Biological and Water Quality Study

of

Mill Creek Watershed

2009, 2012 & 2013

Delaware, Logan and Union Counties

OHIO EPA Technical Report EAS/2014-02-02

Division of Surface Water
Ecological Assessment Section
May 23, 2014

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Executive Summary

Rivers and streams in Ohio support a variety of uses such as recreation, water supply, and aquatic life. Ohio EPA evaluates each stream to determine the appropriate beneficial use designations and to also determine if the uses are meeting the goals of the federal Clean Water Act. In 2009, 2012, and 2013, four streams in the Mill Creek watershed, located in Delaware, Logan, and Union counties, were evaluated for aquatic life and recreation use potential (Table 1).

All of the sites sampled are designated Warmwater Habitat (WWH) except for the upstream site on Blues Creek which is designated Modified Warmwater Habitat (MWH). Of the 24 biological stations assessed, 16 sites (67%) were fully meeting the designated aquatic life use (ALU), 3 (12%) were partially attaining, and 5 (21%) were not attaining (Figure 1 and Table 2). Excessive sediment and silt caused by agricultural runoff led to impairment at six sites. Resuspension of historically contaminated sediments was also found to be a source for impairment at one location. Five sites were impaired by organic enrichment associated with illicit discharges (Table 2).

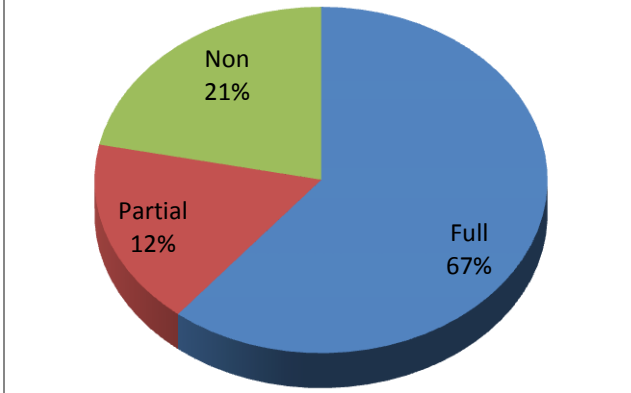


Figure 1. Percent aquatic life use attainment of biological sampling stations in the Mill Creek watershed, 2009, 2012, and 2013.

Eleven locations in the Mill Creek study area were sampled for *E. coli* bacteria 5 to 7 times apiece between May and October, 2012. Town Run at Walnut Street was sampled twice. Evaluation of *E. coli* results revealed that, at 6 of the 11 sampling locations, values were in excess of the applicable geometric mean criterion, indicating an impairment of the Primary Contact Recreation (PCR) Class B use at these locations (Figure 21). Elevated bacteria concentrations were nearly ubiquitous in Mill Creek with the exception of the lower approximately 10 river miles. The most probable source of bacteria varies depending on the site location and surrounding land use.

Water quality samples were collected from 29 sites in the Mill Creek study area (Table 1). All sites were sampled a minimum of five times, typically at two-week intervals, from June 2012 to August 2012; a few select sites near the Marysville Water Reclamation Facility (WRF, formerly known as the wastewater treatment plant) were sampled during 2013 as well. Dissolved oxygen exceedances were found in all of the streams (totaling ten sample locations) in the watershed. This was mostly attributed to organic enrichment from unsewered areas and illicit dischargers within the watershed.

Improvements made based on recommendations from the 1995 survey (46% full ALU attainment) have helped the overall water quality and biological integrity in the Mill Creek watershed. The city of Marysville has removed two dams, constructed a new wastewater treatment plant and upground drinking water reservoir, and the Scott's Company effluent has been tied into the Marysville treatment plant.

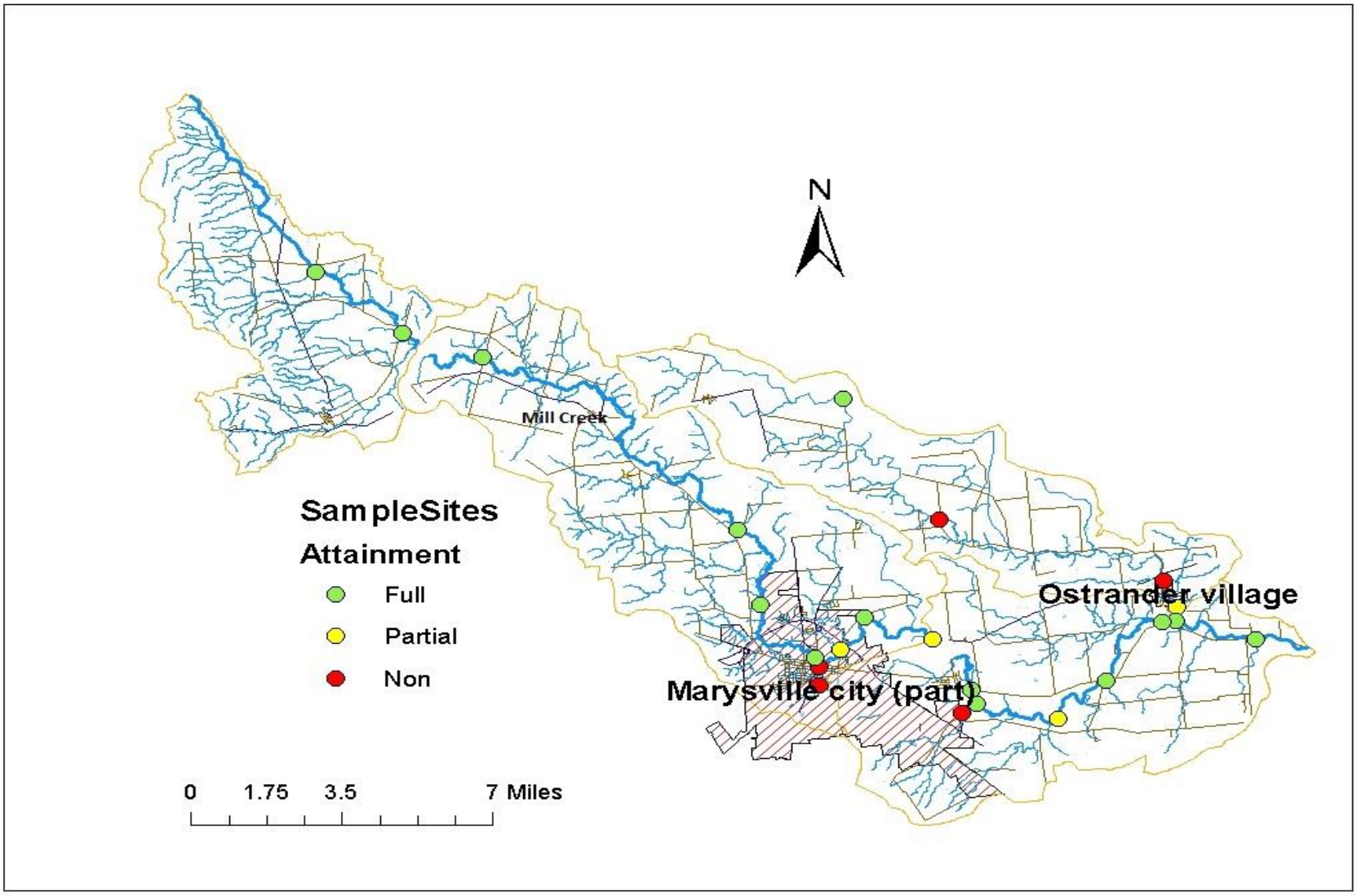


Figure 2. ALU attainment map for biological stations sampled in the Mill Creek watershed, 2009, 2012, & 2013.

Table 1. Sampling stations for the Mill Creek watershed with sample types indicated, where X = sample type. Sampling in Town Run was conducted in 2009 and all other samples were collected in 2012/2013.

Station ID	NAME	Basin	Stream	Trib	RM	DA$_{mi}^2$	ALU	HUC	Lat	Long	F	B	C	Bac-T	S	E	D	DW	CA
V03W12	MILL CREEK N OF NORTH GREENFIELD @ T-131	02	109	000	42.56	11.1	WWH	05060001070010	40.388600	-83.588300	x	x	x						
V03K07	MILL CREEK NE OF EAST LIBERTY @ CO. RD. 142	02	109	000	39.20	22.5	WWH	05060001070010	40.365000	-83.549900	x	x	x	x	x		x		
V03W13	MILL CREEK S OF LUNDA @ BENNINGTON-NEWLAND RD.	02	109	000	36.05	38.0	WWH	05060001070020	40.355800	-83.514200	x	x	x	x					
V03S17	Mill Creek @ Wheeler Green Rd	02	109	000	28.13	54.0	WWH	05060001070020	40.311880	-83.435594			x	x					
V03P14	MILL CREEK UPST. MARYSVILLE @ COTTON SLASH RD.	02	109	000	24.74	62.0	WWH	05060001070020	40.289200	-83.401100	x	x	x	x			x		
301874	Mill Creek upst inflatable dam and water intake	02	109	000	21.65	65.0	WWH	05060001070020	40.260132	-83.390823	x	x	x					x	
V03S07	MILL CREEK AT MARYSVILLE @ ST. RT. 4 (MAIN ST.)	02	109	000	19.00	80.0	WWH	05060001070020	40.240000	-83.366800	x	x	x				x		
301928	Mill Creek Upst. Cherry Street, Dst. Old sewage disposal and post dam removal	02	109	000	18.14	82.0	WWH	05060001070020	40.243198	-83.355904	x	x	x	x	x		x		
601350	MILL CK OFF WALDO ROAD @ MARYSVILLE	02	109	000	16.80	88.0	WWH	05060001070020	40.255800	-83.345400	x	x	x				x		
V03P19	MILL CREEK E OF MARYSVILLE @ U.S. RT. 36	02	109	000	14.54	94.7	WWH	05060001070030	40.247200	-83.315000	x	x	x				x		
301925	Mill Creek Estates WWTP Outfall **Effluent Only**	02	109	000	12.59	NA	WWH	05060001070030	40.231440	-83.302400						x			
V03P20	MILL CREEK DST. MARYSVILLE @ HINTON MILL RD.	02	109	000	12.17	102.0	WWH	05060001070030	40.227500	-83.298100	x	x	x	x			x		
V03W07	MILL CREEK DST. CROSSES RUN	02	109	000	11.70	107.0	WWH	05060001070030	40.222500	-83.295500	x	x	x				x		x
203153	Mill Creek Upst. BMY Trib. (9.30), Adj. Watkins Rd.	02	109	000	9.42	109.0	WWH	05060001070020	40.21560	-83.2653	x	x	x						
301924	Mill Creek New Marysville WWTP Outfall access at 11320 Watkins Rd Effluent Only	02	109	000	9.25	NA	WWH	05060001070020	40.214730	-83.263030						x			
301872	Mill Creek Dst. New Marysville WWTP 11320 Watkins Rd	02	109	000	9.20	115.0	WWH	5060001070020	40.216702	-83.259903	x	x	x						x
V03P23	MILL CREEK NE OF WATKINS @ HINTON MILL RD.	02	109	000	6.89	120.0	WWH	05060001070030	40.231700	-83.238900	x	x	x	x			x		
V03W14	MILL CREEK UPST. BLUES CREEK, ADJ. BELLPOINT RD.	02	109	000	4.21	130.0	WWH	05060001070030	40.254700	-83.214200	x	x	x				x		

Station ID	NAME	Basin	Stream	Trib	RM	DA$_{mi}^2$	ALU	HUC	Lat	Long	F	B	C	Bac-T	S	E	D	DW	CA
301926	Ostrander WWTP Outfall Effluent Only	02	109	000	3.95	NA	WWH	05060001070030	40.255910	-83.210950						x			
V03W11	MILL CREEK S OF OSTRANDER, JUST DST. BLUES CREEK	02	109	000	3.90	167.0	WWH	05060001070030	40.255300	-83.208600	x	x	x				x		x
601260	MILL CREEK UPST. BELLPOINT@ U.S.G.S. GAGE	02	109	000	1.57	178.0	WWH	05060001070030	40.248100	-83.173600	x	x	x	x	x		x		
V03S12	BLUES CREEK @ TAYLOR-CLAIBORNE RD.	02	109	001	16.30	8.4	MWH	05060001070040	40.341100	-83.355800	x	x	x						
V03S10	BLUES CREEK @ LEEPER-PERKINS RD.	02	109	001	10.15	16.7	WWH	05060001070040	40.293800	-83.312800	x	x	x						
V06P12	BLUES CREEK N OF OSTRANDER @ OSTRANDER RD.	02	109	001	2.00	33.8	WWH	05060001070040	40.270800	-83.214200	x	x	x				x		x
V03P25	BLUES CREEK DST. OSTRANDER @ OSTRANDER RD.	02	109	001	0.60	37.1	WWH	05060001070040	40.260800	-83.207800	x	x	x	x	x		x		
V03W06	CROSSES RUN E OF MARYSVILLE @ WATKINS RD.	02	109	005	0.80	4.4	WWH	05060001070030	40.218600	-83.301900	x	x	x		x		x		
V03K10	TOWN RUN AT MARYSVILLE @ WALNUT ST. (LOWER CROSSING)	02	109	015	0.70	1.3	WWH	05060001070020	40.229200	-83.365000	x	x	x	x			x		
V03G02	TOWN RUN AT MARYSVILLE @ 5TH STREET, DST. CULVERT	02	109	015	0.20	1.7	WWH	05060001070020	40.236300	-83.365000	x	x	x		x		x		

Key
Trib – Tributary
RM – River Mile
DA$_{mi}^2$ – Drainage Area per mile^2
ALU – Aquatic Life Use
HUC – Hydrologic Unit Code
Lat – Latitude
Long - Longitude
F - Fish
B - Macroinvertebrate
C - Water Column Chemistry
Bac-T - Bacteria
S - Sediment
E - WWTP Effluent Only Sample
D - Datasonde
DW - Drinking Water
CA - Chlorophyll-a, rock scraping

Table 2. Aquatic life use attainment status for sampling locations in the Mill Creek watershed, 2009, 2012, and 2013. The Index of Biotic Integrity (IBI), Modified Index of Well-being (MIwb), and Invertebrate Community Index (ICI) scores are based on the performance of the biological community. The Qualitative Habitat Evaluation Index (QHEI) is based on the ability of the stream habitat to support a biological community. The Mill Creek watershed is located in the Eastern Corn Belt Plains (ECBP) ecoregion. If biological impairment has occurred, the cause(s) and source(s) of the impairment are noted.

RM	Stream Name	Aquatic Life Use	IBI	MIwb	ICI	Macro Narrative	QHEI	Attainment Status	Cause	Source	Comments
Basin & Stream Code: 02-109-000											
42.56[H]	MILL CREEK N OF NORTH GREENFIELD @ CO. RD. 131	WWH	50	NA	-	Good	61.00	Full			
39.20[W]	MILL CREEK NE OF EAST LIBERTY @ CO. RD. 142	WWH	43	8.56	-	Good	61.50	Full			
36.05[W]	MILL CREEK S OF LUNDA @ BENNINGTON-NEWLAND RD.	WWH	43	9.12	46		66.50	Full			
24.74[W]	MILL CREEK UPST. MARYSVILLE @ COTTON SLASH RD.	WWH	46	9.32	50		72.80	Full			
21.65[W]	MILL CREEK UPST. MARYSVILLE @ INFLATABLE DAM WATER INTAKE	WWH	44	8.57	44		76.80	Full			
19.00[W]	MILL CREEK AT MARYSVILLE @ ST. RT. 4 (MAIN ST.)	WWH	49	9.13	-	Marginally Good	68.80	Full			
18.14[W]	MILL CREEK AT MARYSVILLE @ CHERRY ST. (NO WWTP OR DAM UPST)	WWH	36[ns]	7.24*	22*		61.50	Partial	Sedimentation/siltation, direct habitat alteration, organic enrichment (sewage) biological indicators	Urban runoff/ storm sewers , channelization, illicit connections/hook-ups to storm sewers	
16.80[W]	MILL CREEK DST. MARYSVILLE WWTP , OFF WALDO ROAD	WWH	48	8.31	46		74.30	Full			
14.54[W]	MILL CREEK E OF MARYSVILLE @ U.S. RT. 36	WWH	34*	7.83[ns]	-	Good	66.50	Partial	Sedimentation/siltation, organic enrichment (sewage) biological indicators	Agricultural, illicit connections/hook-ups to storm sewers	
12.17[W]	MILL CREEK DST. MARYSVILLE @ HINTON MILL RD.	WWH	42	8.87	44		75.30	Full			
11.70[W]	MILL CREEK DST. CROSSES RUN	WWH	47	9.61	34[ns]		76.80	Full			

RM	Stream Name	Aquatic Life Use	IBI	MIwb	ICI	Macro Narrative	QHEI	Attainment Status	Cause	Source	Comments
9.42[W]	MILL CREEK UPST. BMY TRIB. (9.30), ADJ. WATKINS RD.	WWH	41	9.36	46		79.00	Full	**Sampled as follow-up work in 2013**		
9.20[W]	MILL CREEK DST. NEW MARYSVILLE WWTP	WWH	41	9.2	42		81.50	Full	**Sampled as follow-up work in 2013**		Higher than average flows in 2013. Nutrients still above target levels.
9.20[W]	MILL CREEK DST. NEW MARYSVILLE WWTP	WWH	39[ns]	8.87	28*		81.50				Partial attainment in 2012 due to nutrient enrichment, resampled in 2013 because of lower than average flows in 2012.
6.89[W]	MILL CREEK NE OF WATKINS @ HINTON MILL RD.	WWH	43	9.05	-	Good	83.30	Full	**Sampled as follow-up work in 2013**		
6.89[W]	MILL CREEK NE OF WATKINS @ HINTON MILL RD.	WWH	38[ns]	9.31	42		83.30	Full			
4.21[W]	MILL CREEK UPST. BLUES CREEK, ADJ. MILLS RD. (CO. RD. 150)	WWH	49	9.73	50		91.30	Full			
3.90[W]	MILL CREEK S OF OSTRANDER, JUST DST. BLUES CREEK	WWH	52	10.08	48		91.80	Full			
1.57[W]	MILL CREEK UPST. BELLPOINT@ MILLS RD. U.S.G.S. GAGE	WWH	51	9.74	38		87.00	Full			
Basin & Stream Code: 02-109-001											
16.30[H]	BLUES CREEK @ TAYLOR-CLAIBORNE RD.	MWH-C	30	NA	-	Fair	41.00	Full			
10.15[H]	BLUES CREEK @ LEEPER-PERKINS RD.	WWH	30*	NA	-	Poor*	47.00	Non	Sedimentation/siltation, Direct habitat alterations	Agricultural	
2.00[W]	BLUES CREEK N OF OSTRANDER @ OSTRANDER RD.	WWH	33*	5.70*	-	Marginally Good	66.00	Non	Sedimentation/siltation	Agricultural	
0.60[W]	BLUES CREEK DST. OSTRANDER @ OSTRANDER RD.	WWH	39[ns]	7.19*	-	Marginally Good*	71.50	Partial	Sedimentation/siltation	Agricultural	

RM	Stream Name	Aquatic Life Use	IBI	MIwb	ICI	Macro Narrative	QHEI	Attainment Status	Cause	Source	Comments
Basin & Stream Code: 02-109-005											
0.80[H]	CROSSES RUN E OF MARYSVILLE @ WATKINS RD.	WWH	34*	NA	-	Poor*	75.30	Non	Sedimentation/siltation, sediment screening value (Exceedance)	Agricultural, Sediment resuspension (contaminated sediments)	
Basin & Stream Code: 02-109-01 5 ***Samples Collected in 2009***											
0.20[H]	Town Run at Marysville at 5th street, dst culvert	WWH	20*	NA	-	Very Poor*	50.00	Non	Direct habitat alterations, organic enrichment (sewage) biological indicators, solids (suspended/bedload)	Channelization, illicit discharges	
0.70[H]	Town Run at Marysville at Walnut street	WWH	22*	NA	-	Poor*	44.00	Non	Direct habitat alterations, organic enrichment (sewage) biological indicators, solids (suspended/bedload)	Channelization, illicit discharges	

Biological Criteria

Eastern Corn Belt Plains

Index – Site Type	WWH	MWH-C
IBI – Headwaters	40	24
IBI – Wading	40	24
MIwb – Wading	8.3	6.2
ICI	36	22

[a] - A narrative evaluation of the qualitative sample based on attributes such as EPT taxa richness, number of sensitive taxa, and community composition was used when quantitative data was not available (or considered unreliable due to current velocities less than 0.3 fps flowing over the artificial substrates.) VP=Very Poor, P=Poor, F=Fair, MG=Marginally Good, G=Good, VG=Very Good, E=Exceptional.

