status[a]	IBI	MIwb	ICI / Narrative[b]	QHEI	Drainage Area	Causes[d]	Sources[e]
WAU: 05080001 160 (continued)								
Nettle Creek				*CWH*				
4.4 / 4.5	Full	44	NA	50	72	15		
2.5 / 2.8	Partial	34*	NA	G	69	19.8	Siltation (sand)	Undetermined, possibly natural
0.1 / —	(Full)	NA	NA	48		46.2		
Anderson Creek				*CWH*				
5.9 / 5.9	Full	48	NA	G	71.5	5.4		
3.7 / 3.7	Full	52	NA	MG[ns]	68.5	10.7		
1.0 / 1.0	Full	38[ns]	NA	G	68.5	17.2		
Harban Creek				*CWH (verified)*				
— / 0.1	(Full)	58	NA		75	0.6		
Russell Creek				*PHWH candidate[c]*				
0.1 / —	NA		NA	P*				
Owens Creek				*CWH existing / WWH recommended*				
0.1 / 0.1	Full	54	NA	VG	66	5.7		
Hog Creek				*CWH existing / WWH recommended*				
0.6 / 0.6	Full	44	NA	G	69.5	0.9		

Table A.1 (con't)

Stream River Mile, Invertebrate / Fish	Attainment Status[a]	IBI	MIwb	ICI / Narrative[b]	QHEI	Drainage Area	Causes[d]	Sources[e]
WAU: 05080001 160 (continued)								
Trib. to Nettle Creek (RM 8.80)				*WWH*				
2.7 / 2.7	NON	42	NA	P*	44.5	1.1	Habitat alteration, organic enrichment / DO	Channelization, urban runoff, sanitary overflows
2.6 / 2.6	NON	46	NA	VP*	73	1.2	Habitat alteration, organic enrichment / DO	Channelization, urban runoff, sanitary overflows, municipal WWTP discharge
Stony Creek				*CWH existing / WWH recommended*				
0.7 / 0.7	NON	38[ns]	NA	P*	51	1.5		
Storms Creek				*CWH (verified)*				
2.1 / 2.7	Full	50	NA	G	76	5.8		
0.7 / 0.7	Full	46	NA	G	61	9.1		
Chapman Creek				*CWH*				
10.1 / 10.1	Partial	30*	NA	MG[ns]	68	5.8		
6.9 / 6.9	Full	56	NA	VG	76	10.5		
4.0 / 4.0	Full	48	NA	52	61.5	18.6		
0.8 / 0.8	Full	45	NA	48	57.5	24.7		

Table A.1 (con't)

Stream River Mile, Invertebrate / Fish	Attainment Status[a]	IBI	MIwb	ICI / Narrative[b]	QHEI	Drainage Area	Causes[d]	Sources[e]
WAU: 05080001 160 (continued)								
Deer Creek			*CWH existing / WWH recommended*					
0.6 / 0.6	Full	48	NA	G	72.5	0.9		
Blacksnake Creek			*CWH existing / WWH recommended*					
0.4 / 0.4	Full	48	NA	MG[ns]	41.5	3.2		

Table A.1 (con't)

Stream River Mile, Invertebrate / Fish	Attainment Status[a]	IBI	MIwb	ICI / Narrative[b]	QHEI	Drainage Area	Causes[d]	Sources[e]
WAU: 05080001 170 Buck Creek								
Buck Creek				*PHWH candidate*[c]				
19.5 / —	NA		NA	P*		3.8		
				CWH (verified)				
17.5 / 17.5	Full	54	NA	VG	82.5	9.5		
13.1 / 13.1	Full	46	NA	48	73.5	30.5		
				WWH				
6.4 / 6.4	Partial	44	8.7	24*	69.5	82	Habitat and flow alteration	Upstream impoundment
0.6 / 0.6	Full	46	9.4	52	60	141		
Beaver Creek				*CWH existing / WWH recommended*				
10.2 / 10.2	Full	54	NA	G	62.5	11		
4.5 / 4.5	Full	51	8.2[ns]	52	62	21		
				WWH				
0.7 / 0.7	Full	38[ns]	7.8[ns]	54	83	39		
Sinking Creek				*WWH (verified)*				
4.6 / 4.6	Full	38[ns]	NA	MG[ns]	55.5	10.5		

Table A.1 (con't)

Stream River Mile, Invertebrate / Fish	Attainment Status[a]	IBI	MIwb	ICI / Narrative[b]	QHEI	Drainage Area	Causes[d]	Sources[e]
WAU: 05080001 170 (continued)								
East Fork Buck Creek				*CWH (verified)*				
5.2 / 5.0	Full	40	NA	G	51	5		
0.3 / 0.3	Full	37[ns]	NA	54	78	28		
U.T. to East Fork Buck Creek				*PHWH candidate[c]*				
0.9 / —	NA		NA	F*				
Dugan Ditch				*undesignated / CWH recommended*				
2.2 / 2.2	Full	42	NA	VG	34.5	11.2		

Table A.1 (con't)

Stream River Mile, Invertebrate / Fish	Attainment Status[a]	IBI	MIwb	ICI / Narrative[b]	QHEI	Drainage Area	Causes[d]	Sources[e]
WAU: 05080001 180 Downstream Chapman Cr. to upstream Mud Cr. (excluding Buck Cr.)								
Mad River				*CWH*				
29.6 / 29.6	Full	44	NA	54	73.5	310		
27.0 / 27.0	Full	46	NA	G	79	323		
				WWH				
25.5 / 25.8	Partial	35*	8.7	42	84.5	464	Habitat alteration	Agricultural related channelization
24.1 / 24.1	Full	38[ns]	9.0	G	75	490		
Moore Run				*WWH*				
4.1 / 4.1	NON	28*	NA	F*	28.5	6.6	Habitat alteration	Agricultural related channelization
2.5 / 2.5	Partial	38[ns]	NA	F*	49.5	9.3	Habitat alteration, ammonia, enrichment / DO, metals, organics	Channelization, industrial point sources contaminated sediments
0.8 / 0.8	Full	46	NA	MG[ns]	65	18.2		
Kenton Creek				*WWH*				
0.3 / 0.7	Partial	48	NA	F*	69.5	4.8	Flow alteration	Agricultural related channelization
Pondy Creek				*CWH existing / WWH recommended*				
1.1 / 1.1	Partial	32*	NA	MG[ns]	47.5	5.5	Apparently goes dry	Natural

Table A.1 (con't)

Stream River Mile, Invertebrate / Fish	Attainment Status[a]	IBI	MIwb	ICI / Narrative[b]	QHEI	Drainage Area	Causes[d]	Sources[e]
WAU: 05080001 180 (continued)								
Dry Run				*CWH existing / WWH recommended*				
0.3 / 0.3	Full	38[ns]	NA	G	48.5	2.7		
Mill Creek				*WWH (verified)*				
3.2 / 3.2	Full	46	NA	VG	83	5.1		
0.1 / 0.1	Full	52	NA	MG[ns]	70.5	15.3		
Rock Run				*WWH (verified)*				
0.1 / 0.1	Full	46	NA	VG	74	9.1		
Miller Creek				*WWH (verified)*				
0.1 / 0.1	Full	40	NA	VG	75	2.6		
Donnels Creek				*EWH existing / WWH recommended*				
7.5 / 7.5	Full	48		VG	81.5	11.2		
3.7 / 3.7	Full	44	8.2[ns]	VG	73	23.1		
1.9 / 1.9	Partial	40	7.7*	VG	62.5	25.6	Lowered water table	Natural
East Fork Donnels Creek				*WWH (verified)*				
2.9 / 2.9	Full	46	NA	MG[ns]	84	5.5		
0.1 / 0.1	Full	52	NA	E	77.5	9.1		

Table A.1 (con't)

Stream River Mile, Invertebrate / Fish	Attainment Status[a]	IBI	MIwb	ICI / Narrative[b]	QHEI	Drainage Area	Causes[d]	Sources[e]
WAU: 05080001 180 (continued)								
Jackson Creek			*EWH existing / WWH recommended*					
3.8 / 3.8	Full	48	NA	VG	61.5	5		
0.9 / 0.9	Full	56	NA	MG[ns]	52	8.7		

Table A.1 (con't)