[b] - Attainment status derived from one organism group is parenthetically expressed.

NA - MIwb is not applicable to headwater streams with drainage areas ≤ 20 mi^2.

[H] – Headwater site

[W] – Wading site

ns - Nonsignificant departure from biocriteria (≤4 IBI or ICI units, or ≤0.5 MIwb units).

* - Indicates significant departure from applicable biocriteria (>4 IBI or ICI units, or >0.5 MIwb units).

Underlined scores are in the Poor or Very Poor range.

- No sample taken.

Blue highlight signifies the samples were collected as follow-up work in 2013.

Beneficial Use Designations and Recommendations

The streams in the Mill Creek watershed study area currently listed in the Ohio Water Quality Standards (WQS) are assigned the Warmwater Habitat (WWH) and Channel Modified Warmwater Habitat (MWH-C) aquatic life use designations. The aquatic life use designations of all streams sampled during this survey were verified in past surveys using biological data.

Four streams in the Mill Creek watershed were evaluated for aquatic life and recreational use status in 2009, 2012, and 2013 (Table 1). Significant findings include the following:

- All of the streams have an existing WWH use designation for all or part of their length and should retain that aquatic life use. These streams are the following: Mill Creek, Crosses Run, Town Run, and Blues Creek (State Route 4 to the mouth).

- From its headwaters to State Route 4, Blues Creek is designated MWH-C.

All of the streams in this study except Town Run should retain the Primary Contact Recreation use, along with the Agricultural Water Supply (AWS) and Industrial Water Supply (IWS) uses. Town Run should be changed from Secondary Contact Recreation use (SCR) to PCR because of its accessibility to the public within the city of Marysville park boundaries. On more than one occasion, children were witnessed playing in and around Town Run in Eljer Park by Ohio EPA staff during sampling runs.

General Recommendations

Once a watershed's condition has been studied and any impairments identified, it is useful to examine ways to correct the problems. In this section, some general recommendations for the Mill Creek watershed are discussed. More specific, quantified recommendations may result from the Total Maximum Daily Load project (TMDL). Recommendations are not limited to this chapter. Recommendations for changes at specific locations that would benefit stream resource quality (for example, riparian and streamside buffer practices and land use changes) are interspersed throughout this document. The greatest concerns to water quality identified by this study were nutrient enrichment and bacteria, storm water runoff and sedimentation, and direct habitat alterations.

Managing Storm Water, Sedimentation, and Direct Habitat Alterations

The Mill Creek watershed and the overall water quality downstream are directly affected by storm water drainage and the manner in which the watershed is buffered from precipitation events. Reduction of sediment, nutrients, fertilizers/chemicals, erosion, and hydrologic modifications can be accomplished through proper storm water management.

Re-establishing natural riparian buffers (wetland and wooded riparian corridors) in the watershed to help slow storm water and filter pollutants before they reach the surface waters are positive mechanisms to reduce storm water pollution. In addition to restoring riparian buffers an effort should be made to take advantage of the streams' natural assimilative capacities. Natural development of stream channels provide an array of beneficial services including settling fine sediments into adjacent floodplains, processing of nutrients into productive biomass instead of nuisance algae, improved water quality, creation of natural instream habitats to increase carrying capacity of biomass, and ultimately evolution into a stable channel and the slowing of erosion. All of the streams in the study area were impaired in all or parts of their reaches by storm water runoff and sedimentation, and direct habitat alterations.

Organic Enrichment and Bacteria

Organic enrichment was detected in every stream within the study area. Illicit dischargers were the biggest contributors to organic enrichment. It is recommended to tie the illicit dischargers into the municipal sewage treatment system. All of the streams in the study were found to be impaired by organic enrichment in all or parts of their reaches.

Town Run had originally been designated a SCR waterbody, with an associated WQS criterion of 1030 cfu/100 ml *E. coli*. However, remediation of the former Eljer Plumbingware industrial site in the headwaters of Town Run involved creating a public park which now abuts the stream. Because of increased public access with corresponding observations of children playing in the stream, it is evident that the less-protective SCR designation is no longer appropriate for Town Run. It is recommended that Town Run be redesignated as Primary Contact Recreation Class B, having a WQS criterion of 161 cfu/100 ml.

Chemical parameters downstream from the Marysville WRF outfall in Mill Creek are elevated for TDS (total dissolved solids), total phosphorus, and nitrates. The rise in TDS in Mill Creek downstream from the Marysville WRF outfall (RM 9.2) is almost two fold compared to upstream levels (Figure 9 and Appendix G). Nitrates and phosphorus were both much higher than the 95th percentile ecoregional reference values (Figure 11 and Appendix G). During the 2012 sampling, Mill Creek (RM 9.2) was found to be in partial-attainment because of these elevated pollutant levels. Resampling was conducted in 2013 around the WRF in order to eliminate any other possible sources. Sampling locations were added in a direct tributary to Mill Creek upstream from the WRF outfall and a second site was added two tenths of a mile upstream in the mainstem of Mill Creek (RM 9.4) in 2013. Results from the 2013 sampling yielded full ALU attainment downstream from the WRF. However, 2013 was a higher base flow summer than 2012 (Appendix I) and concentrations of stressor pollutants such as nutrients and TDS (Table 8), while higher than criteria concentrations, were relatively lower in 2013 than in 2012. TDS sensitive taxa (mayflies) were much fewer at RM 9.2 (downstream from the outfall) compared to just upstream at RM 9.4 (Table 3). It is recommended that the city of Marysville reduce nutrient loads and closely monitor TDS from receiving facilities to alleviate the negative effects the dissolved solids components are having on Mill Creek during low flow years, i.e., contributing to partial ALU attainment in 2012 when flow conditions were below the 68 year period of record average (Figure 5).

Table 3. Percentages of mayflies collected from artificial substrates upstream and downstream from the Marysville WRF, 2013.

Location	River Mile	Percent Mayfly
Upstream from Marysville WRF	9.42	32.47%
Downstream from Marysville WRF	9.20	4.56%

Table 4. Waterbody use designation recommendations for the Mill Creek watershed. Designations based on the 1978 and 1985 Ohio Water Quality Standards appear as asterisks (*). A plus sign (+) indicates a confirmation of an existing use and a triangle (▲) denotes a new recommended use based on the findings of this report.

Water Body Segment	Use Designations												Comments
		Aquatic Life Habitat						Water Supply			Recreation		
	SRW	WWH	EWH	MWH	SSH	CWH	LRW	PWS	AWS	IWS	BW	PCR	SCR	
Mill creek - at RM 19.45		+						o	+	+		+		PWS intake - Marysville
- all other segments		+							+	+		+		
Blues creek – headwaters to State Route 4 (RM 11.5)				+					+	+		+		ECBP ecoregion - channel modification
- State Route 4 to the mouth		+							+	+		+		
Ronolds run		*							*	*		*		
Dry run		*							*	*		*		
Grassy run		*							*	*		*		
Dun run		*							*	*		*		
BMY tributary (Mill creek RM 9.3)							+		+	+			+	Small drainageway maintenance
Phelps run		*							*	*		*		
Crosses run		+							+	+		+		
North branch		+							+	+			+	
Town run		+										▲		Public stream access at Eljer Park
Otter run		*							*	*		*		
Otter creek		+							+	+		+		

SRW = state resource water; WWH = warmwater habitat; EWH = exceptional warmwater habitat; MWH = modified warmwater habitat; SSH = seasonal salmonid habitat; CWH = coldwater habitat; LRW = limited resource water; PWS = public water supply; AWS = agricultural water supply; IWS = industrial water supply; BW = bathing water; PCR = primary contact recreation; SCR = secondary contact recreation.

Introduction

During 2012, Ohio EPA conducted a water resource assessment of four streams in the Mill Creek study area using standard Ohio EPA protocols as described in Appendix F. Included in this study were assessments of the biological, surface water and recreational (bacterial) condition. A total of 24 biological, 29 water chemistry, and 11 bacterial stations were sampled in the Mill Creek study area. Summarized biological and raw chemical and bacterial results can be viewed in the appendices B, C, D, and E.

Specific objectives of the evaluation were to:

- Establish the present biological conditions in the selected sites in the Mill Creek watershed by evaluating fish and macroinvertebrate communities,
- Assess physical habitat influences on stream biotic integrity,
- Determine recreational water quality,
- Determine the attainment status of designated beneficial uses and recommend changes if appropriate, and
- Follow-up the 1995, 2000, and 2001 survey data and 2003 TMDL recommendations http://epa.ohio.gov/dsw/tmdl/SciotoRiver.aspx.

The findings of this evaluation may factor into regulatory actions taken by the Ohio EPA (e.g. NPDES permits, Director's Orders, or the Ohio Water Quality Standards (OAC 3745-1)), and may eventually be incorporated into State Water Quality Management Plans, the Ohio Nonpoint Source Assessment, Total Maximum Daily Loads (TMDLs) and the biennial Integrated Water Quality Monitoring and Assessment Report (305[b] and 303[d] report.

Figure 3. Location of Mill Creek watershed, Ohio.

Study Area Description

The Mill Creek watershed is located in portions of Logan, Union and Delaware counties in west central Ohio Figure 3. The watershed drains 179 mi^2 and includes four 12 digit Hydrologic Unit Codes (HUC-12): Upper Mill Creek (050600010601), Middle Mill Creek (050600010602), Blues Creek (050600010603) and Lower Mill Creek (050600010604). The Mill Creek mainstem is 37.8 miles long and flows from a northwest to a southeast direction across the study area. Blues Creek is the longest tributary stream (12.5 miles) and flows mostly parallel to Mill Creek prior to its confluence near Ostrander in Delaware County. Located throughout the watershed are several intermittent streams including Dry Run, Grassy Run, Phelps Run and Ronolds Run. No large lakes exist in the watershed. However, a public drinking water reservoir for the city of Marysville is located to the northwest of town. The drinking water reservoir is filled from Mill Creek at RM 21.65 via an inflatable dam and pumping station with an average distribution of 2.2 million gallons per day (mgd).

The Mill Creek watershed is positioned entirely within the ECBP ecoregion and includes the central Ohio till plain. The headwaters of Mill Creek begin near a series of terminal moraines adjacent the Bellefontaine upland complex of Logan County and about two miles southeast of Rushylvannia. Here the elevation at the source is approximately 1,074 feet. Approximately 20 miles downstream in Marysville, elevation declines approximately seventy five (75) feet. From Marysville, Mill Creek falls an additional 160 feet to an elevation of 840 feet at the mouth near Bellpoint. A moderate gradient stream, the average fall for Mill Creek is 6.2 feet per mile (Ohio EPA, 1995).

Similar sized alternating bands of ground moraine and end moraine extend from the northwest to southeast across the watershed. The ground moraines have gently sloping terrain and the end moraines display steeper slopes while both are comprised of similar silt, clay, and till deposits. Sand, gravel and silt deposits are common along alluvial terraces and outwashes along Mill Creek (Ohio EPA, 1995).

Common soil associations present in the watershed include Blount-Wetzel-Morley, Blount-Morley-Pewamo and Napanee-Paulding-St. Clair. These soil associations are generally poorly drained fine textured glacial till. There are soils with high erosion potential (frequently on the slopes of end moraines) and soils of slow permeability (often in ground moraine areas) within the study area. These characteristics present limitations for cultivation, construction, septic treatment and other uses, which if exceeded may impact surface water. Along Mill Creek floodplains and terraces, the Genessee-Eel-Shoals-Fox soil association dominates. These areas include soils derived from calcareous glacial till and tend to be well-drained (USDA, 1975).

Land use and land cover have an important influence on water quality conditions found in the watershed. Overall, agricultural land uses (row crop, pasture) dominate with about 75% of the study area in this classification (Xian, Fry 2009). This is evident in Union County with 932 farms averaging 232 acres. In 2011, Union County ranked 14th in the state of Ohio in soybean production (acres harvested) and 16th in the state in number of hogs and pigs (ODA, 2011).

Forested (and other vegetative) cover (13%) and development (10%) represent the other major land use and land cover types in the study area. Subwatershed (HUC 12) land use generally follows this pattern. The most developed subwatershed includes the central section of Mill Creek in the study area. Impervious areas associated with the city of Marysville help account for the 15% of developed land in this subwatershed. Forested cover in the upper Mill Creek watershed in Logan County is the highest in the study area at 25% and is generally concentrated along the ridges of the end moraine extending through this area. Riparian cover generally varies from sparse in the headwaters to moderate in the lower section of Mill Creek through Ostrander to the mouth (Figure 4).

The largest population center in the study area is Marysville. From 2000 to 2010, the population of the city of Marysville has increased 39% from 15,942 to 22,094. Similarly, new housing units increased 33% from 2000 to 2010. The majority of population growth in Union County is expected to continue in and around the Marysville area (Union County Commissioners, 2013).

Besides Marysville, the watershed is mostly rural with few towns and villages. Population density remains low in these watershed areas. Ostrander, located in the lower portion of the watershed in Delaware County had a 2010 population of 643. This was up from 405 in 2000 (U.S. Census, 2010).

The new city of Marysville Water Reclamation Facility (WRF) was completed in the spring of 2009 with an average daily design flow of 8.0 mgd. The WRF was built to accommodate future growth including areas south of the city of Marysville. The Union County Commissioners have also developed a plan to sewer the villages of Peoria and Raymond in northwest Union County. This new wastewater treatment plant is expected to be completed in early 2014 with service connections to 185 equivalent dwelling units finished in late 2014.

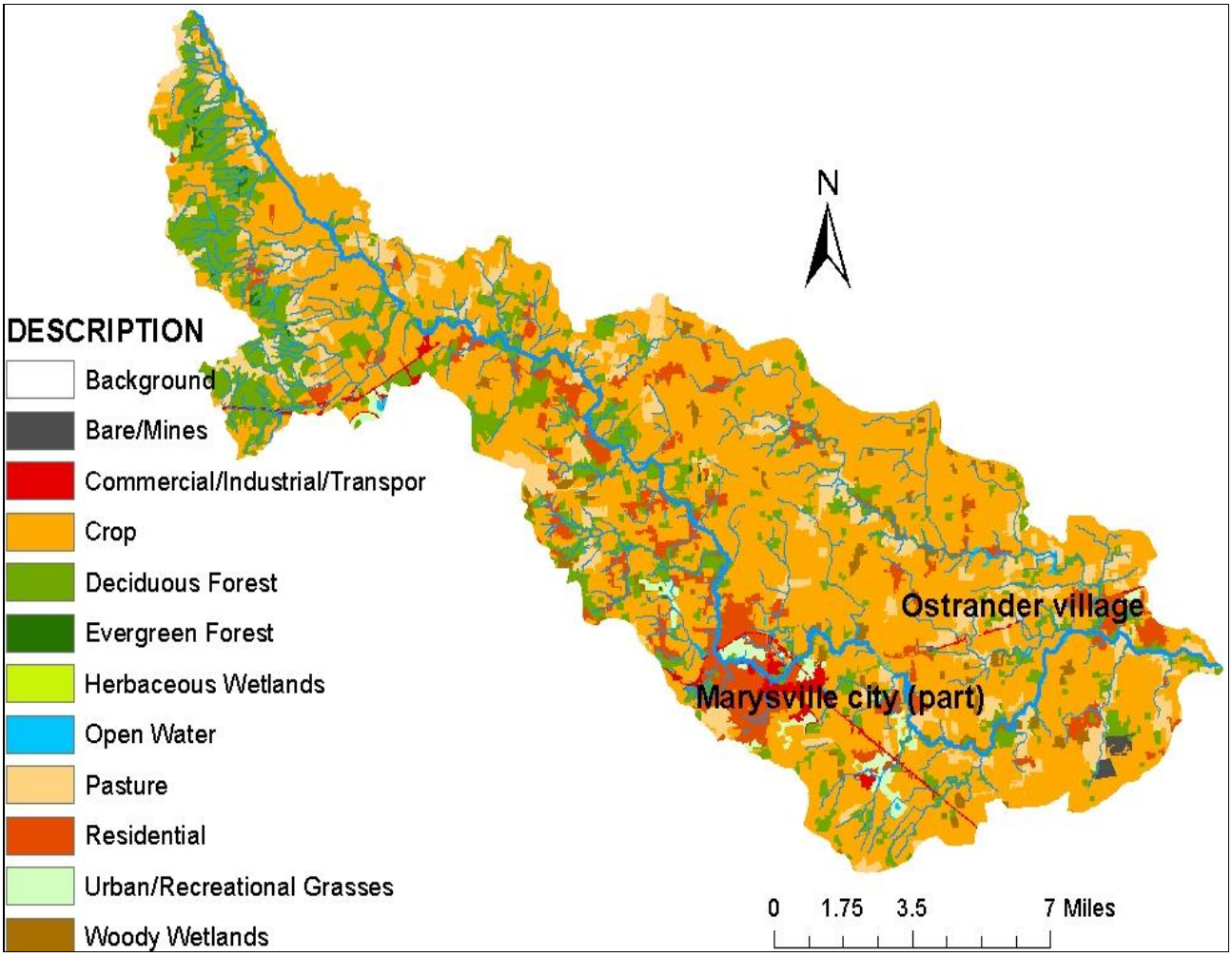


Figure 4. Land use coverage within the Mill Creek watershed (Xian and Fry, 2009).

Results

Water Chemistry

Surface water chemistry samples were collected from sites in the Mill Creek study area from February through October 2012. Data from all 2012 sampling dates were used to identify any violations, exceedances, or excursions of applicable Ohio Water Quality Standards (OAC3745-1) criteria. Selected sites near the Marysville Water Reclamation Facility were also sampled in the summer of 2013. *E. coli* bacteria samples were collected during the defined recreation season of May 1 through October 31 and compared to the Ohio Water Quality Standards recreation use criteria.

Metals, total dissolved solids (TDS) and inorganic nutrients that have been linked to the degradation of aquatic biological communities, specifically nitrate+nitrite (NO_3+NO_2) and total phosphorous (TP), are highlighted and discussed below. Nutrients are discussed in relation to surface water concentration targets suggested by Ohio EPA in the 1999 report *Association Between Nutrients, Habitat and the Aquatic Biota in Ohio Rivers and Streams,* commonly referred to as the "Associations Document" (Ohio EPA 1999). Metals, TDS and other water quality parameters are compared to any applicable Ohio Water Quality Standards (WQS) criteria. Associations Document suggested nutrient criteria were established using multiyear data from the period of June 15 through October 15. Geometric mean concentrations of Mill Creek nitrate-nitrite and total phosphorus chemistry data were compared to these targets, but sample results from outside the June 15 through October 15, 2012 timeframe were excluded from the discussion below in order to facilitate a direct comparison.

Water samples were collected at 29 locations throughout the Mill Creek mainstem and larger tributaries (Table 1). Stations were established in free flowing sections of the stream, and samples were typically collected at or near bridge crossings. To the extent possible, sampling locations were kept consistent with those used in previous Ohio EPA studies of this watershed. All surface water samples were collected in appropriate containers, preserved and delivered to Ohio EPA's Environmental Services laboratory for analysis. Collected water was preserved using methods outlined in the Manual of Ohio EPA Surveillance Methods and Quality Assurance Practices (Ohio EPA 2009). Surface water chemical data is accessible to the public online using interactive maps to display data and access downloadable Microsoft Excel files at: http://www.epa.ohio.gov/dsw/gis/index.aspx (Select "Water Chemistry and Stream Sediment Data" from the drop-down menu at right. Use the zoom tool to display the area of interest. Clickable chemistry sampling locations only become visible at a relatively close zoom.)

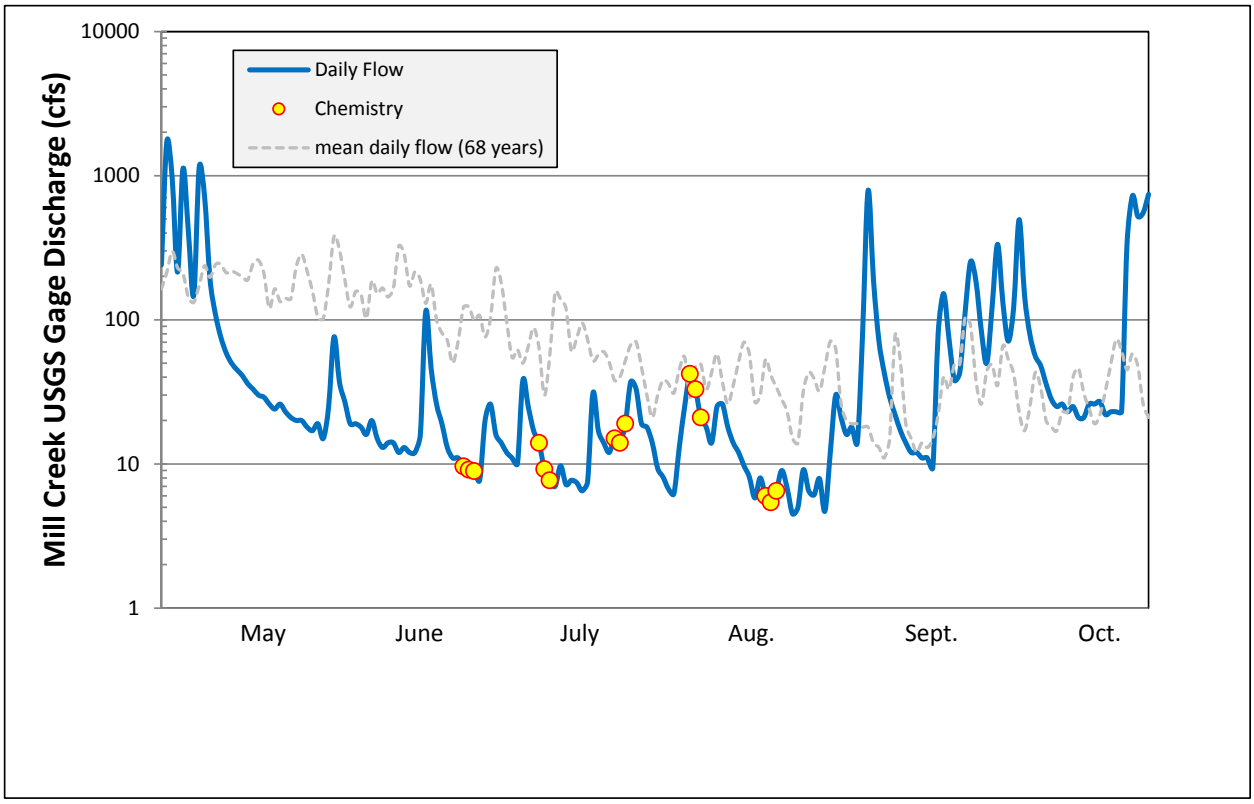


Figure 5. Stream discharge at USGS Mill Creek gaging station, summer 2012.

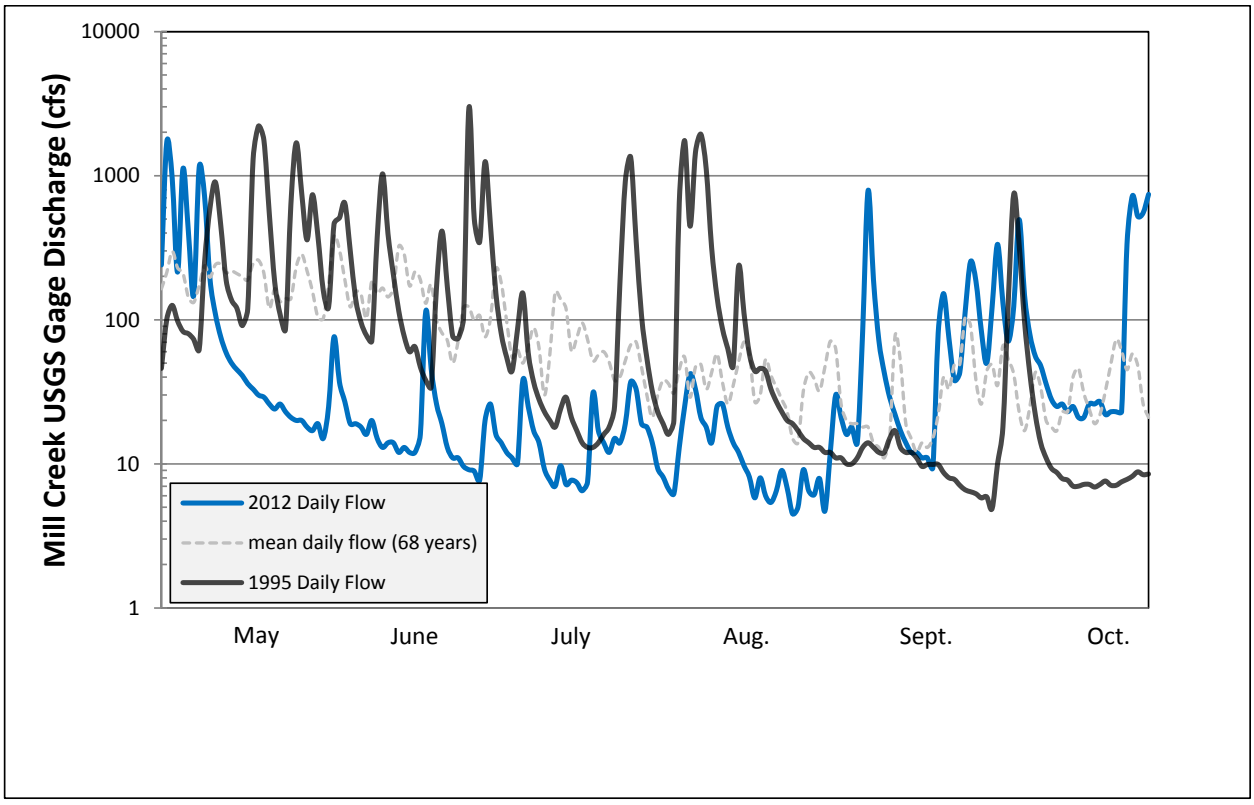


Figure 6. Comparison of 1995 and 2012 summer stream discharge at the USGS Mill Creek gaging station.

Surface water samples were analyzed for common metals, nutrients, bacteria, pH, temperature, alkalinity, conductivity, suspended (TSS) and dissolved (TDS) solids, chemical oxygen demand (COD), dissolved oxygen (D.O.), and percent D.O. saturation (Appendix G). A summary of nutrients and TDS measured in the Mill Creek watershed are detailed in Table 7 and are depicted graphically by river mile in Figures 7-9.

A plot of stream discharge from the Mill Creek USGS gaging station at Bellpoint (03220000), Figure 5, shows flow trends in the Mill Creek watershed during the summer 2012 sampling period. Stream discharges on the dates when chemistry samples were collected are highlighted in the figure. Summer stream chemistry sampling was carried out in five, three-day sampling passes. Each of the fifteen sampling dates covered approximately ten stream sites apiece.

Flow conditions during the summer sampling season were typically lower than the historic mean during the same season (Figure 6). Three of the five chemistry sampling passes occurred during Mill Creek's lowest flow conditions of the year (>80% annual flow exceedance), while the 8/7 through 8/9 sampling event captured mid-range flows (~50% annual flow exceedance) (Figure 5). During the 1995 Ohio EPA biosurvey of this watershed, streamflows were generally higher than in 2012 (Figure 6).

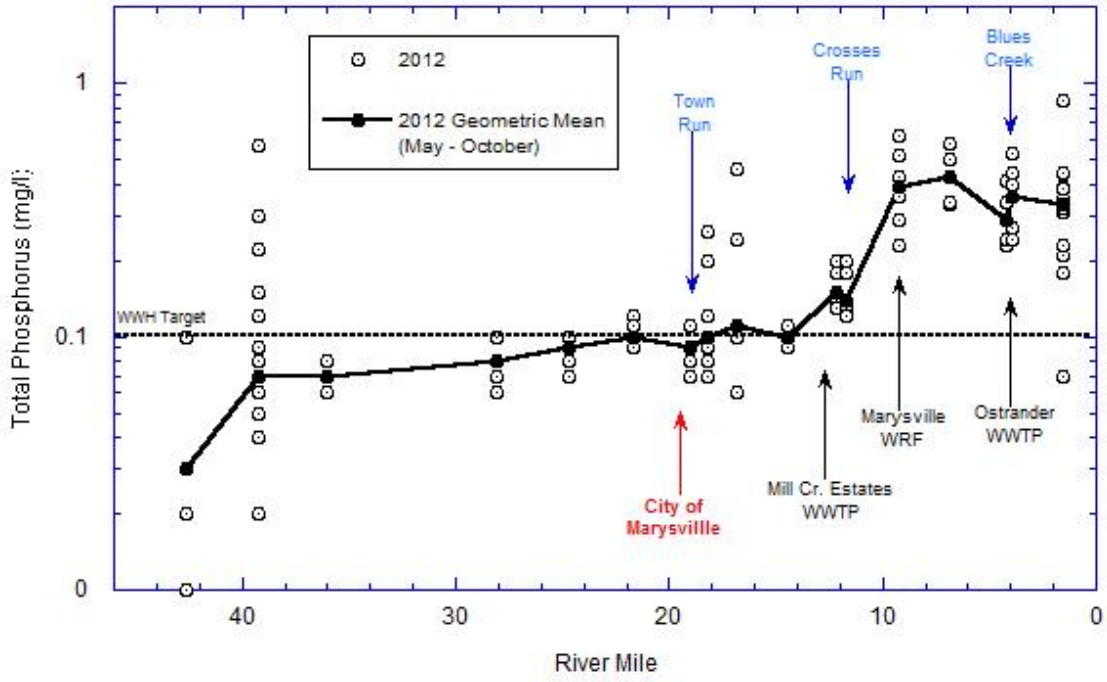


Figure 7. Total phosphorus (mg/l) concentrations for the Mill Creek mainstem listed by river mile, 2012.

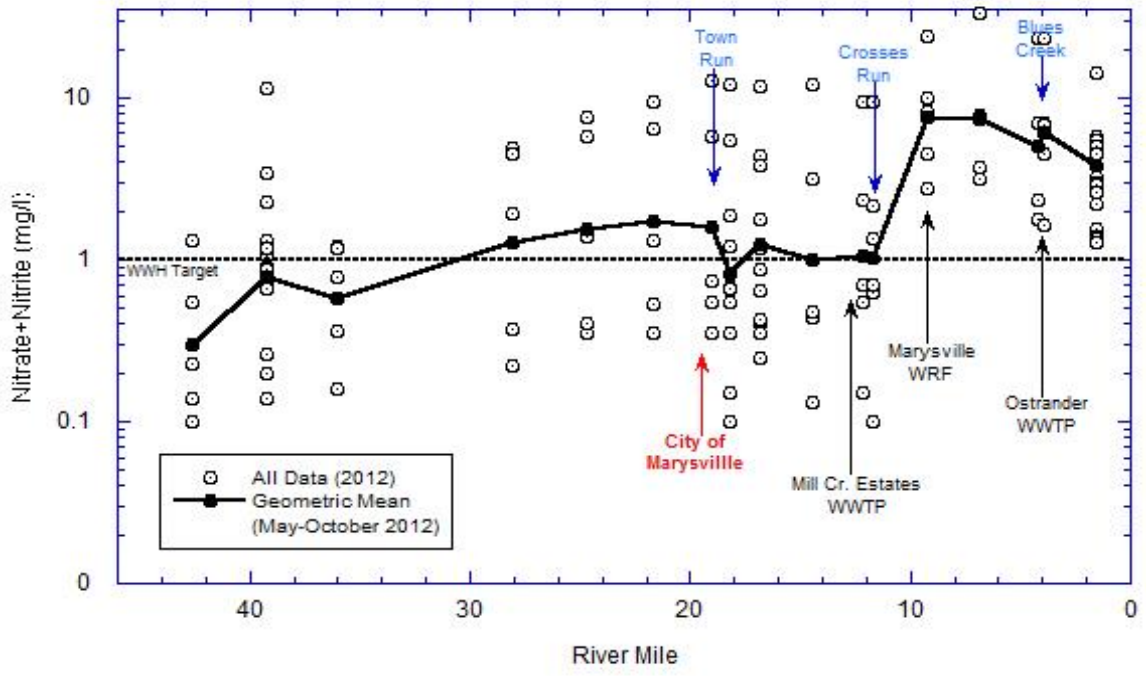


Figure 8. Nitrate + nitrite (mg/l) concentrations for the Mill Creek mainstem sites listed by river mile, 2012.