Stream River Mile, Invertebrate / Fish	Attainment Status[a]	IBI	MIwb	ICI / Narrative[b]	QHEI	Drainage Area	Causes[d]	Sources[e]
WAU: 05080001 190 Lower Mad River tribs.								
Mud Creek				*undesignated / WWH recommended*				
5.0 / 5.0	NON	40	NA	P*	50.5	5.9	Organic enrichment / DO	Small WWTP point source
2.5 / 2.5	Partial	46	NA	F*	56.5	9.1	Organic enrichment / DO	Small WWTP point source
0.6 / 0.6	Full	52	NA	MG[ns]	82	19.6		
Mud Run				*WWH (verified)*				
9.7 / 9.7	Full	56	NA	E	65	11.8		
7.8 / 7.8	Full	54	9.2	56	77	20.4		
3.3 / 3.3	Full	40	7.8[ns]	56	69	25.5		
2.0 / 2.0	Full	51	8.0[ns]	48	73	26.4		
0.8 / 0.8	Partial	41	6.4*	48	57	27.2		
Clear Creek				*WWH (verified)*				
0.5 / 0.5	Full	48	NA	G	65	5.2		
Trib. to Mud Run (RM 9.8)				*undesignated / WWH recommended*				
0.7 / 0.7	NON	24*	NA	G	65.5	5.6	Habitat alteration	Landfill past practices
Drylick Run				*undesignated / WWH recommended*				
1.6 / 1.7	Full	40	NA	MG[ns]	74.5	4.6		

Table A.1 (con't)

Stream River Mile, Invertebrate / Fish	Attainment Status[a]	IBI	MIwb	ICI / Narrative[b]	QHEI	Drainage Area	Causes[d]	Sources[e]
WAU: 05080001 190 (continued)								
Hebble Creek				*MWH*				
5.0 / 5.0	Full	30	NA	F	34	5		
0.1 / —	(Full)		NA	G				
Lilly Creek				*MWH*				
0.1 / 0.1	Partial	22*	NA	F	70.5	6.6	Habitat and flow alteration, organic enrichment / DO	Urban runoff, hydromodification

Table A.1 (con't)

Ecoregion Biocriteria: E. Corn Belt Plains (ECBP)

INDEX - Site Type	LRW	MWH channel modified	CWH	WWH	EWH
IBI, Headwater or Wading / Boat MIwb, Wading / Boat ICI	18 / 18 4.0 / 4.0 8	24 / 24 6.2 / 5.8 22	40 — / 6.6 36	40 / 42 8.3 / 8.5 36	50 9.4 / 9.6 46

a Use attainment status based on one organism group is parenthetically expressed.

b Narrative evaluation used in lieu of ICI (E=Exceptional; G=Good; MG^{ns}=Marginally Good; F=Fair; P=Poor).

c Designation of aquatic life use for small watercourses that can be best characterized as a Class III Primary Headwater Habitat (PHWH) water body will remain undesignated pending promulgation of the PHWH use in the Ohio Water Quality Standards. Primary Headwater Habitat classes are defined in *Ohio Environmental Protection Agency. 2002. Field Evaluation Manual for Ohio's Primary Headwater Streams, Final Version 1.0. Division of Surface Water, Columbus, Ohio.* When the PHWH use becomes codified, these streams will be assigned an appropriate aquatic life use utilizing the Ohio EPA rulemaking process established for designating aquatic life uses for Ohio streams.

d Causes listed are considered to be a primary influence on water quality, but may not be the only issue leading to impairment. See text for discussion of additional causes that cumulatively led to impairment.

e Sources listed are considered to be a primary influence on water quality, but may not be the only issue leading to impairment. See text for discussion of additional causes that cumulatively led to impairment.

* Significant departure from ecoregion biocriterion; poor and very poor results are underlined.

ns Nonsignificant departure from biocriterion (<4 IBI or ICI units; <0.5 MIwb units).

NA Not Applicable. The MIwb is not applicable to headwater sites.

Table A.2 Details of Habitat and Bedload TMDLs

Bedload TMDL Categories

QHEI Category	WWH Target
Substrate	≥13
Channel	≥14
Riparian	≥5
Bedload TMDL ➤	≥32

Habitat TMDL Categories

QHEI Category	WWH Target	Score
QHEI Score	≥ 60	+1
High Influence #	< 2	+1
Total # Modified	< 5	+1
Habitat TMDL ➤		3

Modified Attributes

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

Table A.3 Habitat Assessment Results for LRAU* 05080001 003: Mad River mainstem downstream Donnels Creek (RM 18.4) to mouth

		WWH Attributes											MWH Attributes: High Influence						MWH Attributes: Moderate Influence													
River Mile	QHEI	No Channelization or Recovered	Boulder or Cobble or Gravel Substrate	Silt Free Substrate	Excellent or Good Development	Moderate or High Sinuosity	Extensive or Moderate Cover	Fast Velocity or Eddies	Normal or No Substrate Embeddedness	Maximum Pool Depth > 40 cm	Low or No Riffle/Run Embeddedness	**Total WWH Attributes**	Recent Channelization or No Recovery	Silt or Muck Substrate	Low or No Sinuosity and Drainage Area <= 20 sq. mi.	Sparse or Nearly Absent Cover	< 40 cm Max. Pool Depth and Wadeable or Headwater Site	**Total High-Influence MWH Attributes**	Recovering Channelization	Silt Heavy or Silt Moderate	Sand Substrate and Boat Site	Hardpan Substrate Origin	Fair or Poor Development	Low or No Sinuosity and Drainage Area > 20 sq. mi.	Two or Less Cover Types	Intermittent Pools and Max. Pool Depth < 40 cm	No Fast Current Velocity	Extensive or Moderate Substrate Embeddedness	Extensive or Moderate Riffle Embeddedness	No Riffle	**Total Moderate-Influence MWH Attributes**	Current Use Attainment Status (○ = full, ◑ = partial, ● = non)
HUC 05080001-180-080 - Mad River below Donnels Cr. to above Mud Cr. [except Jackson Cr.]																																
Mad River (WWH)																																
17.5	77.5		■		■		■	■	■	■	■	7				■		1	■				■	■							3	◑
13.1	83.5	■	■		■	■	■	■	■	■	■	9						0	■					■							2	○
11.5	83.0	■	■		■		■	■	■	■	■	8						0	■				■	■				■			4	○
HUC 05080001-190-020 - Mad River below Mud Cr. to Huffman Dam [except Mud Run]																																
Mad River (WWH)																																
8.6	81.5	■	■		■	■	■	■	■	■	■	9				■		1	■					■					■		3	○
6.0	77.5		■		■		■	■		■	■	6						0	■	■	■			■				■			5	○
HUC 05080001-190-040 - Mad River below Huffman Dam to G. Miami R.																																
Mad River (WWH)																																
4.0	76.5		■		■		■	■		■		5				■		1	■	■				■				■	■		5	○
1.6	74.0		■		■		■	■		■		5						0	■	■	■			■				■	■		6	○
0.3	61.0		■					■		■		3	■			■		2	■	■	■		■	■				■	■		7	○

* Large River Assessment Unit

Table A.4 Habitat Assessment Results for WAU* 05080001 150: Upper Mad River

		WWH Attributes											MWH Attributes: High Influence						MWH Attributes: Moderate Influence													
River Mile	QHEI	No Channelization or Recovered	Boulder or Cobble or Gravel Substrate	Silt Free Substrate	Excellent or Good Development	Moderate or High Sinuosity	Extensive or Moderate Cover	Fast Velocity or Eddies	Normal or No Substrate Embeddedness	Maximum Pool Depth > 40 cm	Low or No Riffle/Run Embeddedness	**Total WWH Attributes**	Recent Channelization or No Recovery	Silt or Muck Substrate	Low or No Sinuosity and Drainage Area <= 20 sq. mi.	Sparse or Nearly Absent Cover	< 40 cm Max. Pool Depth and Wadeable or Headwater Site	**Total High-Influence MWH Attributes**	Recovering Channelization	Silt Heavy or Silt Moderate	Sand Substrate and Boat Site	Hardpan Substrate Origin	Fair or Poor Development	Low or No Sinuosity and Drainage Area > 20 sq. mi.	Two or Less Cover Types	Intermittent Pools and Max. Pool Depth < 40 cm	No Fast Current Velocity	Extensive or Moderate Substrate Embeddedness	Extensive or Moderate Riffle Embeddedness	No Riffle	**Total Moderate-Influence MWH Attributes**	Current Use Attainment Status (○ = full, ◑ = partial, ● = non)
HUC 05080001-150-020 - Mad River below SR 33 to above Machochee Cr.																																
Mad River (CWH)																																
61.2	85.0	■	■		■	■	■	■	■	■	■	9						0	■												1	○
57.2	62.0		■			■			■	■	■	5				■		1	■				■	■			■	■			5	○
53.2	67.5		■					■	■	■	■	5				■		1	■				■	■							3	○
52.1	72.0		■		■	■	■	■	■	■	■	8				■		1	■				■	■							3	○
Sugar Creek (CWH)																																
1.0	42.5		■	■					■		■	4	■		■	■	■	4				■	■		■		■				4	○
Peters Ditch (CWH)																																
0.1	63.0		■	■		■			■	■	■	6				■		1	■				■				■				3	○
HUC 05080001-150-030 - Machochee Creek																																
Macochee Creek (CWH)																																
6.2	74.0	■	■		■	■	■	■		■	■	8						0	■									■	■		3	○
3.7	68.0		■		■		■	■		■		5			■			1	■	■								■	■		4	○
3.0	78.0		■		■		■	■	■	■	■	7			■			1	■										■		2	○
1.4	62.5		■		■		■	■	■	■		6			■			1	■				■					■	■		4	○
0.1	71.0	■	■		■	■	■	■		■		7			■			1	■				■					■	■		4	○
HUC 05010008-150-040 - Mad River below Machochee Cr. to above Kings Cr. [except Glady Cr.]																																
Mad River (CWH)																																
51.1	79.0		■		■	■	■	■	■	■	■	8						0	■												1	○
51.0	72.0				■		■	■	■	■	■	6				■		1	■				■	■					■		4	○
49.1	63.0		■	■				■	■	■	■	6	■			■		2	■				■	■					■		4	○
43.9	68.5		■	■				■	■	■	■	6	■			■		2	■				■	■							3	○
Macochee Ditch (CWH)																																
3.4	34.0									■		1	■	■	■	■		4		■			■				■	■		■	5	○
0.7	46.0							■	■	■		3		■	■	■		3	■	■			■							■	4	◑