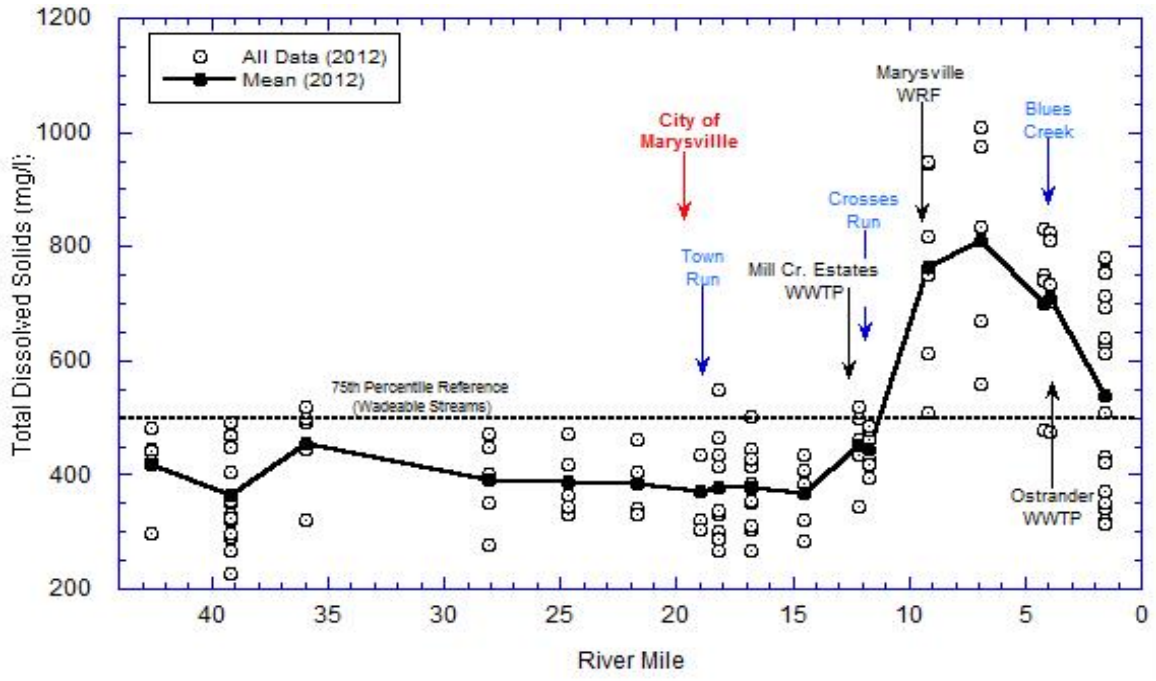


Figure 9. Total dissolved solids (mg/l) concentrations for the Mill Creek mainstem sites listed by river mile, 2012.

Chemicals present in concentrations exceeding Ohio WQS criteria are reported in Table 5. In streams designated as WWH, instantaneous dissolved oxygen concentrations below 4.0 mg/l and 24-hour average concentrations below 5.0 mg/l can negatively impact aquatic organisms and are in violation of WQS criteria. Six sites on Mill Creek had dissolved oxygen measurements below 4.0 mg/l, all six of which were located in the reach between Main Street, (SR-4/31) in downtown Marysville at RM 19.0, and the USGS gage site on Mills Road near Bellpoint at RM 1.57. The Mill Creek tributaries of Crosses Run, North Branch Crosses Run and Town Run each had incidences of low dissolved oxygen; Town Run showed this pattern most consistently.

Elevated concentrations of iron in comparison to the statewide WQS criterion for the protection of the Agricultural Water Supply use were noted in Mill Creek at County Road 142 (RM 39.2), Mill Creek adjacent Waldo Road near Marysville (RM 16.8), and in Mill Creek at the USGS gage station near Bellpoint (RM 1.57). In Blues Creek, iron was elevated at the Ostrander Road crossing, downstream from Ostrander (RM 0.6). Each of these instances was associated with elevated stream flow due to snowmelt or precipitation runoff and most occurred between the months of March and May.

Table 5. Exceedances of Ohio Water Quality Standards aquatic life use criteria (OAC3745-1) for chemical/physical parameters measured in the Mill Creek study area, 2012. Dissolved oxygen values exceeded the WWH aquatic life use Outside Mixing Zone Minimum criterion unless otherwise noted. Bacteria exceedances are presented in the Recreational Use Section.

Stream/RM	Location	Chemical Parameter (mg/l unless noted)
Mill Creek	*WWH Existing*	
19.00	State Route 4 in Marysville	Dissolved Oxygen (3.81)
16.80	Adjacent Waldo Rd in Marysville	Dissolved Oxygen (3.47, 3.78, 3.86, 3.99, 4.37[a], 4.89[a])
12.17	Hinton Mill Rd., DST of Marysville	Dissolved Oxygen (3.63)
11.70	Downstream Crosses Run	Dissolved Oxygen (3.95)
6.89	Hinton Mill Rd. NE Watkins	Dissolved Oxygen (3.92)
1.57	USGS gage near Bellpoint	Dissolved Oxygen (3.83)
Crosses Run	*WWH Existing*	
2.00	UPST Industrial Parkway	Dissolved Oxygen (2.64 and 3.44)
0.80	Watkins Rd	Dissolved Oxygen (0.25, 4.61[a])
North Branch Crosses Run	*WWH Existing*	
0.04	Scottslawn Rd.	Dissolved Oxygen (3.66, 3.69, 3.73, 3.75)
Town Run	*WWH Existing*	
0.21	5th St. DST culvert	Dissolved Oxygen (0.04, 2.12, 3.71, 4.03[a])

[a] Exceedance of the WWH aquatic life Outside Mixing Zone Average water quality criterion.

Stream water was tested for bacteria within the recreation season only (May 1 through October 31). During that timeframe, bacteria samples were collected alongside samples that were analyzed for other chemistry parameters. Bacteria samples were collected at 11 locations. These results are included in the Chemistry Results and Discussion by HUC-12 section below and presented in more detail in the Recreation Use section of this report.

Multiprobe water quality recorders were deployed twice at 16 locations to monitor hourly levels of dissolved oxygen, pH, temperature, and conductivity over a 48-hour period. Additional deployments were made in the vicinity of the Marysville WRF in 2013. See Appendix I for a more detailed discussion of these data.

Chemistry Results and Discussion by HUC-12

Seventeen locations along 41 miles of the Mill Creek mainstem were sampled for water chemistry. Sampling began near the headwaters of Mill Creek at Perry Township Road 131 in Logan County (RM 42.56) and continued downstream through Union County to the Mills Road / CR 150 bridge crossing near Bellpoint (RM 1.57) in western Delaware County.

Nutrient enrichment is an important driver of stream water quality with regard to aquatic organisms, and Ohio streams are generally considered to be saturated in nitrate (as NO_3+NO_2), the form of inorganic nitrogen that is available for direct algae and plant uptake, while total phosphorous (TP) concentrations are generally considered to be limiting to algal productivity. Stated another way, Ohio streams that have high TP concentrations are generally correlated to stream conditions that give rise to more pollution tolerant, less diverse biological communities and vice versa, somewhat independently of nitrate-N concentrations below an upper limit of approximately 15 mg NO_3/l (Ohio EPA 1999).

The recommended statewide nutrient target for WWH *wadeable* streams (drainage area between 20 and 200 mi^2) applies to all Mill Creek mainstem sites, with the exception of the upstream-most sampling site at TR-131 in Logan County, RM 42.56. This site and many of the tributary sampling locations are considered *headwater streams*, based on the smaller amount of upstream land that drains to them. Criteria or targets for nutrients, dissolved oxygen, and *E. coli* bacteria for both stream categories are provided in Table 6.

Table 6. Nutrient, dissolved oxygen, and *E. coli* bacteria values for WWH headwater and wadeable streams.

Chemical parameter	WWH headwater streams (drainage < 20mi^2)	WWH wadeable streams (20mi^2 < drainage < 200mi^2)
Total Phosphorous (TP) [1]	0.08 mg/l	0.1 mg/l
Nitrate+Nitrite (NO_3+NO_2) [1]	1.0 mg/l	
Dissolved Oxygen (DO) [2]	4.0 mg/l (acute), 5.0 mg/l (24-hr avg.), diel range[3] < 7.0 mg/l	
E. coli, Rec. Use WQS[4]	161 cfu/100 ml	

[1] Ohio EPA 1999, Association Between Nutrients

[2] WQS criteria

[3] Miltner 2010, suggested target

[4] Primary Contact Recreation Class B criterion

The nutrient and TDS concentrations at each chemical sampling location are expressed as geometric means in Table 7 below for reference. A geometric mean is a mathematical measure of central tendency, and similar to an average or median, it describes a range of data using a single number. Geometric means are used to describe most of the chemical data results within this report because with a geometric mean the influence of extremely high or low data points is minimized. Furthermore several of the chemical concentration criteria used by this report are given in the form of a geometric mean.

Geometric mean concentrations in excess of targets are listed in bold. Because high concentrations of total ammonia can function as an acute toxin to aquatic life, more so than other nutrients, the single sample maximum WQS ammonia criterion is also listed in parentheses alongside the geometric mean.

Table 7. Geometric mean concentration of selected nutrients and total dissolved solids at chemistry sampling sites in the Mill Creek watershed, 2012.[1]

Sampling Location	#No. of Samples	RM	NO_3+NO_2	TP	Total NH_4 (max)	TDS
Upper Mill Creek HUC-12: (05060001-06-01)						
Mill Creek at TR-131	5	42.56	0.26	0.029	0.029 (0.051)	412
at CR-142	8	39.20	0.69	0.066	0.053 (0.330)	396
Middle Mill Creek HUC-12: (05060001-06-02)						
at Benn.-Newland (Lunda) Rd.	5	36.05	0.58	0.069	0.030 (0.061)	449
at Wheeler-Green Rd.	5	28.13	**1.29**	0.081	0.040 (0.056)	384
at Cotton Slash Rd.	5	24.74	**1.53**	0.089	*BDL, < 0.050*	384
at Inflatable Dam Water Intake	5	21.65	**1.70**	**0.102**	0.030 (0.058)	383
at Main St, Marysville	5	19.00	**1.60**	0.088	0.036 (0.156)	369
Town Run at Walnut Street	*4*	*0.70*	*0.10*	*0.057*	*0.063 (0.389)*	*607*
Town Run downstream 5th St.	*7*	*0.20*	*0.14*	*0.252*	*0.103 (0.715)*	*620*
Mill Creek at Cherry St, Marysville	8	18.14	0.80	0.096	0.041 (0.089)	387
adj. Waldo Rd.	5	16.80	**1.30**	**0.100**	0.084 (0.125)	404
Lower Mill Creek HUC-12 (05060001-06-04)						
at US-36	5	14.54	**1.00**	**0.100**	*BDL, < 0.050*	362
at Hinton-Mill Rd. (West)	5	12.17	**1.04**	**0.150**	0.047 (0.097)	447
Crosses Run at Industrial Parkway	*5*	*2.00*	***1.87***	*0.220*	*0.133 (1.94)*	*384*
N. Br. Crosses at Scottslawn Rd.	*5*	*0.04*	*0.56*	*0.084*	*0.067 (0.108)*	*717*
Crosses Run at Watkins Rd.	*8*	*0.80*	*0.57*	***0.138***	*0.038 (0.094)*	*565*
Mill Creek downstream Crosses Run	6	11.70	**1.06**	**0.140**	0.038 (0.067)	444
downstream Marysville WRF	6	9.20	**7.54**	**0.387**	0.032 (0.057)	745
at Hinton-Mill Rd. (East)	5	6.89	**7.43**	**0.427**	*BDL, < 0.050*	790
upstream Blues Ck., adj. Mills Rd.	4	4.21	**5.05**	**0.294**	0.043 (0.099)	687
just downstream Blues Ck.	5	3.90	**6.03**	**0.360**	0.039 (0.222)	696
at Mills Rd. USGS gage	8	1.57	**3.99**	**0.346**	*BDL, < 0.050*	648
Blues Creek (05060001-06-03)						
at Taylor-Claiborne Rd.	5	16.30	<0.1, BDL	0.047	0.049 (0.099)	418
at Leeper-Perkins Rd.	5	10.15	0.38	0.136	0.057 (0.151)	443
N of Ostrander at Ost. Rd.	5	2.00	0.60	0.076	0.069 (0.107)	539
downstream Ostrander at Ost. Rd.	8	0.60	0.45	0.076	0.031 (0.062)	618

[1]Geometric means in excess of targets listed in bold. Tributary sites in italics. NH_4 max listed in parentheses. "BDL" = result is below method detection limit.

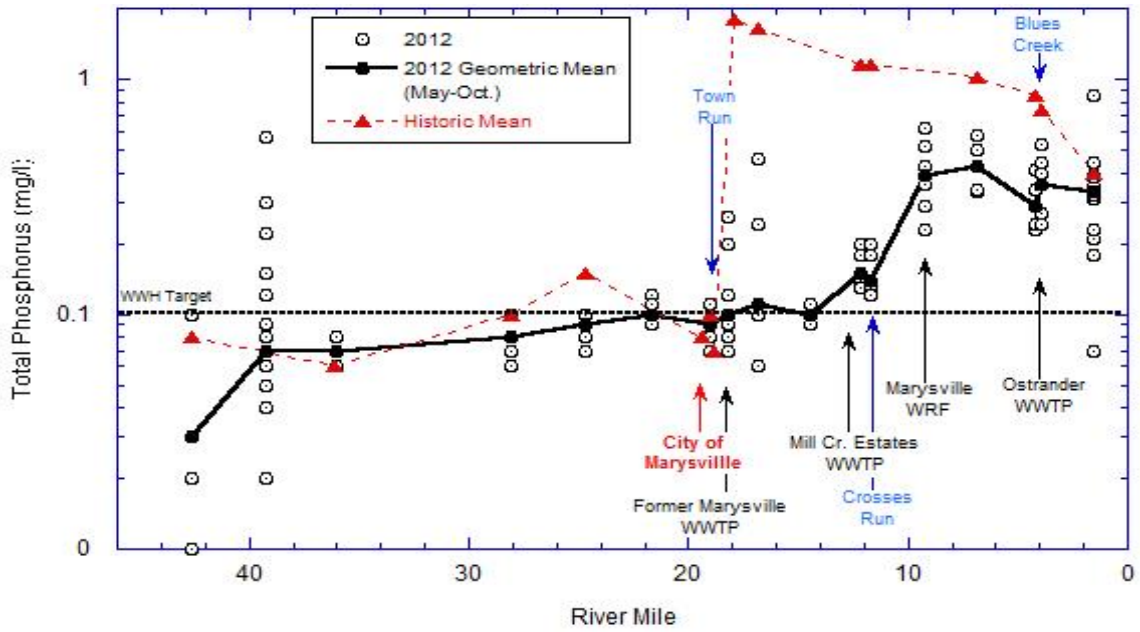


Figure 10. Total phosphorus (mg/l) concentration values for the Mill Creek mainstem sites listed by river mile, 2012.

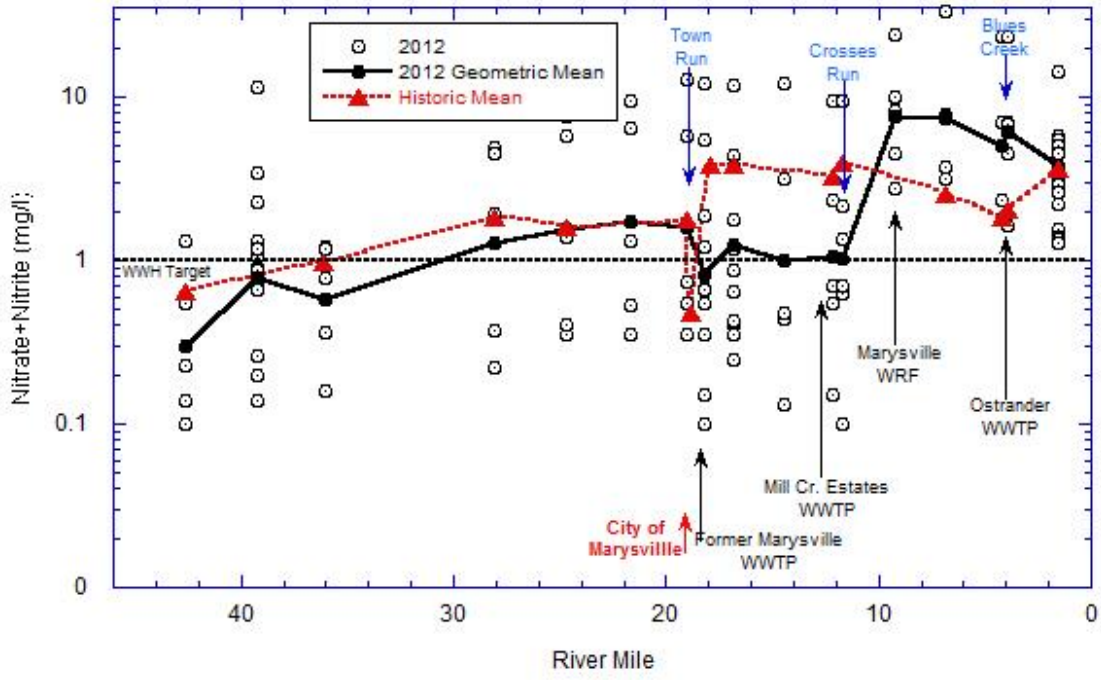


Figure 11. Nitrate + nitrite (mg/l) concentration values for the Mill Creek mainstem sites listed by river mile, 2012.

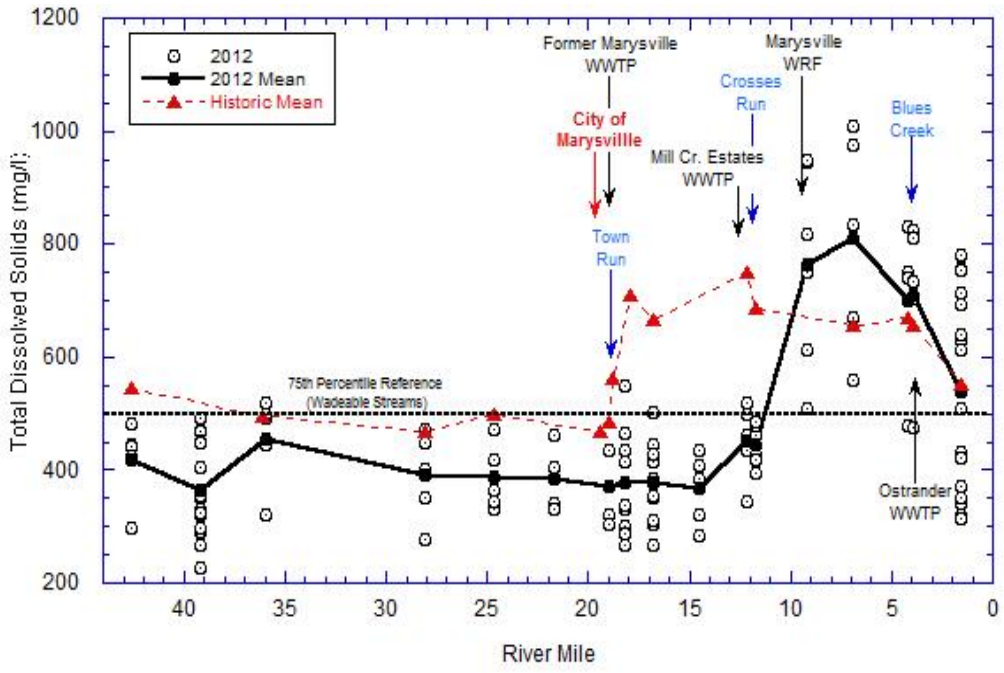


Figure 12. Total dissolved solids (mg/l) values for the Mill Creek mainstem sites listed by river mile, 2012.

Upper Mill Creek HUC-12 (050600010601)

Two stations were sampled in the headwaters HUC-12 of Mill Creek, the uppermost at RM 42.56 where Mill Creek is crossed by Perry Township Road 131 in Logan County and downstream at Union County Road 142 at RM 39.2. Both of these sites fully met the WWH aquatic life use and provided adequate stream habitat characteristics, with QHEI scores of 61.0 and 61.5, respectively.

Dissolved oxygen was in a normal range between 5 and 8 mg/L and no problematic diel shifts were observed. Neither of these sites had median nutrient concentrations in excess of Ohio EPA thresholds for *headwater* or *wadeable* streams.

E. coli. samples taken at the Union County Road 142 station, representing the headwaters HUC-12, had a geometric mean in exceedance of the WQS criterion. This stream location had the second highest maximum *E. coli.* concentration (2600 cfu/100ml) found in the Mill Creek basin. Inadequate residential sewage treatment, livestock production and fertilizing cropland with animal manure are all potential pathways for elevated *E. coli* concentrations in this area's surface water.

In addition, two samples from the Union County Road 142 station site were elevated in comparison to the Agricultural Water Supply OMZA WQS criterion for iron (7810 and 27700 µg/l v. 5000 µg/l criterion). Both of these samples were associated with significant runoff events and were not considered a significant water quality issue.

Middle Mill Creek HUC-12 (050600010602)

Mill Creek is crossed by Bennington-Newland Road (a.k.a. Lunda Road) at RM 36.05. This sampling point lies downstream from two large manure spills that occurred during the summers of 2000 and 2001. Current monitoring results indicate that this portion of Mill Creek has recovered from those events as it is

fully attaining its WWH ALU designation (Table 2). Median nutrient concentrations remained below threshold levels.

Approximately eight miles downstream, Mill Creek was sampled at Wheeler Green Road (RM 28.13) in Liberty Township, downstream from the communities of Raymond and Peoria. Nitrate geometric mean concentrations rose above the WWH target of 1.0 mg/l beginning at this site (1.29 mg/l geometric mean) and remained elevated downstream through the HUC-12 with geometric mean concentrations ranging from 0.80 to 1.7 mg/l NO_3+NO_2. Total phosphorus concentrations were in a satisfactory range at Wheeler-Green Road with a geometric mean of 0.081 mg/l. *E. coli* concentrations were in excess of the WQS criterion at this location, with a geometric mean of 236 and a max of 440 cfu/100 ml. Biological assessments and QHEI measurements were not conducted at this site.

At the time of this report's preparation, the Union County Engineer's office had officially begun the process of constructing a wastewater collection system and regional wastewater treatment facility in Liberty Township, designed to serve the communities of Raymond and Peoria. Concentrations of nutrients and pathogens in this portion of Mill Creek would be expected to diminish in the future as a result of this infrastructure investment. The project is scheduled for completion in 2015 (Personal communication with Union County Engineer's office).

The next sampling site downstream on Mill Creek was at Cotton Slash Road (RM 24.74). This site was in full attainment of WWH and had a QHEI score of 72.8 indicating good quality stream habitat. Nutrient concentrations continued to rise (geometric mean of 1.53 mg/l NO_3+NO_2 and 0.089 mg/l TP). However, there were no dissolved oxygen WQS criteria exceedances. This site was in non-attainment for PCR Class B recreation use with an *E. coli* geometric mean concentration of 309 cfu/100 ml.

Mill Creek was sampled at RM 21.65 where it flows through Marysville's inflatable dam water intake structure at the northwestern edge of Marysville's suburban development. Biological assessments were made just upstream from the PWS intake structure. The inflatable dam and associated pump station were constructed in 2008 in coordination with construction of the Marysville Reservoir for the purpose of withdrawing public drinking water for the city of Marysville from Mill Creek during specific flow conditions. According to Marysville's official website,

> "The Inflatable Dam is designed to mimic the natural flow characteristics of Mill Creek to preserve the habitat in the creek as nature intended. Creek flows are constantly monitored in relation to the operation of the pump station to provide ample flow in the stream.
>
> The 40 mgd pump station was constructed for the purpose of filling the upground reservoir on Raymond Road. The pump station is fully automated and can be operated remotely from the Water Treatment Plant." (City of Marysville 2013)

Stream habitat at this site had the highest QHEI score in the upper reaches of the Mill Creek watershed, and both the fish and macroinvertebrate communities met WWH goals. Total phosphorous concentrations in this reach of Mill Creek were just above the target value at 0.102 mg/l. There were no documented excursions below the dissolved oxygen WQS criterion at this site. Recreation use was not assessed at this particular site; however adjacent upstream and downstream sites on Mill Creek were both in non-attainment.

Nitrate concentrations are of particular importance in this part of Mill Creek because, in addition to designated aquatic life uses, additional water quality requirements apply to a public drinking water supply (PDWS). The geometric mean for NO_3+NO_2 during the summer assessment period (middle of June through the middle of October) was elevated above target values for WWH aquatic life use, at 1.70 mg/l, and the maximum concentration was 6.46 mg/l. These concentrations remain below the drinking water threshold of 10 mg/l during this timeframe. For the protection of human health, the PDWS is assessed separately using a larger dataset, and additional chemical criteria, over a period of up to two full calendar years. These results are presented separately in Table 18.

At the next site assessed, Main Street (RM 19.0) in Marysville, Mill Creek enters the western edge of the most heavily developed, urbanized portion of the watershed. The nitrate geometric mean was above the target, at 1.60 mg/l and one violation of the D.O.-minimum WQS criterion was recorded, at 3.81 mg/l.

During routine sampling, Ohio EPA field staff observed a drainage tile contributing a small discharge, <0.5 cfs and having visual characteristics of untreated wastewater, flowing into Mill Creek from its north bank just downstream from the Main Street bridge and downstream from the chemistry sampling location at this site. This discharge was sampled in July 2012, and it was exceptionally high in chlorides and sulfates and had concentrations of nutrients, total dissolved solids, conductivity and *E. coli* bacteria that were elevated above background levels. The city of Marysville was notified and subsequently plugged the discharge, preventing it from entering Mill Creek.

This single instance, given the small volume of drainage relative to the Mill Creek flow, was not likely to have caused significant impact to Mill Creek beyond the immediate area where it entered the waterway. Nutrient and total dissolved solids concentrations did not appear to change significantly between upstream and downstream sampling locations. But a few small unpermitted discharges such as this collectively could create a water pollution impact that occurs in residential or urbanized areas where collection systems or home sewage treatment systems experience a failure, discharge into a stormwater conveyance, or are routed directly to a stream. These types of point source discharges of untreated or inadequately treated wastewater, enriched with nutrients and dissolved solids, are detrimental to stream water quality--especially during the dry conditions typical during summer and early fall. Under these conditions streams have relatively low assimilative capacity because upstream diluting flows are at their annual low flow.

Town Run, a tributary to Mill Creek with a mostly urbanized drainage area of about 1.5 mi^2, enters Mill Creek at RM 18.9. Town Run was sampled at two locations a half mile apart: an upstream site at RM 0.75 and another site near the mouth at RM 0.21. The total phosphorous geometric mean concentration at 5th Street (RM 0.5) was elevated, at 0.252 mg/l. Dissolved oxygen concentrations were consistently problematic in Town Run. Diel D.O. concentration ranged (daily maximum minus daily minimum) as high as 18 mg/l, a strong indication of eutrophic conditions, were documented during the July Datasonde® deployment. Several measurements were well below the WWH minimum WQS criterion of 4 mg/l (0.04, 2.12, 3.71 mg/l). A 24-hour average concentration, 4.03 mg/l, fell below the chronic D.O. criterion of 5 mg/l.

High concentrations of *E. coli* bacteria were documented at both sampling locations in Town Run, near the mouth at 5th Street and upstream at Eljer Park (727 and 461 cfu/100 ml geometric mean *E. coli*,

respectively). Town Run had originally been designated a SCR waterbody, with an associated WQS criterion of 1030 cfu/100 ml *E. coli*. However, remediation of the former Eljer Plumbingware industrial site in the headwaters of Town Run involved creating a public park which now abuts the stream. Because of increased public access with corresponding observations of children playing in the stream, it is evident that the less-protective SCR designation is no longer appropriate for Town Run. It is recommended that Town Run be redesignated as Primary Contact Recreation Class B, having a WQS criterion of 161 cfu/100 ml.

At the time of this report's preparation, a stream restoration project was underway on Town Run funded by the Clean Ohio Fund, Ohio EPA and local matching funds. This effort is focused on the lower segment of Town Run between the intersections of 4th and 5th Streets in Marysville. Ongoing stream habitat improvements have the potential to improve Town Run's low D.O. conditions in the lower reach, lessening the excessive algae growth-respiration-decomposition cycle that degrades water quality. Any subsequent efforts to improve water quality in the upper reach of Town Run would have the potential to amplify the effect that this restoration will have on the overall quality of Town Run and Mill Creek in this central, visible part of 'Uptown Marysville'.

Continuing downstream on Mill Creek, the mainstem was sampled in the vicinity of the Cherry Street bridge in Marysville, just downstream from the former Marysville wastewater treatment plant's treated effluent discharge to Mill Creek. The city of Marysville completed construction of the new Water Reclamation Facility in 2009 (formerly known as the WWTP) and the discharge point of this facility is now located approximately 9 miles downstream at RM 9.25. Nitrate-nitrite (0.80 mg/l) and TP (0.096 mg/l) concentrations were slightly below WWH target concentrations at this site. Dissolved oxygen concentrations were in a normal range for a WWH stream.

Mill Creek flows northeast away from Marysville, traced by Waldo Road, where it was accessed for sampling near RM 16.8. Total phosphorus concentrations were at the WWH target level (0.10 mg/l geometric mean) and NO_3+NO_2 exceeded the target threshold with a 1.3 mg/l geometric mean. This site had full aquatic life use attainment. However, relative to other Mill Creek mainstem sampling locations, ammonia concentrations at this site were slightly elevated (geometric mean 0.08 mg/l and two measurements at approximately 0.1 mg/l each). The exact source of the ammonia was unclear.

Lower Mill Creek HUC-12 (050600010604)

Further downstream and east from Marysville, Mill Creek turns southward and was sampled at RM 14.5 where it is crossed by US Route 36. Nutrient concentrations were measured exactly at WWH target levels, with a NO_3+NO_2 geometric mean of 1.0 mg-l and a TP geometric mean of 0.10 mg/l. No ammonia was detected in the stream samples here, and D.O. concentrations were in a normal range.

At the western end of Hinton-Mill Road. near Marysville, 2.3 river miles downstream, Mill Creek was sampled again (RM12.17) and found to be in full WWH attainment. One instance of low dissolved oxygen, 3.63 mg/l, was observed. Nitrate+nitrite concentrations were generally consistent with upstream sites (1.04 mg/l NO_3+NO_2 geometric mean). A geometric mean TP concentration of 0.15 mg/l was higher than the WWH threshold value. Problematic levels of *E. coli* were measured during one visit, with the highest single sample measurement of *E. coli* in Mill Creek, 9300 cfu/100ml on 7/26/12. Runoff from rainfall earlier in the week likely contributed to this issue. Four other sampling events also measured *E. coli* in excess of

the PCR Class B standard, but the range of the other samples was an order of magnitude lower (310 – 510 cfu/100 ml, geometric mean of 680 cfu/100 ml).

Crosses Run is a tributary to Mill Creek at Mill Creek RM 11.83. The Crosses Run subwatershed included three chemistry sampling locations: one site near the mouth of Crosses Run at Watkins Road (RM 0.80), a site near the mouth of North Branch Crosses Run and an upstream site on Crosses Run at Industrial Parkway (RM 2.0). There were no WQS criteria violations found for instream ammonia concentrations within the Crosses Run subwatershed; however, on July 25th, 2012, sampling at Crosses Run at Industrial Parkway followed rain the previous day and documented a maximum ammonia concentration of 1.94 mg/l (geometric mean 0.133 mg/l). This is the highest single sample in-stream ammonia concentration found in the Mill Creek study area during 2012 and is an order of magnitude higher than the 95th percentile of headwaters reference sites (0.184 mg/l) in the Eastern Corn Belt Plains ecoregion. Chronically recurring runoff concentrations of ammonia in this range would act as an ecological stressor, especially for sensitive biological taxa. Elevated nitrate+nitrite concentrations (geometric mean 1.87, maximum 6.5 mg/l on 7/25/12) were also documented and, in a pattern similar to ammonia, higher concentrations were associated with runoff conditions. Total phosphorous concentrations were also above target with a geometric mean of 0.220 mg/l. Two D.O. minimum violations were measured (2.64 mg/l and 3.44 mg/l).

North Branch Crosses Run at Scottslawn, near the confluence with Crosses Run, had lower concentrations of nutrients with geometric means of 0.084 mg/l total phosphorous, 0.56 mg/l nitrate+nitrite and 0.067 mg/l ammonia. Four D.O. minimum violations were observed, ranging between 3.66 and 3.75 mg/l.

Despite a high QHEI score of 75.3, Crosses Run at Watkins Road was not attaining its WWH aquatic life use designation, having a *poor* quality macroinvertebrate community and a below criterion IBI of 34. Nitrate+nitrite and ammonia geometric mean concentrations were 0.57 mg/l and 0.038 mg/l, respectively. Total phosphorus had an elevated geometric mean concentration of 0.138 mg/l. Acute and 24-hour average minimum D.O. violations were measured at this site. Following high daytime stream temperatures, hypoxic conditions (0.25 mg/l dissolved oxygen) were documented in the early morning hours of 7/5/12. During this diel period, the D.O. concentration shifted by a range of 6.53 mg/l. This is within the 6.0-7.0 mg/l diel D.O. range that is considered an indicator of nutrient enriched conditions (Miltner 2010) and corresponded to a 24-hour average concentration (4.61 mg/l) just slightly below the WQS criterion. In addition to nutrient and dissolved oxygen stressors in the water column, sediment collected from this site contained levels of the pesticides chlordane, DDD and DDT that are known to negatively affect aquatic biology. See the sediment section for a full discussion of these pollutant parameters.

Mill Creek downstream from Crosses Run (RM 11.7) had geometric mean concentrations of nitrate+nitrite (1.06 mg/l) and total phosphorous (0.140 mg/l) elevated above the WWH targets, in a range similar to Mill Creek sites upstream from Crosses Run. No problematic ammonia levels were observed. Measured D.O. conditions fell slightly below the WWH minimum WQS criterion on one occasion (3.95 mg/l). Mill Creek was sampled next at RM 9.2, immediately downstream from the Marysville Water Reclamation Facility (WRF) outfall. At this sampling location Marysville's WRF treated effluent contributes a significant proportion of the total stream flow in Mill Creek, particularly in the dry summer and fall months.

Ammonia concentrations would not be expected to increase downstream from a well-functioning wastewater treatment plant, and concentrations measured here were in fact similar to background conditions in Mill Creek (0.02 mg/l geometric mean). Concentrations of NO_3+NO_2 and TP increased dramatically at this location (Figure 13 and Figure 14). The NO_3+NO_2 geometric mean of 7.54 mg/l (23.6 mg/l maximum) approached a chronic nitrate toxicity threshold that Camargo, *et. al.* (2005) recommend as a protective threshold concentration for the most sensitive freshwater invertebrate taxa (8.9 mg/l as NO_3). The geometric mean concentration of 0.387 mg/l TP (0.624 mg/l maximum) is several times greater than the target (Figure 13). Each of these nutrient geometric mean concentrations is greater than the 95th percentile concentration found in ECBP ecoregion reference sites, indicating that this portion of Mill Creek is heavily enriched with inorganic nutrients. Dissolved oxygen concentrations however remained in a normal range for WWH streams.

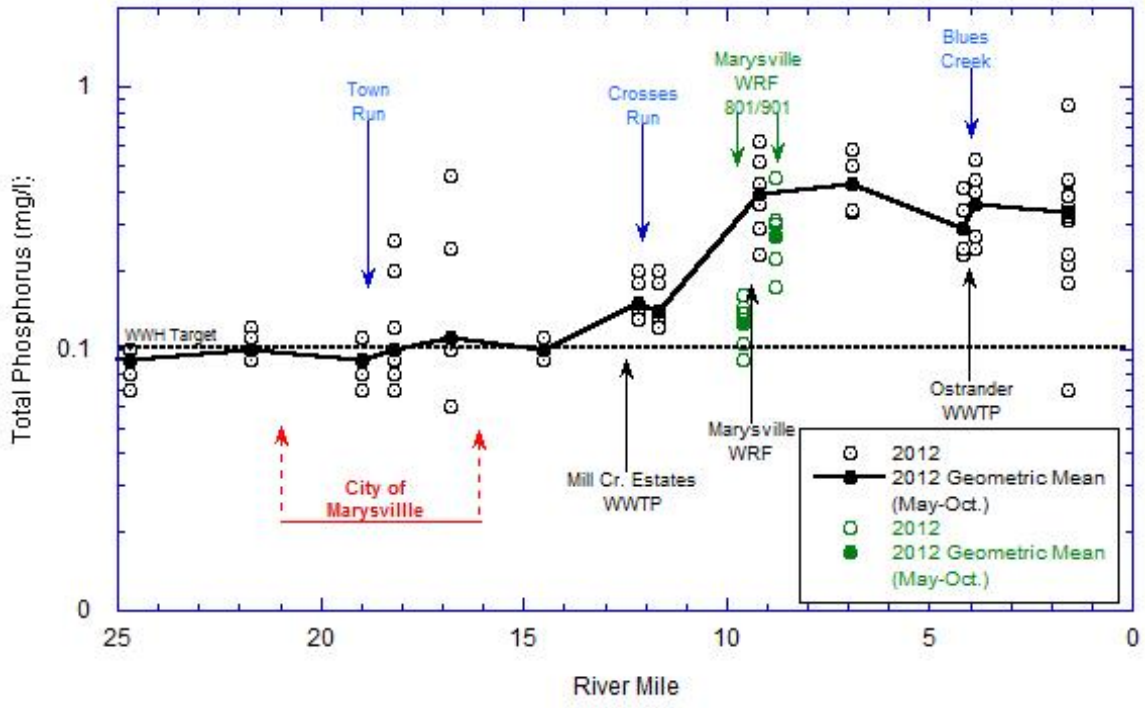


Figure 13. Total phosphorus concentrations (mg/l) for the lower 25 miles of Mill Creek mainstem listed by sampling location, 2012.