* Watershed Assessment Unit

Table A.4 (con't) **Habitat Assessment Results for WAU 05080001 150: Upper Mad River**

		WWH Attributes											MWH Attributes: High Influence						MWH Attributes: Moderate Influence													
River Mile	QHEI	No Channelization or Recovered	Boulder or Cobble or Gravel Substrate	Silt Free Substrate	Excellent or Good Development	Moderate or High Sinuosity	Extensive or Moderate Cover	Fast Velocity or Eddies	Normal or No Substrate Embeddedness	Maximum Pool Depth > 40 cm	Low or No Riffle/Run Embeddedness	**Total WWH Attributes**	Recent Channelization or No Recovery	Silt or Muck Substrate	Low or No Sinuosity and Drainage Area <= 20 sq. mi.	Sparse or Nearly Absent Cover	< 40 cm Max. Pool Depth and Wadeable or Headwater Site	**Total High-Influence MWH Attributes**	Recovering Channelization	Silt Heavy or Silt Moderate	Sand Substrate and Boat Site	Hardpan Substrate Origin	Fair or Poor Development	Low or No Sinuosity and Drainage Area > 20 sq. mi.	Two or Less Cover Types	Intermittent Pools and Max. Pool Depth < 40 cm	No Fast Current Velocity	Extensive or Moderate Substrate Embeddedness	Extensive or Moderate Riffle Embeddedness	No Riffle	**Total Moderate-Influence MWH Attributes**	Current Use Attainment Status (○ = full, ◑ = partial, ● = non)
HUC 05080001-150-050 - Glady Creek																																
Glady Creek (CWH)																																
4.2	66.5				■			■	■	■	■	5			■	■		2	■				■								2	○
HUC 05080001-150-060 - Kings Creek																																
Kings Creek (CWH)																																
6.1	69.5		■		■		■	■	■	■		6			■			1	■										■		2	○
3.9	60.0		■						■	■		3		■		■		2	■				■	■			■			■	5	◑
0.1	81.0	■	■	■	■	■	■	■	■	■	■	10						0	■												1	○
Trib. to Kings Creek, RM 4.99/3.18 (CWH)																																
1.0	74.5		■		■		■	■		■	■	6			■			1	■									■			2	○
Trib. to Kings Creek, RM 0.46 (CWH)																																
0.6	60.0	■			■	■	■			■	■	6		■		■		2	■								■	■	■		4	○

Table A.5 Habitat Assessment Results for WAU 05080001 160: Mad River / Nettle Creek

Legend for Current Use Attainment Status: ○ = full, ◑ = partial, ● = non

River Mile	QHEI	WWH Attributes: No Channelization or Recovered	Boulder or Cobble or Gravel Substrate	Silt Free Substrate	Excellent or Good Development	Moderate or High Sinuosity	Extensive or Moderate Cover	Fast Velocity or Eddies	Normal or No Substrate Embeddedness	Maximum Pool Depth > 40 cm	Low or No Riffle/Run Embeddedness	**Total WWH Attributes**	MWH Attributes, High Influence: Recent Channelization or No Recovery	Silt or Muck Substrate	Low or No Sinuosity and Drainage Area <= 20 sq. mi.	Sparse or Nearly Absent Cover	< 40 cm Max. Pool Depth and Wadeable or Headwater Site	**Total High-Influence MWH Attributes**	MWH Attributes, Moderate Influence: Recovering Channelization	Silt Heavy or Silt Moderate	Sand Substrate and Boat Site	Hardpan Substrate Origin	Fair or Poor Development	Low or No Sinuosity and Drainage Area > 20 sq. mi.	Two or Less Cover Types	Intermittent Pools and Max. Pool Depth < 40 cm	No Fast Current Velocity	Extensive or Moderate Substrate Embeddedness	Extensive or Moderate Riffle Embeddedness	No Riffle	**Total Moderate-Influence MWH Attributes**	Current Use Attainment Status (○ = full, ◑ = partial, ● = non)
HUC 05080001-160-010 - Mad River below Kings Cr. to above Nettle Cr. [except Muddy Cr. & Dugan Run]																																
Mad River (CWH)																																
41.6	73.0		■	■				■	■	■	■	6	■			■		2	■				■	■							3	○
39.9	79.5		■	■	■		■	■	■	■	■	8				■		1	■					■							2	○
38.4	69.0		■	■				■	■	■	■	6	■			■		2	■				■	■							3	○
HUC 05080001-160-020 - Muddy Creek																																
Muddy Creek (CWH)																																
6.3	56.5		■				■		■	■		4	■		■			2					■				■		■		3	◑
0.5	65.5	■	■		■	■	■	■		■		7	■					1					■	■				■	■		4	○
Spring Run (WWH)																																
0.7	37.5									■		1	■		■	■		3	■	■			■				■	■		■	6	○
HUC 05080001-160-030 - Dugan Run																																
Dugan Run (WWH)																																
1.2	59.0		■	■					■	■	■	5				■		1	■				■	■			■	■	■		6	◑
HUC 05080001-160-040 - Nettle Creek [except Anderson Cr.]																																
Nettle Creek (CWH)																																
8.2	89.0	■	■		■	■	■	■	■	■	■	9						0				■									1	○
7.1	60.0		■					■	■	■	■	5	■		■	■		3	■				■								2	○
4.5	72.0		■	■	■	■	■	■	■	■	■	9			■			1	■				■								2	○
2.8	69.0	■	■		■	■	■	■		■		7						0					■					■	■		3	◑
Owens Creek (WWH)																																
0.1	66.0	■	■		■	■	■	■	■	■		8			■	■		2					■					■	■		3	○
Trib. to Nettle Creek, RM 8.80 (WWH)																																
2.7	44.5		■									1	■		■	■	■	4		■			■				■	■	■		5	●
2.6	73.0	■	■		■	■				■	■	6				■		1		■			■				■	■			4	●

Table A.5 (con't) **Habitat Assessment Results for WAU 05080001 160: Mad River / Nettle Creek**

WWH Attributes (columns 3–12); MWH Attributes: High Influence (columns 14–18), Moderate Influence (columns 20–31)

River Mile	QHEI	No Channelization or Recovered	Boulder or Cobble or Gravel Substrate	Silt Free Substrate	Excellent or Good Development	Moderate or High Sinuosity	Extensive or Moderate Cover	Fast Velocity or Eddies	Normal or No Substrate Embeddedness	Maximum Pool Depth > 40 cm	Low or No Riffle/Run Embeddedness	**Total WWH Attributes**	Recent Channelization or No Recovery	Silt or Muck Substrate	Low or No Sinuosity and Drainage Area <= 20 sq. mi.	Sparse or Nearly Absent Cover	< 40 cm Max. Pool Depth and Wadeable or Headwater Site	**Total High-Influence MWH Attributes**	Recovering Channelization	Silt Heavy or Silt Moderate	Sand Substrate and Boat Site	Hardpan Substrate Origin	Fair or Poor Development	Low or No Sinuosity and Drainage Area > 20 sq. mi.	Two or Less Cover Types	Intermittent Pools and Max. Pool Depth < 40 cm	No Fast Current Velocity	Extensive or Moderate Substrate Embeddedness	Extensive or Moderate Riffle Embeddedness	No Riffle	**Total Moderate-Influence MWH Attributes**	Current Use Attainment Status (○ = full, ◑ = partial, ● = non)
HUC 05080001-160-050 - Anderson Creek																																
Anderson Creek (CWH)																																
5.9	71.5	■	■		■	■	■	■	■	■		8						0				■	■						■		3	○
3.7	68.5				■		■	■	■	■	■	6			■	■		2	■				■								2	○
1.0	68.5		■		■		■	■	■	■	■	7			■	■		2	■				■								2	○
Harban Creek (CWH)																																
0.1	75.0	■	■		■	■	■		■	■	■	8				■		1				■					■				2	○
Hog Creek (WWH)																																
0.6	69.5	■	■			■	■			■	■	6				■		1		■			■				■	■			4	○
HUC 05080001-160-060 - Mad River below Nettle Cr. to above Chapman Cr. [except Storms Cr.]																																
Mad River (CWH)																																
32.7	76.0		■		■			■	■	■	■	6				■		1	■				■	■							3	○
Stony Creek (WWH)																																
0.7	51.0										■	1			■	■	■	3	■	■			■				■	■	■		6	●
HUC 05080001-160-070 - Storms Creek																																
Storms Creek (CWH)																																
2.7	76.0	■	■		■	■	■	■	■	■		8						0										■	■		2	○
0.7	61.0	■	■			■	■	■		■		6				■		1					■					■	■		3	○
HUC 05080001-160-080 - Chapman Creek																																
Chapman Creek (CWH)																																
10.1	68.0	■	■		■	■	■	■	■	■	■	9			■	■		2	■				■								2	◑
6.9	76.0		■		■	■	■	■	■	■	■	8			■	■		2	■				■								2	○
4.0	61.5	■	■			■				■		4			■	■		2		■			■				■	■	■		5	○
0.8	57.5	■	■			■		■		■		5				■		1					■	■				■	■		4	○
Deer Creek (WWH)																																
0.6	72.5	■	■		■	■	■		■	■	■	8						0		■			■				■	■			4	○