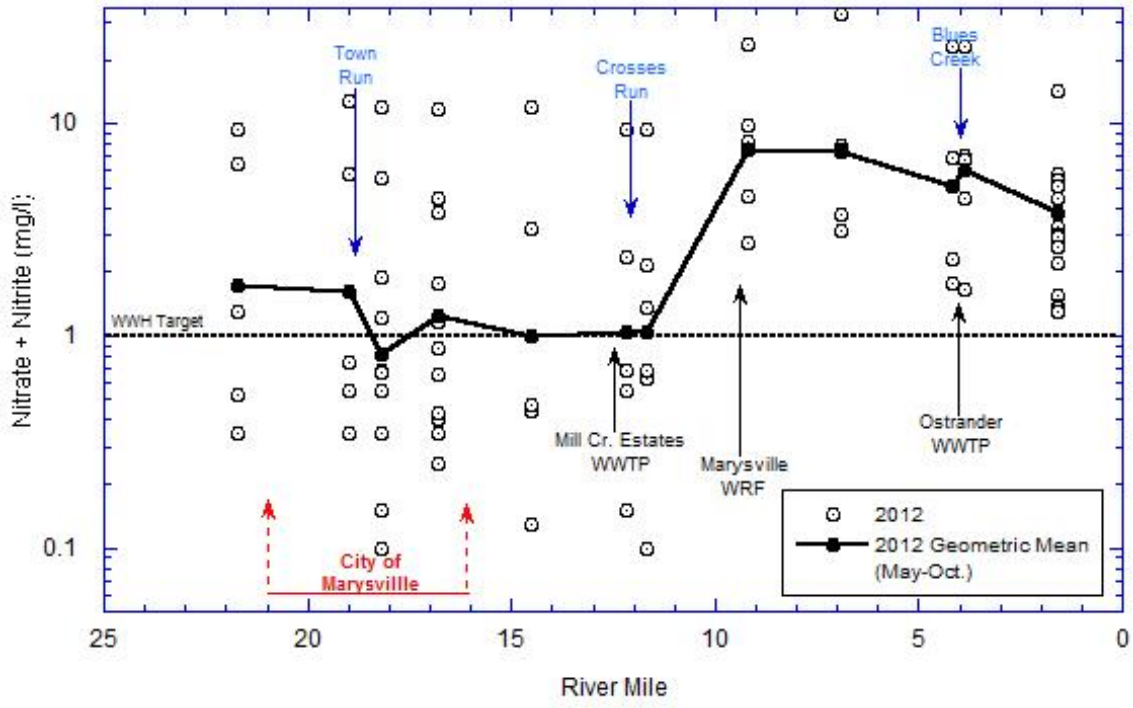


Figure 14. Nitrate + nitrite concentrations (mg/l) for the lower 25 miles of Mill Creek mainstem listed by sampling location, 2012.

Concentrations of total dissolved solids also increase significantly at this location, with a geometric mean of 745 mg/l versus the twelve upstream Mill Creek sites with TDS geometric means ranging from 356 to 449 mg/l.

Follow-up sampling was carried out in the summer of 2013 in a focused portion of Mill Creek, starting just upstream from the Marysville WRF outfall and extending several miles downstream, to better examine the biological stressors in this reach.

As was the case in 2012, no dissolved oxygen WQS violations were observed during the 2013 sampling. Concentrations of stressor pollutants such as nutrients and TDS, while higher than target concentrations in the case of nutrients, were relatively lower in 2013 than in 2012 (Table 8). This is likely owing to higher average summer flows from the upstream reaches of Mill Creek above the WRF. Nitrate+nitrite and total phosphorus remained elevated well above target concentrations at all Mill Creek mainstem sites downstream from the Marysville WRF. In August and September 2013, benthic algae chlorophyll-a concentrations were measured upstream and at three sites within 5 miles downstream of the Marysville WRF (Table 9 and Figure 15).

Table 8. Geometric mean concentration of selected nutrients and TDS at selected sampling locations in the Mill Creek watershed, 2013.

Location Description	#	RM	NO_3+NO_2	TP	Total NH_4 (max)	TDS
Mill Creek upstream BMY Tributary	4	9.30	0.18	**0.149**	0.054 (0.111)	465
BMY Tributary	4	0.01	0.18	0.036	0.031 (0.057)	1053
Mill Creek downstream Marysville WRF	4	9.20	**5.83**	**0.285**	0.038 (0.066)	625
Mill Creek at Hinton-Mill Rd. (East)	5	6.89	**7.11**	**0.292**	0.043 (0.136)	694
Mill Creek upst. Blues Creek	4	4.21	**6.30**	**0.219**	0.048 (0.114)	647

[1]Geometric means in excess of Associations Document targets listed in bold. NH_4 max listed in parenthesis.

Table 9. Benthic and chlorophyll-a concentrations at selected sampling locations in Mill Creek, 2013.

Location Description	RM	Benthic chl-a, µg/l (8/2013)	Benthic chl-a, µg/l (9/2013)
Mill Creek upstream BMY Tributary	9.30	93	100
Mill Creek downstream Marysville WRF	9.20	150	**343**
Mill Creek at Hinton-Mill Rd. (East)	6.89	173	**251**
Mill Creek upst. Blues Creek	4.21	**185**	**224**

Geometric means in excess of recommended management targets listed in bold.

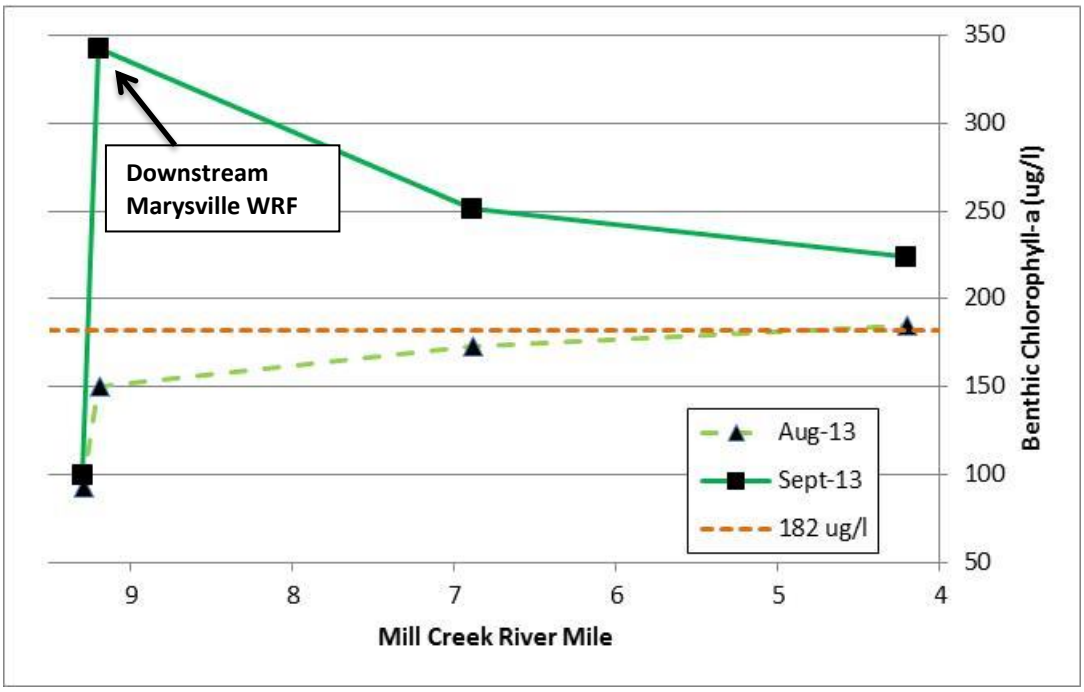


Figure 15. Benthic chlorophyll-a concentrations in Mill Creek longitudinally plotted against the 182 ug\l management target, 2013.

Under the exceptionally low flow conditions of 2012 the stream biota was adversely impacted, likely through a combination of elevated nutrient and TDS concentrations. Biological communities in Mill Creek had recovered to full WWH attainment levels downstream of the Marysville WRF by the time sampling was carried out during the subsequent year. Ohio EPA monitoring during the summers of 2012 and 2013 has demonstrated that several triggers of nutrient eutrophication currently exist in this portion of Mill Creek, including the high concentrations of inorganic nutrients and elevated biomass of benthic algae downstream from the Marysville WRF. Low in-stream dissolved oxygen concentration is considered to be the primary mechanism through which nutrient enrichment coupled with high algal biomass work to adversely impact aquatic biology in Ohio's wadeable streams (Miltner 2010).

Benthic algal biomass (measured as chlorphyll-a, abbreviated *chl.-a*, per unit area of streambed) is directly correlated to nutrient enrichment conditions, and a management threshold value of 182 mg chl.-a/m^2 has been suggested as a maximum value for the protection of aquatic life in wadeable streams. Management actions such as limiting in-stream nutrient concentrations and preserving an intact riparian zone can reduce benthic algae overabundance and thereby avoid D.O. concentrations which fall below 4.0 mg/l (Miltner 2010).

August benthic chlorophyll-a concentrations increased from 93 µg chl-a/m^2 upstream from the WRF to 150 µg/m^2 just downstream from the WRF at RM 9.2. Concentrations of benthic chlorophyll-a continued to increase at subsequent downstream sampling locations, to a maximum concentration of 185 mg chl-a /m^2 at RM 4.21, just above the suggested management target of 182 mg chl-a /m^2. September concentrations of benthic chlorophyll-a downstream from the Marysville WRF were much greater. Concentrations increased from 100 mg chl-a /m^2 upstream from the WRF, to 343 mg chl-a /m^2 just downstream from the

outfall. Both sites further downstream had benthic chlorophyll-a in excess of the suggested target [251 mg chl-a /m^2 (RM 6.89) and 224 mg chl-a /m^2 (RM 4.21)].

Despite the high nutrient concentrations and elevated algal biomass confirmed by high benthic chlorophyll-a concentrations discussed above, dissolved oxygen WQS criteria violations were not documented immediately downstream from the WRF. Water chemistry sampling was made both with instantaneous hand-held field meters during daytime sampling and using continuous data loggers deployed in Mill Creek for 48-hour stretches in 2012 and 2013. Future studies should carefully monitor this reach of Mill Creek to ensure the long term health of the fish and macroinvertebrate communities downstream from the Marysville WRF. In order to maintain nutrient assimilative capacity, it is critical that the largely intact riparian zone and overall stream habitat quality within this reach of Mill Creek are preserved. Any further efforts made by the city of Marysville WRF to reduce inorganic nutrient loading to Mill Creek would also help ensure WWH aquatic life use attainment is maintained in lower Mill Creek.

Without any large tributary input between the Hinton Mill Road site and the upstream site at RM 9.2, nutrient concentrations remained above target thresholds and TDS remained elevated (geometric mean 7.43 mg/l NO_3+NO_2; geometric mean 0.427 mg/l TP; geometric mean 790 mg/l TDS). Only one instance of low D.O. was recorded, (3.92 mg/l) just slightly below the 4.0 mg/l minimum WQS criterion for the WWH use. At Hinton Mill Road (RM 6.89) the geometric mean *E. coli* bacteria concentration (131 cfu/100 ml) met the PCR Class-B WQS criterion. This site and the site near the mouth at RM 1.57 were the only two sites to meet the *E. coli* PCR Class B criterion, out of the eight on Mill Creek that were sampled.

Mill Creek was sampled at RM 4.21 upstream from the confluence with Blues Creek (just upstream from the Village of Ostrander WWTP outfall to Mill Creek), and also downstream from Blues Creek (just south of Ostrander, RM 3.90) and downstream from the Ostrander WWTP outfall, located at RM 3.95. This particular segment of Mill Creek had exceptionally high quality stream habitat (QHEI scores >85). IBI and ICI scores at RMs 4.21 and 3.90 were among the highest found in Mill Creek. Nutrient concentrations remained elevated throughout this reach and increased slightly at Mill Creek RM 3.90. Nitrate+nitrite and TP geometric mean concentrations at RM 4.21 were 5.05 mg/l and 0.294 mg/l, respectively, and at RM 3.90 geometric means were 6.03 mg/l and 0.360 mg/l, respectively. Normal dissolved oxygen concentrations and high quality fish and macroinvertebrate communities in this reach are evidence that high nutrient concentrations do not appear to be locally problematic. The high quality habitat features and a relatively high stream gradient in this segment of Mill Creek appeared to serve as a buffer against the potential for eutrophic nutrient spiraling.

The most downstream sampling point on Mill Creek (RM 1.57) was located at Mills Road near the USGS gaging station upstream from Bellpoint. The WWH aquatic life use designation was fully met and the habitat scored a QHEI of 87. One WQS violation was noted, with a dissolved oxygen concentration of 3.83 mg/l. In June 2012, the diel D.O. ranges were 7.11 to 7.43 mg/l, greater than the 7.0 mg/l indicator of nutrient enrichment. Total phosphorous and nitrate+nitrite geometric means remained elevated at 0.346 mg/l and 3.99 mg/l, respectively. Several WQS criterion exceedances of the Agricultural Water Supply use for iron were documented, ranging from 5520 to 16200 µg/l.

Blues Creek HUC-12 (050600010603)

Blues Creek is a tributary to Mill Creek, joining Mill Creek just south of the Village of Ostrander at Mill Creek RM 3.98. The headwaters sampling location on Blues Creek, RM 16.3 at Taylor-Claiborne Road, is designated MWH and had a QHEI score of 41. The IBI score of 30 and *fair* macroinvertebrate community narrative evaluation met MWH criteria and confirmed full aquatic life use attainment. Downstream sampling locations at Leeper-Perkins (RM 10.15) and north of Ostrander at Ostrander Road (RM 2.0) were not attaining their designated WWH designations. Total phosphorus at Leeper-Perkins was elevated above the 0.08 mg/l target for headwaters streams, at 0.136 mg/l. No other nutrient targets or WQS violations were observed upstream from Ostrander; dissolved oxygen levels were in a satisfactory range throughout Blues Creek. Siltation and sedimentation arising from nearby agricultural land use appeared to be the limiting factor for fish and macroinvertebrate communities in Blues Creek.

At RM 0.6, downstream from the Village of Ostrander at Ostrander Road, Blues Creek was found to be in partial attainment due to a moderate improvement in the IBI score. Two instances of elevated iron concentration in reference to the WQS criterion for the Agricultural Use was measured here, (9640 and 14900 mg/l). Nitrate+nitrite and TP geometric mean concentrations were below nutrient targets at this location (0.45 and 0.076 mg/l, respectively).

Water Quality Modeling

Multi-parameter Datasondes® are deployed within each study area to collect physical parameter data. The Datasondes® have four electrical sensors to record water column dissolved oxygen, pH, electrical conductivity, and temperature. All parameters, excluding electrical conductivity, are exposed to daily (diel) mechanisms that result in general trends in the parameter. Temperature shows strong diel fluctuations that reflect air temperature and solar radiation on the global scale, with local factors such as base flow (groundwater), stream flow, and shading. In general, diel fluctuations in temperature increase as base flow, stream flow, and shading decrease. The inverse is also true.

Dissolved oxygen responds in a similar diel pattern to temperature, as they are affected strongest by similar factors. However, dissolved oxygen trends are directly dependent on temperature, with high temperatures decreasing the solubility of oxygen in water and increasing the reactions driving diel fluctuations. The inverse relationship, without the influence of other environmental conditions, would cause the two parameters to naturally follow opposite trends. The dissolved oxygen response to photosynthesis is strong enough in most instances to overwhelm this inverse relationship causing the trends to follow similar trajectories. The photosynthetic effect on dissolved oxygen is particularly useful for describing the trophic condition of a stream. Increased diel fluctuation relates to an increase in productivity as equilibrium dissolved oxygen concentrations are pushed to super saturation by photosynthesis and depleted by respiration. The result is a diel trend that typically reaches a maximum concentration of dissolved oxygen in the early evening and a minimum near sunrise. Diel trends in pH are reflective of this productivity because carbon dioxide, which dissolves in water to form carbonic acid, is consumed during photosynthesis, thus raising the pH of the stream.

Water Quality Standards

The data collected with the Datasonde® is evaluated with the values established in the WQS for each parameter. All Datasonde® sites within the Mill Creek basin are designated WWH, and therefore the WWH Aquatic Life Use (ALU) standards are used to evaluate the data (OAC 3745-1-07, Tables 1 & 2).

Table 10. Water quality standards for dissolved oxygen, pH and dissolved solids applicable to the Mill Creek (OAC 3745-1-07).

Chemical (ALU)	Units	OMZM[1]	OMZA[1]
Dissolved Oxygen (WWH)	mg/l	4.0	5.0
pH (WWH, MWH)	s.u.	--	6.5-9.0
Dissolved Solids	mg/l	--	1500[2]

[1] *OMZM = outside mixing zone minimum; OMZA = outside mixing zone average.*

[2] *Equivalent 25°C specific conductance value is 2400 micromhos/cm.*

Table 11. Relevant water temperature criteria (OAC 3745-1-07, Table 7-14).

	Units	June 16-30	July 1-31	Aug. 1-31	Sept. 1-15	Sept. 16-30
Average:	^{O}F	82	82	82	82	73
	^{O}C	27.8	27.8	27.8	27.8	22.8
Daily Maximum:	^{O}F	85	85	85	85	78
	^{O}C	29.4	29.4	29.4	29.4	25.6

Sixteen locations were sampled (Figure 16) within the watershed to provide a representative sample of the watershed and also target areas of concern (i.e. point sources or historically impaired areas). Historical survey results indicated certain areas of interest that received denser coverage than are done in a typical survey. These areas were generally linked with Mill Creek (the historic Marysville WWTP), Town Run (historically negatively influenced by the Eijer Plumbing Landfill and illicit discharges), Crosses Run (influenced by The Scott's Company properties) and the confluence with Blues Creek which is the largest tributary to Mill Creek (historically downstream Ostrander WWTP which now discharges directly to Mill Creek). Also, the city of Marysville relocated its WWTP (now referred to as the 'Water Reclamation Facility' - WRF) to a new site nearly seven river miles downstream. Datasondes® were placed in areas to capture the effect of the placement of the new WRF. Based on uncertain causes of biological impairment around the Marysville WRF (4PE00002) a second year of sampling was planned that closely bracketed the plant to explore the impact the WRF is having on the stream locally. The second year included two new locations and revisited three locations from 2012 (Figure 16).

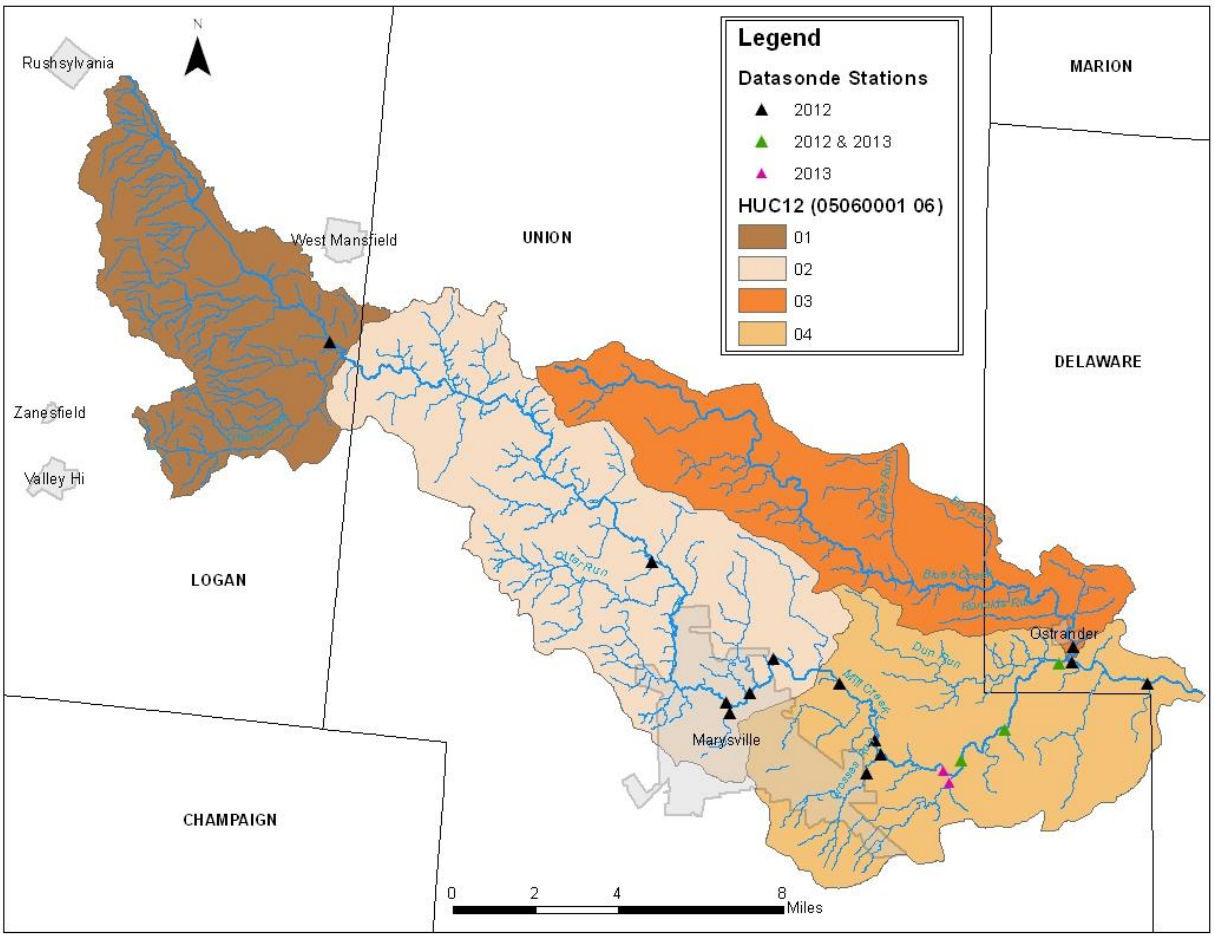


Figure 16. Map of deployment locations for Datasondes® in the Mill Creek watershed in the 2012 & 2013 survey.

Critical conditions for the parameters monitored with Datasondes® are times when flows are low and temperatures are high, and daylight is long. As a result Datasondes® are typically deployed in low flow conditions from June to September representing the time that streams are most sensitive to enrichment by organic matter and nutrients. In 2012 Datasondes® were deployed June 12-14 and July 5-7 (Figure 17). The second deployment benefitted from higher temperatures than the first, resulting in data best representing the previously defined critical condition. The second year deployments occurred from August 27-29 and September 10-12 in the summer of 2013 (Figure 18). The year of 2013 was generally wetter (resulting in higher flows) than an average summer and capturing an effective critical condition was more difficult. However, the second deployment of 2013 benefitted from being preceded by dry weather and late season hot weather.

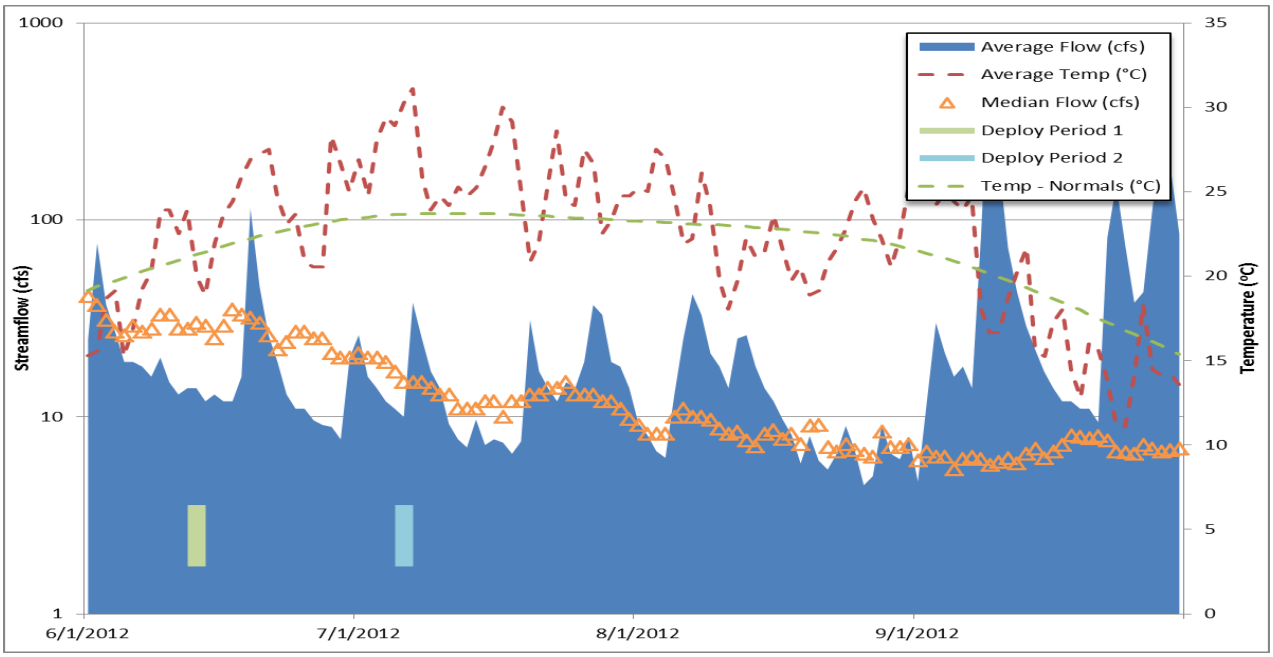


Figure 17. Graph of average daily streamflow relative to the historical (1943-2012) daily median streamflow (USGS 03220000 Mill Creek near Bellepoint OH) including the average daily air temperature (NOAA -GHCND:USC00334979) for the first Datasonde® survey.

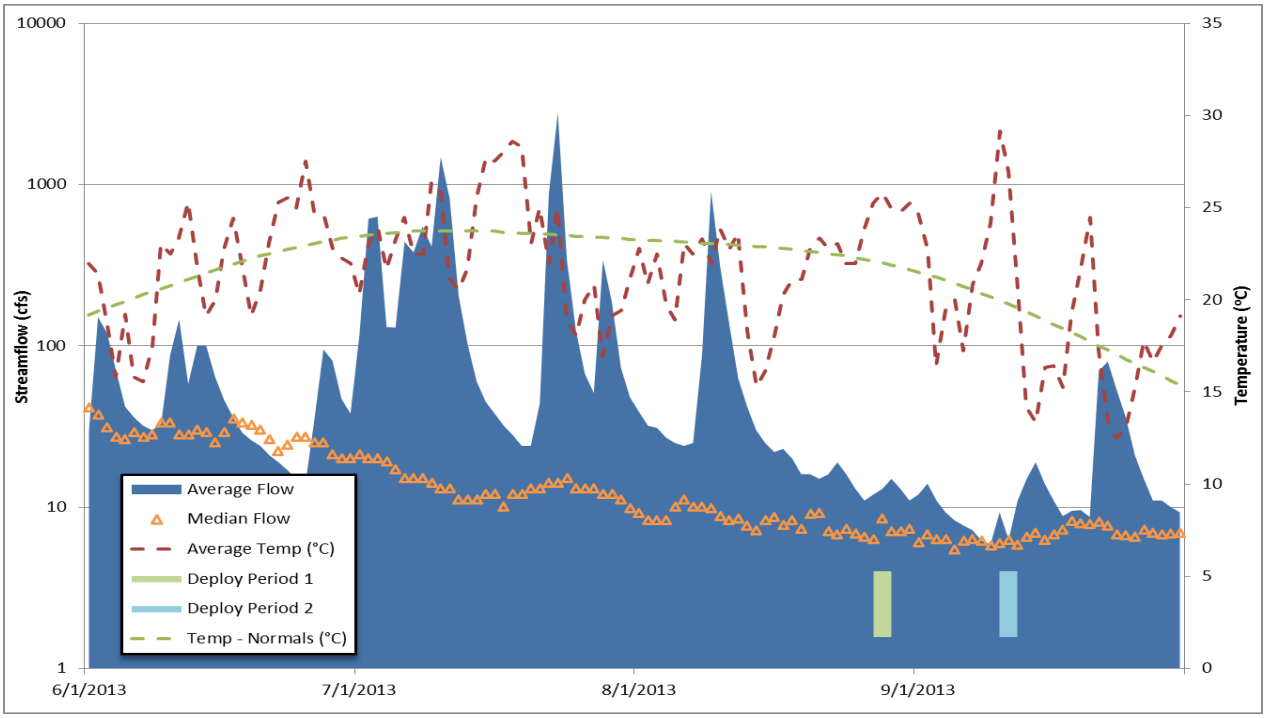


Figure 18. Graph of average daily streamflow relative to the historical (1943-2012) daily median streamflow (USGS 03220000 Mill Creek near Bellepoint OH) including the average daily air temperature (NOAA -GHCND:USC00334979) for the second Datasonde® survey.

Longitudinal plots help visualize measurements of stream water quality as it changes at sampling points along the stream channel (Figure 19 and Figure 20). A longitudinal box-and-whisker plot of dissolved oxygen data from the July 2012 Datasonde® deployment was developed using 24 hours of data (Figure 19). Box-and-whisker plots represent the maximum value as the top of the upper whisker, the 75th percentile value as the top of the upper box, the median as the intersection of the two boxes, the 25th percentile value as the bottom of the lower box, and the minimum as the end of the lower whisker; the average value is represented by a diamond. The "best" 24-hour diel cycle for dissolved oxygen data was chosen for the longitudinal box-and-whisker plot. The "best" 24-hour period from the survey represents the condition nearest the targeted dry/hot weather and low flow critical condition. This occurred from the evening of the first day to the morning of the second day (July 3-4).

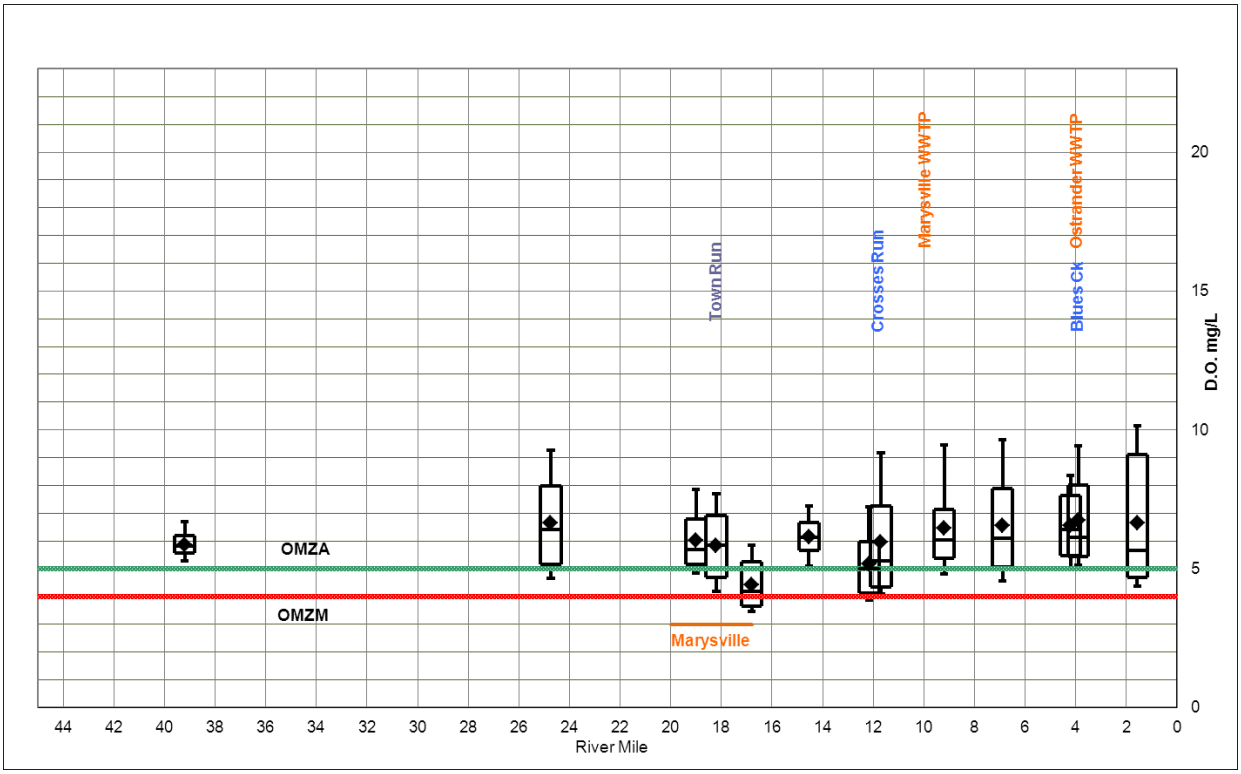


Figure 19. Longitudinal profile for dissolved oxygen on the mainstem of Mill Creek from July 2012 Datasonde® survey. The data represented in the box plots is the same as the data summary in Table 4, range B (July 4-5 from 04:00-03:00, 24hrs).

Three tributaries were also monitored with Datasonde® deployment: Town Run, Crosses Run and Blues Creek. In the first two cases the tributaries were significantly impacted by industrial sources (Town Run – Eijer Plumbing Landfill and Crosses Run – The Scott's Co.) in the prior survey and monitoring was done to document the improvements from significant mitigation at both properties. The third, Blues Creek, is the largest tributary to Mill Creek and its landscape is dominated by agricultural production. Separate box and whisker plots are presented for these tributaries (Figure 20).