		WWH Attributes											MWH Attributes																			
													High Influence						Moderate Influence													
River Mile	QHEI	No Channelization or Recovered	Boulder or Cobble or Gravel Substrate	Silt Free Substrate	Excellent or Good Development	Moderate or High Sinuosity	Extensive or Moderate Cover	Fast Velocity or Eddies	Normal or No Substrate Embeddedness	Maximum Pool Depth > 40 cm	Low or No Riffle/Run Embeddedness	**Total WWH Attributes**	Recent Channelization or No Recovery	Silt or Muck Substrate	Low or No Sinuosity and Drainage Area <= 20 sq. mi.	Sparse or Nearly Absent Cover	< 40 cm Max. Pool Depth and Wadeable or Headwater Site	**Total High-Influence MWH Attributes**	Recovering Channelization	Silt Heavy or Silt Moderate	Sand Substrate and Boat Site	Hardpan Substrate Origin	Fair or Poor Development	Low or No Sinuosity and Drainage Area > 20 sq. mi.	Two or Less Cover Types	Intermittent Pools and Max. Pool Depth < 40 cm	No Fast Current Velocity	Extensive or Moderate Substrate Embeddedness	Extensive or Moderate Riffle Embeddedness	No Riffle	**Total Moderate-Influence MWH Attributes**	Current Use Attainment Status (○ = full, ◑ = partial, ● = non)
HUC 05080001-160-080 - Chapman Creek																																
Blacksnake Creek (WWH)																																
0.4	41.5											0	■		■	■	■	4		■			■				■	■	■		5	○

Table A.6 Habitat Assessment Results for WAU 05080001 170: Buck Creek

River Mile	QHEI	WWH Attributes											MWH Attributes: High Influence						MWH Attributes: Moderate Influence													
		No Channelization or Recovered	Boulder or Cobble or Gravel Substrate	Silt Free Substrate	Excellent or Good Development	Moderate or High Sinuosity	Extensive or Moderate Cover	Fast Velocity or Eddies	Normal or No Substrate Embeddedness	Maximum Pool Depth > 40 cm	Low or No Riffle/Run Embeddedness	**Total WWH Attributes**	Recent Channelization or No Recovery	Silt or Muck Substrate	Low or No Sinuosity and Drainage Area <= 20 sq. mi.	Sparse or Nearly Absent Cover	< 40 cm Max. Pool Depth and Wadeable or Headwater Site	**Total High-Influence MWH Attributes**	Recovering Channelization	Silt Heavy or Silt Moderate	Sand Substrate and Boat Site	Hardpan Substrate Origin	Fair or Poor Development	Low or No Sinuosity and Drainage Area > 20 sq. mi.	Two or Less Cover Types	Intermittent Pools and Max. Pool Depth < 40 cm	No Fast Current Velocity	Extensive or Moderate Substrate Embeddedness	Extensive or Moderate Riffle Embeddedness	No Riffle	**Total Moderate-Influence MWH Attributes**	Current Use Attainment Status (○ = full, ◑ = partial, ● = non)
HUC 05080001-170-010 - Buck Creek above E. Fk. Buck Cr.																																
Buck Creek (CWH)																																
17.5	82.5	■	■		■	■	■	■	■	■	■	9						0													0	○
13.1	73.5		■		■	■	■	■	■	■	■	8				■		1	■				■								2	○
Dugan Ditch (CWH)																																
2.2	34.5									■		1	■	■	■	■		4		■			■				■	■		■	5	○
HUC 05080001-170-020 - East Fork Buck Creek																																
East Fork Buck Creek (CWH)																																
5.0	51.0									■	■	2			■	■		2	■	■			■				■	■			5	○
0.3	78.0				■	■	■	■	■	■	■	7						0	■	■				■				■			4	○
HUC 05080001-170-030 - Buck Creek below E. Fk. to above Beaver Cr.																																
Buck Creek (WWH)																																
6.4	69.5		■					■	■	■	■	5			■	■		2	■				■								2	◑
HUC 05080001-170-040 - Beaver Creek [except Sinking Cr.]																																
Beaver Creek (WWH)																																
10.2	62.5		■						■	■		3			■	■		2	■	■			■				■	■	■		6	○
4.5	62.0		■	■	■			■	■	■	■	7				■		1	■			■	■	■							4	○
0.7	83.0	■	■	■	■	■	■	■	■	■	■	10				■		1													0	○
HUC 05080001-170-050 - Sinking Creek																																
Sinking Creek (WWH)																																
4.6	55.5				■	■	■			■	■	5		■				1	■	■		■	■				■	■	■		7	○
HUC 05080001-170-060 - Buck Creek below Beaver Cr. to Mad River																																
Buck Creek (WWH)																																
0.6	60.0		■						■	■	■	4	■			■		2	■				■	■			■				4	○

Table A.7 Habitat Assessment Results for WAU 05080001 180: Downstream Chapman Creek to upstream Mud Creek (excluding Buck Creek)

		WWH Attributes											MWH Attributes																			
													High Influence						Moderate Influence													
River Mile	QHEI	No Channelization or Recovered	Boulder or Cobble or Gravel Substrate	Silt Free Substrate	Excellent or Good Development	Moderate or High Sinuosity	Extensive or Moderate Cover	Fast Velocity or Eddies	Normal or No Substrate Embeddedness	Maximum Pool Depth > 40 cm	Low or No Riffle/Run Embeddedness	**Total WWH Attributes**	Recent Channelization or No Recovery	Silt or Muck Substrate	Low or No Sinuosity and Drainage Area <= 20 sq. mi.	Sparse or Nearly Absent Cover	< 40 cm Max. Pool Depth and Wadeable or Headwater Site	**Total High-Influence MWH Attributes**	Recovering Channelization	Silt Heavy or Silt Moderate	Sand Substrate and Boat Site	Hardpan Substrate Origin	Fair or Poor Development	Low or No Sinuosity and Drainage Area > 20 sq. mi.	Two or Less Cover Types	Intermittent Pools and Max. Pool Depth < 40 cm	No Fast Current Velocity	Extensive or Moderate Substrate Embeddedness	Extensive or Moderate Riffle Embeddedness	No Riffle	**Total Moderate-Influence MWH Attributes**	Current Use Attainment Status (○ = full, ◑ = partial, ● = non)
HUC 05080001-180-010 - Mad River below Chapman Cr. to above Buck Cr. [except Moore Run]																																
Mad River (CWH)																																
29.6	73.5		■	■				■	■	■	■	6				■		1	■				■	■							3	○
27.0	79.0		■		■	■	■	■	■	■	■	8				■		1	■					■							2	○
Pondy Creek (WWH)																																
1.1	47.5		■						■		■	3	■		■	■	■	4					■			■	■				3	◑
Dry Run (WWH)																																
0.3	48.5		■									1	■		■	■	■	4				■	■				■	■	■		5	○
HUC 05080001-180-020 - Moore Run																																
Moore Run (WWH)																																
4.1	28.5											0	■	■	■	■	■	5		■			■				■	■	■		5	●
2.5	49.5							■		■	■	3	■	■	■	■		4	■	■			■					■			4	◑
0.8	65.0		■				■	■		■	■	5	■		■	■		3	■	■			■					■	■		5	○
Kenton Creek (WWH)																																
0.7	69.5		■		■		■	■	■	■	■	7			■	■		2	■				■								2	◑
HUC 05080001-180-030 - Mad River below Buck Cr. to above Donnels Cr. [except Mill Cr. & Rock Run]																																
Mad River (WWH)																																
25.8	84.5	■	■		■	■	■	■	■	■	■	9						0	■	■								■			3	◑
24.1	75.0		■		■		■	■		■	■	6						0	■	■	■			■				■	■		6	○
HUC 05080001-180-040 - Mill Creek																																
Mill Creek (WWH)																																
3.2	83.0	■	■		■	■	■	■		■		7						0										■	■		2	○
0.1	70.5		■		■	■	■	■		■		6				■		1	■	■								■	■		4	○

Table A.7 (con't) **Habitat Assessment Results for WAU 05080001 180: Downstream Chapman Creek to upstream Mud Creek (excluding Buck Creek)**

River Mile	QHEI	No Channelization or Recovered	Boulder or Cobble or Gravel Substrate	Silt Free Substrate	Excellent or Good Development	Moderate or High Sinuosity	Extensive or Moderate Cover	Fast Velocity or Eddies	Normal or No Substrate Embeddedness	Maximum Pool Depth > 40 cm	Low or No Riffle/Run Embeddedness	**Total WWH Attributes**	Recent Channelization or No Recovery	Silt or Muck Substrate	Low or No Sinuosity and Drainage Area <= 20 sq. mi.	Sparse or Nearly Absent Cover	< 40 cm Max. Pool Depth and Wadeable or Headwater Site	**Total High-Influence MWH Attributes**	Recovering Channelization	Silt Heavy or Silt Moderate	Sand Substrate and Boat Site	Hardpan Substrate Origin	Fair or Poor Development	Low or No Sinuosity and Drainage Area > 20 sq. mi.	Two or Less Cover Types	Intermittent Pools and Max. Pool Depth < 40 cm	No Fast Current Velocity	Extensive or Moderate Substrate Embeddedness	Extensive or Moderate Riffle Embeddedness	No Riffle	**Total Moderate-Influence MWH Attributes**	Current Use Attainment Status (○ = full, ◑ = partial, ● = non)
		WWH Attributes											MWH Attributes: High Influence						MWH Attributes: Moderate Influence													
HUC 05080001-180-050 - Rock Run																																
Rock Run (WWH)																																
0.1	74.0	■	■		■	■	■	■	■	■	■	9						0													0	○
Miller Creek (WWH)																																
0.1	75.0	■	■	■	■		■		■	■	■	8			■	■		2									■		■		2	○
HUC 05080001-180-060 - Donnels Creek [except E. Fk. Donnels Cr.]																																
Donnels Creek (WWH)																																
7.5	81.5	■	■		■	■	■		■	■	■	8						0									■				1	○
3.7	73.0		■	■	■	■		■	■	■	■	8				■		1	■				■								2	○
1.9	62.5		■	■				■	■	■	■	6				■		1	■				■	■							3	◑
HUC 05080001-180-070 - East Fork Donnels Creek																																
East Fork Donnels Creek (WWH)																																
2.9	84.0	■	■	■	■	■	■	■	■	■	■	10						0	■												1	○
0.1	77.5	■	■	■	■	■	■	■	■	■	■	10			■	■		2													0	○
HUC 05080001-180-090 - Jackson Creek																																
Jackson Creek (WWH)																																
3.8	61.5	■	■		■	■			■	■	■	7				■		1	■								■				2	○
0.9	52.0		■				■			■		3	■		■	■		3	■				■				■	■	■		5	○

Table A.8 Habitat Assessment Results for WAU 05080001 190: Lower Mad River Tributaries

		WWH Attributes											MWH Attributes – High Influence						MWH Attributes – Moderate Influence													
River Mile	QHEI	No Channelization or Recovered	Boulder or Cobble or Gravel Substrate	Silt Free Substrate	Excellent or Good Development	Moderate or High Sinuosity	Extensive or Moderate Cover	Fast Velocity or Eddies	Normal or No Substrate Embeddedness	Maximum Pool Depth > 40 cm	Low or No Riffle/Run Embeddedness	**Total WWH Attributes**	Recent Channelization or No Recovery	Silt or Muck Substrate	Low or No Sinuosity and Drainage Area <= 20 sq. mi.	Sparse or Nearly Absent Cover	< 40 cm Max. Pool Depth and Wadeable or Headwater Site	**Total High-Influence MWH Attributes**	Recovering Channelization	Silt Heavy or Silt Moderate	Sand Substrate and Boat Site	Hardpan Substrate Origin	Fair or Poor Development	Low or No Sinuosity and Drainage Area > 20 sq. mi.	Two or Less Cover Types	Intermittent Pools and Max. Pool Depth < 40 cm	No Fast Current Velocity	Extensive or Moderate Substrate Embeddedness	Extensive or Moderate Riffle Embeddedness	No Riffle	**Total Moderate-Influence MWH Attributes**	Current Use Attainment Status (○ = full, ◑ = partial, ● = non)
HUC 05080001-190-010 - Mud Creek																																
Mud Creek (WWH)																																
5.0	50.0		■					■		■	■	4	■		■	■		3	■	■		■	■					■	■		6	●
2.5	56.5		■							■	■	3	■		■	■		3	■				■				■	■			4	◑
0.6	82.0	■	■		■	■	■	■	■	■	■	9						0				■						■			2	○
Drylick Run (WWH)																																
1.7	74.5	■	■		■	■	■		■	■	■	8						0					■				■				2	○
HUC 05080001-190-020 - Mad River below Mud Cr. to Huffman Dam [except Mud Run]																																
Hebble Creek (MWH)																																
5.0	34.0											0	■	■	■	■	■	5		■			■				■	■	■		5	○
HUC 05080001-190-030 - Mud Run																																
Mud Run (WWH)																																
9.7	65.0		■	■	■	■	■	■	■	■	■	9			■	■		2	■				■					■	■		4	○
7.8	77.0		■	■	■		■	■	■	■	■	8				■		1	■				■	■							3	○
3.3	69.0	■							■	■	■	4				■		1	■	■			■	■			■	■			6	○
2.0	73.0		■		■		■	■		■		5				■		1	■				■	■				■	■		5	○
0.8	57.0		■							■		2	■			■		2	■	■		■	■	■			■	■	■		8	◑
Clear Creek (WWH)																																
0.5	65.0		■		■	■	■	■		■		6				■		1	■	■			■					■	■		5	○
Trib. to Mud Run, RM 9.8 (WWH)																																
0.7	65.5	■			■	■	■	■	■	■	■	8				■		1					■								1	●
HUC 05080001-190-040 - Mad River below Huffman Dam to G. Miami R.																																
Lilly Creek (MWH)																																
0.1	70.5	■	■		■	■	■			■	■	7						0				■	■				■	■	■		5	◑

Table A.9 Bedload and Habitat TMDLs for LRAU[†] 05080001 003: Mad River mainstem downstream Donnels Creek (RM 18.4) to mouth

		Bedload TMDL						Habitat TMDL						
TMDL Targets	**Use**	Allocations			TMDL			Allocations			Subscore			TMDL
	WWH	*≥13*	*≥14*	*≥5*	*32*			*≥60 = 1*	*<2 = 1 pt*	*<5 = 1 pt*				*3 pts*
Existing Scores Stream/River (Use) *indicates use is not being met*	**River Mile**	QHEI Categories: Substrate	Channel	Riparian	Total Bedload Score	% Deviation from Target	Main Impaired Category if any	QHEI Score	# of High Influence Attributes	Total # of Modified Attributes	QHEI	High Influence	# Modified Attributes	Total Habitat Score
Mad River below Donnels Cr. to above Mud Cr. [except Jackson Cr.] (05080001-180-080)														
Mad River (WWH)	17.5	17	11	5.5	33.5	---	channel	77.5	1	4	1	1	1	3
	13.1	18	13	6	37	---	channel	83.5	0	2	1	1	1	3
	11.5	16.5	12	8.5	37	---	channel	83.0	0	4	1	1	1	3
Mad River below Mud Cr. to Huffman Dam [except Mud Run] (05080001-190-020)														
Mad River (WWH)	8.6	17	13	7.5	37.5	---	channel	81.5	1	4	1	1	1	3
	6.0	13.5	12	6.5	32	---	channel	77.5	0	5	1	1	0	2
Mad River below Huffman Dam to G. Miami R. (05080001-190-040)														
Mad River (WWH)	4.0	16	13	8	37	---	channel	76.5	1	6	1	1	0	2
	1.6	13.5	12	6	31.5	2%	channel	74.0	0	6	1	1	0	2
	0.3	13.5	8.5	3.5	25.5	20%	channel	61.0	2	9	1	0	0	1

[†] Large River Assessment Unit

Table A.10 Bedload and Habitat TMDLs for WAU‡ 05080001 150: Upper Mad River

		Bedload TMDL						Habitat TMDL						
TMDL Targets	**Use**	Allocations			TMDL			Allocations			Subscore			TMDL
	WWH	*≥13*	*≥14*	*≥5*	*32*			*≥60 = 1*	*<2 = 1 pt*	*<5 = 1 pt*				*3 pts*
Existing Scores Stream/River (Use) *indicates use is not being met*	**River Mile**	QHEI Categories: Substrate	Channel	Riparian	Total Bedload Score	% Deviation from Target	Main Impaired Category if any	QHEI Score	# of High Influence Attributes	Total # of Modified Attributes	QHEI	High Influence	# Modified Attributes	Total Habitat Score
Mad River below SR 33 to above Machochee Cr. 05080001-150-020														
Mad River (CWH)	61.2	18	15.5	7.5	41	---	---	85	0	1	1	1	1	3
	57.2	16.5	10.5	4	31	3%	channel	62	1	6	1	1	0	2
	53.2	16	10	4	30	6%	channel	67.5	1	4	1	1	1	3
	52.1	17	11.5	4.5	33	---	channel	72	1	4	1	1	1	3
Sugar Creek (CWH)	1.0	14.5	6	3	23.5	27%	channel	42.5	4	8	0	0	0	0
Peters Ditch (CWH)	0.1	17.5	10.5	8.5	36.5	---	channel	63	1	4	1	1	1	3

‡ Watershed Assessment Unit

Table A.10 Bedload and Habitat TMDLs for WAU 05080001 150: Upper Mad River (con't)

TMDL Targets	Use	Bedload TMDL: Allocations			Bedload TMDL: TMDL			Habitat TMDL: Allocations			Subscore			Habitat TMDL: TMDL
	WWH	*≥13*	*≥14*	*≥5*	*32*			*≥60 = 1*	*<2 = 1 pt*	*<5 = 1 pt*				*3 pts*
Existing Scores Stream/River (Use) *indicates use is not being met*	**River Mile**	QHEI Categories: Substrate	Channel	Riparian	Total Bedload Score	% Deviation from Target	Main Impaired Category if any	QHEI Score	# of High Influence Attributes	Total # of Modified Attributes	QHEI	High Influence	# Modified Attributes	Total Habitat Score
Machochee Creek 05080001-150-030														
Machochee Creek (CWH)	6.2	15	13.5	7.5	36	---	channel	74	0	3	1	1	1	3
	3.7	16.5	12	4	32.5	---	riparian	68	1	5	1	1	0	2
	3.0	19	12	5.5	36.5	---	channel	78	1	3	1	1	1	3
	1.4	17.5	11	4	32.5	---	channel	62.5	1	5	1	1	0	2
	0.1	16	12	4	32	---	riparian	71	1	5	1	1	0	2

Table A.10 Bedload and Habitat TMDLs for WAU 05080001 150: Upper Mad River (con't)

TMDL Targets	Use	Bedload TMDL: Allocations			Bedload TMDL: TMDL			Habitat TMDL: Allocations			Subscore			Habitat TMDL: TMDL
	WWH	*≥13*	*≥14*	*≥5*	*32*			*≥60 = 1*	*<2 = 1 pt*	*<5 = 1 pt*				*3 pts*
Existing Scores Stream/River (Use) *indicates use is not being met*	**River Mile**	QHEI Categories: Substrate	Channel	Riparian	Total Bedload Score	% Deviation from Target	Main Impaired Category if any	QHEI Score	# of High Influence Attributes	Total # of Modified Attributes	QHEI	High Influence	# Modified Attributes	Total Habitat Score
Mad River below Machochee Cr. to above Kings Cr. [except Glady Cr.] 05080001-150-040														
Mad River (CWH)	51.1	16	13.5	4.5	34	---	riparian	79	0	1	1	1	1	3
	51.0	14.5	10.5	5.5	30.5	5%	channel	72	1	5	1	1	0	2
	49.1	18	9	3.5	30.5	5%	channel	63	2	6	1	0	0	1
	43.9	19	9.5	5.5	34	---	channel	68.5	2	5	1	0	0	1
Macochee Ditch (CWH)	3.4	1	7.5	4.5	13	59%	substrate	34	4	9	0	0	0	0
	0.7	*6*	*10.5*	*3.5*	*20*	*38%*	*substrate*	*46*	*3*	*7*	*0*	*0*	*0*	*0*
Glady Creek 05080001-150-050														
Glady Creek (CWH)	4.2	15	11.5	3.5	30	6%	riparian	66.5	2	4	1	0	1	2

Table A.10 Bedload and Habitat TMDLs for WAU 05080001 150: Upper Mad River (con't)

TMDL Targets	Use	Bedload TMDL: Allocations			Bedload TMDL: TMDL			Habitat TMDL: Allocations			Habitat TMDL: Subscore			Habitat TMDL: TMDL
	WWH	*≥13*	*≥14*	*≥5*	*32*			*≥60 = 1*	*<2 = 1 pt*	*<5 = 1 pt*				*3 pts*
Existing Scores Stream/River (Use) *indicates use is not being met*	**River Mile**	QHEI Categories: Substrate	QHEI Categories: Channel	QHEI Categories: Riparian	Total Bedload Score	% Deviation from Target	Main Impaired Category if any	QHEI Score	# of High Influence Attributes	Total # of Modified Attributes	QHEI	High Influence	# Modified Attributes	Total Habitat Score
Kings Creek 05080001-150-060														
Kings Creek (CWH)	6.1	17	12	3.5	32.5	---	riparian	69.5	1	3	1	1	1	3
	3.9	*13*	*10*	*4*	*27*	*16%*	*channel*	*60*	*2*	*7*	*1*	*0*	*0*	*1*
	0.1	18	14.5	4.5	37	---	riparian	81	0	1	1	1	1	3
Trib. to Kings Creek (RM 4.99/3.18) (CWH)	1.0	17	12	3.5	32.5	---	riparian	74.5	1	3	1	1	1	3
Trib. to Kings Creek (RM 0.46) (CWH)	0.6	7	14	6	27	16%	substrate	60	2	6	1	0	0	1

Table A.11 Bedload and Habitat TMDLs for WAU 05080001 160: Mad River / Nettle Creek

		Bedload TMDL						Habitat TMDL						
	Use	Allocations			TMDL			Allocations			Subscore			TMDL
TMDL Targets	*WWH*	*≥13*	*≥14*	*≥5*	*32*			*≥60 = 1*	*<2 = 1 pt*	*<5 = 1 pt*				*3 pts*
Existing Scores Stream/River (Use) *indicates use is not being met*	**River Mile**	QHEI Categories: Substrate	Channel	Riparian	Total Bedload Score	% Deviation from Target	Main Impaired Category if any	QHEI Score	# of High Influence Attributes	Total # of Modified Attributes	QHEI	High Influence	# Modified Attributes	Total Habitat Score
Mad River below Kings Cr. to above Nettle Cr. [except Muddy Cr. & Dugan Run] 05080001-160-010														
Mad River (CWH)	41.6	19.5	9	5.5	34	---	channel	73	2	5	1	0	0	1
	39.9	20	13	5	38	---	channel	79.5	1	3	1	1	1	3
	38.4	18	9.5	5	32.5	---	channel	69	2	5	1	0	0	1
Muddy Creek 05080001-160-020														
Muddy Creek (CWH)	*6.3*	*14*	*6.5*	*3*	*23.5*	*27%*	*channel*	*56.5*	*2*	*5*	*0*	*0*	*0*	*0*
	0.5	17	9	5.5	31.5	2%	channel	65.5	1	5	1	1	0	2
Spring Run (WWH)	0.7	11	6.5	3	20.5	36%	channel	37.5	3	9	0	0	0	0
Dugan Run 05080001-160-030														
Dugan Run (WWH)	*1.2*	*16.5*	*11*	*5.5*	*33*	*---*	*channel*	*59*	*1*	*7*	*0*	*1*	*0*	*1*

Table A.11 Bedload and Habitat TMDLs for WAU 05080001 160: Mad River / Nettle Creek (con't)

		Bedload TMDL						Habitat TMDL						
TMDL Targets	**Use**	Allocations			TMDL			Allocations			Subscore			TMDL
	WWH	*≥13*	*≥14*	*≥5*	*32*			*≥60 = 1*	*<2 = 1 pt*	*<5 = 1 pt*				*3 pts*
Existing Scores Stream/River (Use) *indicates use is not being met*	**River Mile**	QHEI Categories: Substrate	Channel	Riparian	Total Bedload Score	% Deviation from Target	Main Impaired Category if any	QHEI Score	# of High Influence Attributes	Total # of Modified Attributes	QHEI	High Influence	# Modified Attributes	Total Habitat Score
Nettle Creek [except Anderson Cr.] 05080001-160-040														
Nettle Creek (CWH)	8.2	15.5	19	6.5	41	---	---	89	0	1	1	1	1	3
	7.1	17	8.5	3.5	29	9%	channel	60	3	5	1	0	0	1
	4.5	16.5	11.5	4	32	---	riparian	72	1	3	1	1	1	3
	2.8	*13*	*13*	*4*	*30*	*6%*	*riparian*	*69*	*0*	*3*	*1*	*1*	*1*	*3*
Owens Creek (WWH)	0.1	14.5	13	3	30.5	5%	riparian	66	2	5	1	0	0	1
Trib. to Nettle Creek (RM 8.80) (WWH)	*2.7*	*14*	*6*	*4.5*	*24.5*	*23%*	*channel*	*44.5*	*4*	*9*	*0*	*0*	*0*	*0*
	2.6	*13.5*	*16*	*9.5*	*39*	*---*	*---*	*73*	*1*	*5*	*1*	*1*	*0*	*2*

Table A.11 Bedload and Habitat TMDLs for WAU 05080001 160: Mad River / Nettle Creek (con't)

		Bedload TMDL						Habitat TMDL						
TMDL Targets	**Use**	Allocations			TMDL			Allocations			Subscore			TMDL
	WWH	*≥13*	*≥14*	*≥5*	*32*			*≥60 = 1*	*<2 = 1 pt*	*<5 = 1 pt*				*3 pts*
Existing Scores Stream/River (Use) *indicates use is not being met*	**River Mile**	QHEI Categories: Substrate	Channel	Riparian	Total Bedload Score	% Deviation from Target	Main Impaired Category if any	QHEI Score	# of High Influence Attributes	Total # of Modified Attributes	QHEI	High Influence	# Modified Attributes	Total Habitat Score
Anderson Creek 05080001-160-050														
Anderson Creek (CWH)	5.9	16.5	15	6	37.5	---	---	71.5	0	3	1	1	1	3
	3.7	14.5	11.5	4.5	30.5	5%	channel	68.5	2	4	1	0	1	2
	1.0	16	11	4	31	3%	channel	68.5	2	4	1	0	1	2
Harban Creek (CWH)	0.1	17	17.5	8.5	43	---	---	75	1	3	1	1	1	3
Hog Creek (WWH)	0.6	15	14	4.5	33.5	---	riparian	69.5	1	5	1	1	0	2
Mad River below Nettle Cr. to above Chapman Cr. [except Storms Cr.] 05080001-160-060														
Mad River (CWH)	32.7	17	12	6	35	---	channel	76	1	4	1	1	1	3
Stony Creek (WWH)	0.7	11	10	4	25	22%	channel	51	3	9	0	0	0	0
Storms Creek 05080001-160-070														
Storms Creek (CWH)	2.7	16.5	16.5	5	38	---	---	76	0	2	1	1	1	3
	0.7	16	12.5	3.5	32	---	riparian	61	1	4	1	1	1	3

Table A.11 Bedload and Habitat TMDLs for WAU 05080001 160: Mad River / Nettle Creek (con't)														
		Bedload TMDL						**Habitat TMDL**						
TMDL Targets	**Use**	Allocations			TMDL			Allocations			Subscore			TMDL
	WWH	*≥13*	*≥14*	*≥5*	*32*			*≥60 = 1*	*<2 = 1 pt*	*<5 = 1 pt*				*3 pts*
Existing Scores Stream/River (Use) *indicates use is not being met*	**River Mile**	QHEI Categories: Substrate	Channel	Riparian	Total Bedload Score	% Deviation from Target	Main Impaired Category if any	QHEI Score	# of High Influence Attributes	Total # of Modified Attributes	QHEI	High Influence	# Modified Attributes	Total Habitat Score
Chapman Creek 05080001-160-080														
Chapman Creek (CWH)	10.1	17	12.5	7	36.5	---	channel	68	2	4	1	0	1	2
	6.9	17	12.5	6.5	36	---	channel	76	2	4	1	0	1	2
	4.0	14.5	13	4.5	32	---	riparian	61.5	2	7	1	0	0	1
	0.8	16	12	5.5	33.5	---	channel	57.5	1	5	0	1	0	1
Deer Creek (WWH)	0.6	15	16	6	37	---	---	72.5	0	4	1	1	1	3
Blacksnake Creek (WWH)	0.4	13	7	2	22	31%	riparian	41.5	4	9	0	0	0	0

Table A.12 Bedload and Habitat TMDLs for WAU 05080001 170: Buck Creek

		Bedload TMDL						**Habitat TMDL**						
	Use	Allocations			TMDL			Allocations			Subscore			TMDL
TMDL Targets	*WWH*	*≥13*	*≥14*	*≥5*	*32*			*≥60 = 1*	*<2 = 1 pt*	*<5 = 1 pt*				*3 pts*
Existing Scores Stream/River (Use) *indicates use is not being met*	**River Mile**	QHEI Categories: Substrate	Channel	Riparian	Total Bedload Score	% Deviation from Target	Main Impaired Category if any	QHEI Score	# of High Influence Attributes	Total # of Modified Attributes	QHEI	High Influence	# Modified Attributes	Total Habitat Score
Buck Creek above E. Fk. Buck Cr. 05080001-170-010														
Buck Creek (CWH)	17.5	16	16.5	4.5	37	---	riparian	82.5	0	0	1	1	1	3
	13.1	14	12	6.5	32.5	---	channel	73.5	1	3	1	1	1	3
Dugan Ditch (CWH)	2.2	2	5	3.5	10.5	67%	substrate	34.5	4	9	0	0	0	0
East Fork Buck Creek 05080001-170-020														
East Fork Buck Creek (CWH)	5.0	10	9	3.5	22.5	30%	channel	51	2	7	0	0	0	0
	0.3	14	12	8	34	---	channel	78	0	4	1	1	1	3

Table A.12 Bedload and Habitat TMDLs for WAU 05080001 170: Buck Creek (con't)

TMDL Targets	Use	Bedload TMDL: Allocations			TMDL			Habitat TMDL: Allocations			Subscore			TMDL
	WWH	*≥13*	*≥14*	*≥5*	*32*			*≥60 = 1*	*<2 = 1 pt*	*<5 = 1 pt*				*3 pts*
Existing Scores Stream/River (Use) *indicates use is not being met*	**River Mile**	QHEI Categories: Substrate	Channel	Riparian	Total Bedload Score	% Deviation from Target	Main Impaired Category if any	QHEI Score	# of High Influence Attributes	Total # of Modified Attributes	QHEI	High Influence	# Modified Attributes	Total Habitat Score
Buck Creek below E. Fk. to above Beaver Cr. 05080001-170-030														
Buck Creek (WWH)	6.4	15.5	10	4.5	30	6%	channel	69.5	2	4	1	0	1	2
Beaver Creek [except Sinking Cr.] 05080001-170-040														
Beaver Creek (WWH)	10.2	14.5	9.5	1.5	25.5	20%	riparian	62.5	2	8	1	0	0	1
	4.5	17.5	11.5	4	33	---	riparian	62	1	5	1	1	0	2
	0.7	18	17.5	6	41.5	---	---	83	1	1	1	1	1	3
Sinking Creek 05080001-170-050														
Sinking Creek (WWH)	4.6	7.5	12	4.5	24	25%	substrate	55.5	1	8	0	1	0	1
Buck Creek below Beaver Cr. to Mad River 05080001-170-060														
Buck Creek (WWH)	0.6	15.5	9	4.5	29	9%	channel	60	2	6	1	0	0	1

Table A.13 Bedload and Habitat TMDLs for WAU 05080001 180: Downstream Chapman Creek to upstream Mud Creek (excluding Buck Creek)

TMDL Targets	Use	Bedload TMDL: Allocations			Bedload TMDL: TMDL			Habitat TMDL: Allocations			Habitat TMDL: Subscore			Habitat TMDL: TMDL
	WWH	*≥13*	*≥14*	*≥5*	*32*			*≥60 = 1*	*<2 = 1 pt*	*<5 = 1 pt*				*3 pts*
Existing Scores Stream/River (Use) *indicates use is not being met*	**River Mile**	QHEI Categories: Substrate	QHEI Categories: Channel	QHEI Categories: Riparian	Total Bedload Score	% Deviation from Target	Main Impaired Category if any	QHEI Score	# of High Influence Attributes	Total # of Modified Attributes	QHEI	High Influence	# Modified Attributes	Total Habitat Score
Mad River below Chapman Cr. to above Buck Cr. [except Moore Run] 05080001-180-010														
Mad River (CWH)	29.6	17.5	11	6	34.5	---	channel	73.5	1	4	1	1	1	3
	27	16.5	14	6	36.5	---	---	79	1	3	1	1	1	3
Pondy Creek (WWH)	1.1	16	6.5	5.5	28	13%	channel	47.5	4	7	0	0	0	0
Dry Run (WWH)	0.3	10	8	5	23	28%	channel	48.5	4	9	0	0	0	0
Moore Run 05080001-180-020														
Moore Run (WWH)	4.1	1	5.5	4.5	11	66%	substrate	28.5	5	10	0	0	0	0
	2.5	3.5	8	5	16.5	48%	substrate	49.5	4	8	0	0	0	0
	0.8	12	9	4	25	22%	channel	65	3	8	1	0	0	1
Kenton Creek (WWH)	0.7	16	10.5	6	32.5	---	channel	69.5	2	4	1	0	1	2

Table A.13 Bedload and Habitat TMDLs for WAU 05080001 180: Downstream Chapman Creek to upstream Mud Creek (excluding Buck Creek) (con't)

TMDL Targets	Use	Bedload TMDL – Allocations			Bedload TMDL – TMDL			Habitat TMDL – Allocations			Subscore			Habitat TMDL – TMDL
	WWH	*≥13*	*≥14*	*≥5*	*32*			*≥60 = 1*	*<2 = 1 pt*	*<5 = 1 pt*				*3 pts*
Existing Scores Stream/River (Use) *indicates use is not being met*	**River Mile**	QHEI Categories – Substrate	QHEI Categories – Channel	QHEI Categories – Riparian	Total Bedload Score	% Deviation from Target	Main Impaired Category if any	QHEI Score	# of High Influence Attributes	Total # of Modified Attributes	QHEI	High Influence	# Modified Attributes	Total Habitat Score
Mad River below Buck Cr. to above Donnels Cr. [except Mill Cr. & Rock Run] 05080001-180-030														
Mad River (WWH)	25.8	15.5	15.5	9	40	---	---	84.5	0	3	1	1	1	3
	24.1	14	13	4	31	3%	riparian	75	0	6	1	1	0	2
Mill Creek 05080001-180-040														
Mill Creek (WWH)	3.2	16	17	7	40	---	---	83	0	2	1	1	1	3
	0.1	13	13	5.5	31.5	2%	channel	70.5	1	5	1	1	0	2
Rock Run 05080001-180-050														
Rock Run (WWH)	0.1	17.5	16.5	6.5	40.5	---	---	74	0	0	1	1	1	3
Miller Creek (WWH)	0.1	16.5	15	6.5	38	---	---	75	2	4	1	0	1	2

Table A.13 Bedload and Habitat TMDLs for WAU 05080001 180: Downstream Chapman Creek to upstream Mud Creek (excluding Buck Creek) (con't)

		Bedload TMDL						Habitat TMDL						
TMDL Targets	**Use**	Allocations			TMDL			Allocations			Subscore			TMDL
	WWH	*≥13*	*≥14*	*≥5*	*32*			*≥60 = 1*	*≤2 = 1 pt*	*≤5 = 1 pt*				*3 pts*
Existing Scores Stream/River (Use) *indicates use is not being met*	**River Mile**	QHEI Categories: Substrate	Channel	Riparian	Total Bedload Score	% Deviation from Target	Main Impaired Category if any	QHEI Score	# of High Influence Attributes	Total # of Modified Attributes	QHEI	High Influence	# Modified Attributes	Total Habitat Score
Donnels Creek [except E. Fk. Donnels Cr.] 05080001-180-060														
Donnels Creek (WWH)	7.5	17	16.5	6.5	40	---	---	81.5	0	1	1	1	1	3
	3.7	18	13	6.5	37.5	---	channel	73	1	3	1	1	1	3
	1.9	18	9	5	32	---	channel	62.5	1	4	1	1	1	3
East Fork Donnels Creek 05080001-180-070														
East Fork Donnels Creek (WWH)	2.9	18	15	6.5	39.5	---	---	84	0	1	1	1	1	3
	0.1	19	16.5	8	43.5	---	---	77.5	2	2	1	0	1	2
Jackson Creek 05080001-180-090														
Jackson Creek (WWH)	3.8	14.5	16.5	5.5	36.5	---	---	61.5	1	3	1	1	1	3
	0.9	12.5	8.5	4	25	22%	channel	52	3	8	0	0	0	0

Table A.14 Bedload and Habitat TMDLs for WAU 05080001 190: Lower Mad River Tributaries

		Bedload TMDL						Habitat TMDL						
TMDL Targets	Use	Allocations			TMDL			Allocations			Subscore			TMDL
	WWH	*≥13*	*≥14*	*≥5*	*32*			*≥60 = 1*	*≤2 = 1 pt*	*≤5 = 1 pt*				*3 pts*
Existing Scores Stream/River (Use) *indicates use is not being met*	**River Mile**	QHEI Categories: Substrate	Channel	Riparian	Total Bedload Score	% Deviation from Target	Main Impaired Category if any	QHEI Score	# of High Influence Attributes	Total # of Modified Attributes	QHEI	High Influence	# Modified Attributes	Total Habitat Score
Mud Creek 05080001-190-010														
Mud Creek (WWH)	5.0	11.5	9	5	25.5	20%	channel	50.5	3	9	0	0	0	0
	2.5	14.5	9	4.5	28	13%	channel	56.5	3	7	0	0	0	0
	0.6	16	15.5	6	37.5	---	---	82	0	2	1	1	1	3
Drylick Run (WWH)	1.7	16.5	14	8.5	39	---	---	74.5	0	2	1	1	1	3
Mad River below Mud Cr. to Huffman Dam [except Mud Run] 05080001-190-020														
Hebble Creek (MWH)	5.0	0	4.5	7	11.5	n/a	substrate	34	5	10	---	---	---	n/a

Table A.14 Bedload and Habitat TMDLs for WAU 05080001 190: Lower Mad River Tributaries (con't)															
		Bedload TMDL						Habitat TMDL							
TMDL Targets	Use	Allocations			TMDL			Allocations			Subscore			TMDL
	WWH	*≥13*	*≥14*	*≥5*	*32*			*≥60 = 1*	*<2 = 1 pt*	*<5 = 1 pt*				*3 pts*
Existing Scores Stream/River (Use) *indicates use is not being met*	**River Mile**	QHEI Categories: Substrate	Channel	Riparian	Total Bedload Score	% Deviation from Target	Main Impaired Category if any	QHEI Score	# of High Influence Attributes	Total # of Modified Attributes	QHEI	High Influence	# Modified Attributes	Total Habitat Score
Mud Run 05080001-190-030														
Mud Run (WWH)	9.7	14	11.5	4	29.5	8%	riparian	65	2	6	1	0	0	1
	7.8	17.5	12	3.5	33	---	riparian	77	1	4	1	1	1	3
	3.3	14	9.5	8	31.5	2%	channel	69	1	7	1	1	0	2
	2.0	15.5	12	5.5	33	---	channel	73	1	6	1	1	0	2
	0.8	*10*	*10*	*5*	*25*	*22%*	*channel*	*57*	*2*	*10*	*0*	*0*	*0*	*0*
Clear Creek (WWH)	0.5	14	12	5.5	31.5	2%	channel	65	1	6	1	1	0	2
Trib. to Mud Run (RM 9.8) (WWH)	*0.7*	*14*	*16*	*7.5*	*37.5*	*---*	*---*	*65.5*	*1*	*2*	*1*	*1*	*1*	*3*
Mad River below Huffman Dam to G. Miami R. 05080001-190-040														
Lilly Creek (MWH)	*0.1*	*15*	*12.5*	*9*	*36.5*	*n/a*	*channel*	*70.5*	*0*	*5*	*---*	*---*	*---*	*n/a*

Appendix B

Example Nitrate TMDL Calculation

The text below is an example of a calculation deriving nitrate a TMDL for the 14-digit hydrologic unit 05080001 170 020.

Table 8 in the USGS report shows a nitrate load reduction of 32.7% is necessary for this hydrologic unit.

Table 8. TMDLs for Assessment Unit 05080001 170 020.

East Fork Buck Creek 05080001 170 020		Load (pounds/day)
Pollutant	**TMDL Component**	
Nitrate	Current Load	1,452.05
	TMDL = LA + WLA + MOS	977.26
	LA	958.90
	LA: Nonpoint source runoff	958.90
	LA: Failed HSTS	0
	LA: Cattle in streams	0
	WLA: Village of Catawba WWTP	18.36
	TMDL Reduction (%)	32.7%

The following existing loads were taken from Table 21 in the USGS report (mean annual nitrate loads, 1999-2003, in pounds):

	WWTPs	Failed HSTS	Cattle in Streams	CSOs	Nonpoint Source Runoff	Total
Existing load	6,700	6,400	72	0	520,000	530,000
Source-reduction load	6,700	0	0	0	350,000	360,000

Because all the nitrate loads are expressed in mean annual loads, each quantity was divided by 365 to calculate daily loads. The source-reduction load model was applied to nonpoint sources, failed HSTS and cattle in the streams to reach a TMDL and percent reduction of nitrate. Calculations for the TMDL (using the source-reduction load model) are shown below.

	Mean Annual Load (lbs / year)	Daily load (lbs / day)
Total Existing Load	530,000	530,000 / 365 = 1,452.05
WWTPs (source-reduction)	6,700	6,700 / 365 = 18.36
Failed HSTS (source-reduction)	0	0 / 365 = 0
Cattle in Streams (source-reduction)	0	0 / 365 = 0
NPS Runoff (source-reduction)	350,000	350,000 / 365 = 958.90
Total Nonpoint Source Load Allocation (source-reduction)		0 + 0 + 958.90 = 958.90
TMDL = WLA + LA + MOS (implicit)		**977.26 lbs / day**