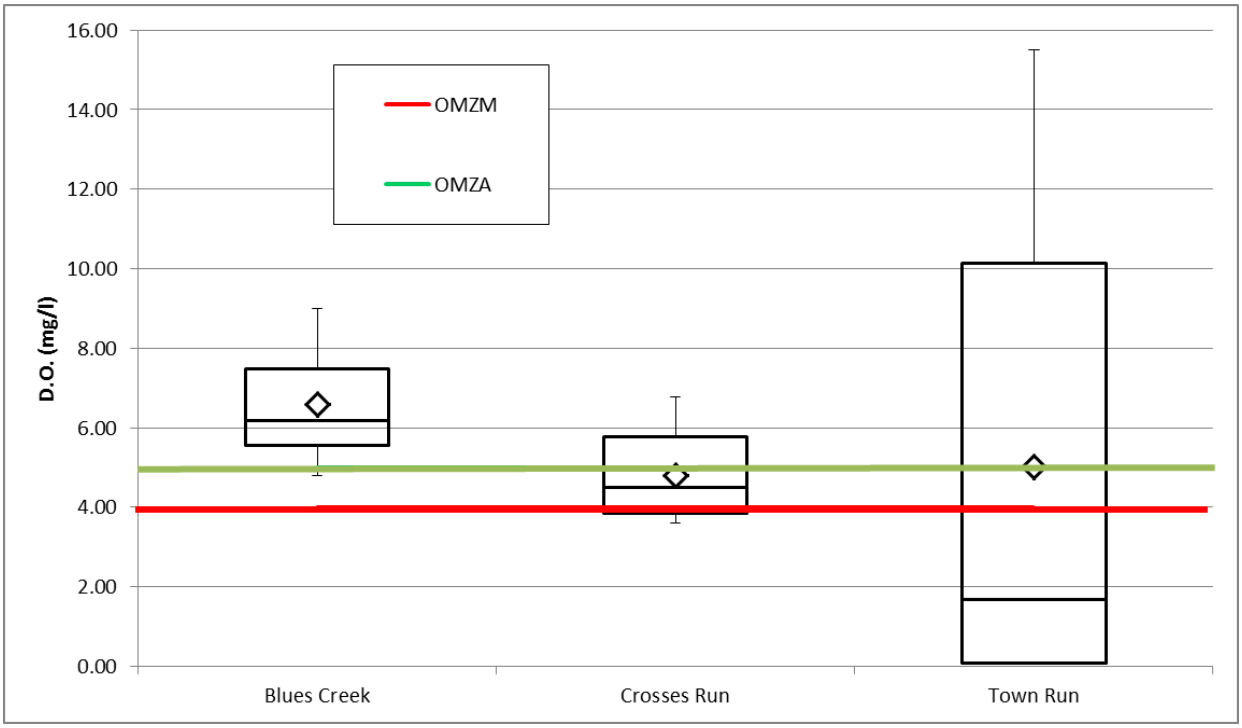


Figure 20. Dissolved oxygen representing 24 hour dissolved oxygen values for Blues Creek, Crosses Run and Town Run in the Mill Creek watershed. The Blues Creek and Town Run plots are the same time frame as Figure 4 (July 4-5 from 04:00-03:00, 24hrs). The Crosses Run plot is from July 5 from 00:00-23:00, 24hrs.

The additional data that was collected is summarized in the following tables (Table 12 - Table 15). Each table includes a summary of pH, conductivity, dissolved oxygen, and temperature data collected by the Datasondes®. Data is summarized by identifying the minimum, average, maximum, and range captured during a 24-hour period. The typical Datasonde® deployment captures three 24-hour time frames that include the needed critical values to perform these calculations. Generally during a deployment the following critical values are recorded: local maximum on day one, a local minimum and maximum on day two, and a local minimum on day three. These four critical values represent three diel swings: one between the day one maximum and day two minimum, one between the day two minimum and day two maximum, and one between the day two maximum and day three minimum. These three ranges are presented as A, B, and C in the tables and capture the full scope of potential water quality violations in a 48 hour Datasonde® deployment. Values that do not meet water quality criteria are flagged (shown in bold with bold cell borders). Additionally, while not a water quality standard, 24-hour DO minimum to maximum ranges that exceed 7 mg/l are strong indications of nutrient enrichment (Miltner 2010). These are also shown in bold with bold cell borders.

Table 12. Summary of Datasonde® data from the June 2012 survey as three separate diel cycles (A, B, & C).

				Temperature (°C)				pH (SU)				Sp Conductivity (µS/cm)				Dissolved Oxygen (mg/L)			
Stream (ALU)	**River Mile**	**Storet**	**Range***	**Min**	**Ave**	**Max**	**Range**	**Min**	**Ave**	**Max**	**Range**	**Min**	**Ave**	**Max**	**Range**	**Min**	**Ave**	**Max**	**Range**
Dates sampled: June 12 - 14, 2012																			
Mill Creek	39.2	V03K07	A	19.68	21.56	23.48	3.80	7.79	7.86	7.92	0.13	726	732	738	12	5.37	6.42	8.24	2.87
(WWH)			B	19.45	20.68	22.00	2.55	7.82	7.88	7.95	0.13	726	730	733	7	5.37	6.53	8.11	2.74
			C	18.02	20.22	22.00	3.98	7.82	7.89	7.95	0.13	726	731	734	8	5.40	6.66	8.11	2.71
Mill Creek	24.74	V03P14	A	20.10	22.48	25.57	5.47	8.01	8.10	8.20	0.19	786	795	802	16	6.03	7.64	10.08	4.05
(WWH)			B	20.04	21.66	23.80	3.76	8.01	8.12	8.22	0.21	796	800	805	9	6.03	7.76	10.11	4.08
			C	18.17	21.20	23.80	5.63	8.05	8.13	8.22	0.17	796	802	808	12	6.48	7.86	10.11	3.63
Mill Creek	19	V03S07	A	22.70	**24.17**	25.71	3.01	7.86	8.00	8.15	0.29	800	807	810	10	6.51	7.45	8.70	2.19
(WWH)			B	22.70	**23.54**	24.41	1.71	8.02	8.14	8.22	0.20	802	805	808	6	6.51	7.83	9.49	2.98
			C	21.26	23.20	24.41	3.15	8.09	8.17	8.22	0.13	800	804	806	6	6.51	7.97	9.49	2.98
Mill Creek	18.2	301928	A	20.78	22.91	25.44	4.66	7.90	8.00	8.08	0.18	827	854	882	55	5.68	6.77	8.00	2.32
(WWH)			B	20.78	22.32	24.07	3.29	7.90	8.04	8.16	0.26	818	828	847	29	5.68	7.12	8.38	2.70
			C	19.65	22.02	24.07	4.42	7.91	8.06	8.16	0.25	814	822	832	18	5.76	7.28	8.38	2.62
Mill Creek	16.8	601350	A	21.50	22.91	24.51	3.01	7.73	7.80	7.89	0.16	804	826	845	41	4.08	**4.86**	6.22	2.14
(WWH)			B	21.02	22.53	24.19	3.17	7.73	7.79	7.88	0.15	804	814	827	23	4.08	**4.88**	6.36	2.28
			C	19.56	22.06	24.19	4.63	7.73	7.79	7.88	0.15	804	817	829	25	4.18	**4.97**	6.36	2.18
Mill Creek	14.54	V03P19	A	20.02	22.64	24.91	4.89	7.89	7.97	8.03	0.14	820	831	840	20	Dissolved oxygen sensor failure			
(WWH)			B	20.02	21.99	23.57	3.55	7.89	7.99	8.05	0.16	820	826	832	12				
			C	19.02	21.72	23.57	4.55	7.90	7.99	8.05	0.15	820	824	832	12				
Mill Creek	12.17	V03P20	A	20.98	23.18	26.00	5.02	7.85	7.94	8.00	0.15	905	926	960	55	5.09	6.90	9.08	3.99
(WWH)			B	20.98	22.69	24.65	3.67	7.85	7.96	8.08	0.23	885	910	960	75	5.09	7.22	9.73	4.64
			C	19.50	22.35	24.65	5.15	7.89	7.98	8.08	0.19	883	894	923	40	5.54	7.31	9.73	4.19
Mill Creek	11.7	V03W07	A	20.58	23.24	**27.09**	6.51	7.93	8.02	8.15	0.22	902	923	947	45	5.78	7.59	10.79	5.01
(WWH)			B	20.58	22.61	25.60	5.02	7.93	8.04	8.15	0.22	883	907	947	64	5.78	7.77	10.76	4.98
			C	19.09	22.27	25.60	6.51	7.96	8.05	8.15	0.19	883	896	941	58	5.92	7.81	10.76	4.84
Mill Creek	9.2	301872	A	20.20	21.45	23.52	3.32	7.77	8.27	8.62	0.85	1279	1380	1436	157	6.51	7.89	9.73	3.22
(WWH)			B	20.20	21.34	22.89	2.69	8.04	8.34	8.62	0.58	1279	1405	1504	225	6.51	7.95	10.10	3.59
			C	19.38	21.18	22.89	3.51	8.04	8.42	9.02	0.98	1144	1367	1504	360	6.38	7.93	10.10	3.72
Mill Creek	6.89	V03P23	A	20.56	23.20	26.59	6.03	7.65	7.78	7.95	0.30	1264	1301	1339	75	5.51	7.50	10.30	4.79
(WWH)			B	20.56	22.48	25.10	4.54	7.65	7.80	7.97	0.32	1249	1286	1310	61	5.51	7.74	10.70	5.19
			C	18.86	22.07	25.10	6.24	7.67	7.81	7.97	0.30	1249	1282	1310	61	5.87	7.84	10.70	4.83

				Temperature (°C)				pH (SU)				Sp Conductivity (µS/cm)				Dissolved Oxygen (mg/L)			
Stream (ALU)	**River Mile**	**Storet**	**Range***	**Min**	**Ave**	**Max**	**Range**	**Min**	**Ave**	**Max**	**Range**	**Min**	**Ave**	**Max**	**Range**	**Min**	**Ave**	**Max**	**Range**
Dates sampled: June 12 - 14, 2012																			
Mill Creek	4.21	V03W14	A	20.81	**23.40**	26.06	5.25	7.85	8.00	8.14	0.29	1219	1245	1257	38	5.56	7.41	9.43	3.87
(WWH)			B	20.81	22.72	24.62	3.81	7.85	8.02	8.18	0.33	1219	1245	1267	48	5.56	7.73	9.95	4.39
			C	19.33	22.38	24.62	5.29	7.87	8.03	8.18	0.31	1219	1247	1269	50	5.91	7.82	9.95	4.04
Mill Creek	3.9	V03W11	A	20.87	**23.78**	**27.24**	6.37	7.81	7.96	8.20	0.39	1214	1224	1232	18	5.65	7.87	11.48	5.83
(WWH)			B	20.87	23.08	25.99	5.12	7.81	7.99	8.26	0.45	1220	1230	1244	24	5.65	8.21	12.12	6.47
			C	19.31	22.67	25.99	6.68	7.81	8.01	8.26	0.45	1223	1239	1274	51	5.92	8.34	12.12	6.20
Mill Creek	1.57	601260	A	20.81	**23.68**	**27.43**	6.62	7.79	8.01	8.36	0.57	959	1020	1142	183	5.54	8.11	12.65	**7.11**
(WWH)			B	20.67	23.15	26.62	5.95	7.79	8.05	8.40	0.61	699	886	1048	349	5.54	8.40	12.97	**7.43**
			C	19.11	22.75	26.62	7.51	7.84	8.06	8.40	0.56	699	835	1027	328	5.82	8.47	12.97	**7.15**
Blues Creek	0.6	V03P25	A	19.37	21.71	24.93	5.56	7.82	7.92	8.02	0.20	991	1001	1019	28	6.01	7.92	10.23	4.22
(WWH)			B	19.37	20.81	22.85	3.48	7.82	7.93	8.05	0.23	1001	1014	1022	21	6.01	8.06	10.62	4.61
			C	17.82	20.39	22.85	5.03	7.82	7.94	8.05	0.23	1014	1017	1022	8	6.07	8.23	10.62	4.55
Crosses Run	0.8	V03W06	A	18.28	20.15	22.71	4.43	7.54	7.58	7.66	0.12	783	814	838	55	4.18	**4.94**	5.92	1.74
(WWH)			B	17.93	19.14	20.14	2.21	7.54	7.57	7.62	0.08	816	824	835	19	4.18	**4.95**	5.70	1.52
			C	16.33	18.64	20.14	3.81	7.54	7.57	7.62	0.08	816	826	835	19	4.18	5.01	5.70	1.52
Town Run	0.21	V03G02	A	16.86	18.61	22.03	5.17	7.45	7.59	7.89	0.44	1143	1167	1186	43	**2.69**	**4.34**	7.02	4.33
(WWH)			B	16.86	18.55	20.73	3.87	7.45	7.71	8.18	0.73	1171	1198	1242	71	**2.24**	**4.37**	7.18	4.94
			C	16.10	18.41	20.73	4.63	7.46	7.71	8.18	0.72	1183	1216	1251	68	**2.12**	**4.23**	7.18	5.06

***Three 24-hour cycles capture unique ranges between critical values during a 48-hour Datasonde® deployment. Range A is from 6/12/12 at 15:00 to 6/13/12 at 14:00 except for Mill Creek at RM 24.74 where the stream start and stop times are delayed by 1 hour. Range B is from 6/13/12 at 04:00 to 6/14/12 at 03:00. Range C is from 6/13/12 at 10:00 to 6/14/12 at 09:00.**

Table 13. Summary of Datasonde® data from the July 2012 survey as three separate diel cycles (A, B, & C).

				Temperature (°C)				pH (SU)				Sp Conductivity (µS/cm)				Dissolved Oxygen (mg/L)			
Stream (ALU)	**River Mile**	**Storet**	**Range***	**Min**	**Ave**	**Max**	**Range**	**Min**	**Ave**	**Max**	**Range**	**Min**	**Ave**	**Max**	**Range**	**Min**	**Ave**	**Max**	**Range**
Dates sampled: June 12 - 14, 2012																			
Mill Creek	39.2	V03K07	A	24.9	25.94	27.11	2.12	7.67	7.74	7.83	0.16	691	695	699	8	5.28	6.10	6.89	2.87
(WWH)			B	23.9	26.25	28.33	4.37	7.52	7.72	7.83	0.31	460	675	703	243	5.28	5.86	6.69	2.74
			C	21.7	25.34	28.33	6.63	7.42	7.65	7.83	0.41	328	579	703	375	5.28	6.07	6.69	2.71
Mill Creek	24.74	V03P14	A	25.4	26.92	28.50	3.06	7.98	8.12	8.27	0.29	727	735	740	13	4.66	6.95	9.98	5.32
(WWH)			B	25.4	27.37	**29.4**	3.99	7.98	8.11	8.24	0.26	728	734	740	12	4.66	6.66	9.26	4.60
			C	25.0	27.34	**29.4**	4.39	7.94	8.10	8.24	0.30	728	732	739	11	4.33	6.55	9.26	4.93
Mill Creek	19	V03S07	A	27.4	**28.19**	28.88	1.47	7.80	7.90	8.01	0.21	658	668	673	15	4.83	6.20	7.73	2.90
(WWH)			B	27.5	**28.89**	**30.4**	2.90	7.80	7.90	8.05	0.25	666	675	682	16	4.83	6.03	7.86	3.03
			C	27.6	**28.97**	**30.4**	2.82	7.73	7.89	8.05	0.32	672	678	682	10	**3.81**	5.78	7.86	4.05
Mill Creek	18.2	301928	A	26.1	27.35	28.63	2.44	7.66	7.81	7.97	0.31	667	672	683	16	4.19	5.76	7.58	3.39
(WWH)			B	26.1	**27.97**	**29.9**	3.75	7.66	7.83	8.05	0.39	673	681	687	14	4.19	5.83	7.69	3.50
			C	26.2	**28.04**	**29.9**	3.73	7.61	7.82	8.05	0.44	678	686	695	17	4.05	5.83	7.69	3.64
Mill Creek	16.8	601350	A	25.8	26.99	28.18	2.36	7.41	7.48	7.59	0.18	617	631	647	30	**3.47**	**4.40**	6.03	2.56
(WWH)			B	25.8	27.40	29.08	3.26	7.41	7.50	7.61	0.20	634	655	681	47	**3.47**	**4.43**	5.84	2.37
			C	25.5	27.39	29.08	3.54	7.43	7.51	7.61	0.18	644	670	693	49	**3.51**	**4.44**	5.84	2.33
Mill Creek	14.54	V03P19	A	25.8	27.23	28.86	3.06	7.62	7.72	7.80	0.18	608	613	616	8	5.10	6.49	7.32	2.22
(WWH)			B	25.8	**27.82**	29.28	3.48	7.62	7.71	7.86	0.24	610	613	615	5	5.10	6.15	7.26	2.16
			C	25.6	**27.85**	29.28	3.68	7.58	7.70	7.86	0.28	610	613	615	5	4.91	6.08	7.26	2.35
Mill Creek	12.17	V03P20	A	25.9	27.43	28.86	2.91	7.41	7.52	7.66	0.25	554	596	626	72	**3.67**	5.30	7.27	3.60
(WWH)			B	25.9	**27.97**	**30.1**	4.24	7.41	7.53	7.66	0.25	615	635	675	60	**3.67**	5.17	7.22	3.55
			C	25.8	**28.02**	**30.1**	4.36	7.45	7.54	7.66	0.21	619	655	704	85	**3.48**	5.16	7.22	3.74
Mill Creek	11.7	V03W07	A	25.6	27.60	**29.9**	4.25	7.46	7.65	7.96	0.50	551	584	623	72	4.09	6.11	9.34	5.25
(WWH)			B	25.6	**28.20**	**31.3**	5.68	7.46	7.64	7.95	0.49	593	618	642	49	4.09	5.95	9.16	5.07
			C	25.4	**28.20**	**31.3**	5.93	7.47	7.64	7.95	0.48	612	634	675	63	**3.95**	5.84	9.16	5.21
Mill Creek	9.2	301872	A	24.4	25.02	25.78	1.37	7.38	7.44	7.54	0.16	1017	1156	1298	281	4.80	6.59	9.37	4.57
(WWH)			B	24.4	25.30	26.35	1.94	7.38	7.46	7.61	0.23	1010	1196	1380	370	4.80	6.47	9.46	4.66
			C	24.3	25.30	26.35	2.00	7.41	7.48	7.61	0.20	1010	1216	1380	370	4.86	6.46	9.46	4.60
Mill Creek	6.89	V03P23	A	25.4	27.16	28.84	3.42	7.68	7.88	8.13	0.45	751	961	1046	295	4.55	6.83	10.08	5.53
(WWH)			B	25.4	**27.81**	**30.2**	4.84	7.68	7.87	8.10	0.42	751	1001	1046	295	4.55	6.54	9.66	5.11

				Temperature (°C)				pH (SU)				Sp Conductivity (µS/cm)				Dissolved Oxygen (mg/L)			
Stream (ALU)	**River Mile**	**Storet**	**Range***	**Min**	**Ave**	**Max**	**Range**	**Min**	**Ave**	**Max**	**Range**	**Min**	**Ave**	**Max**	**Range**	**Min**	**Ave**	**Max**	**Range**
Dates sampled: June 12 - 14, 2012																			
			C	25.4	**27.92**	**30.2**	4.81	7.69	7.87	8.10	0.41	924	1015	1063	139	**3.92**	6.39	9.66	5.74
Mill Creek	4.21	V03W14	A	25.9	27.64	29.04	3.07	7.44	7.67	7.92	0.48	970	990	1002	32	5.02	6.83	8.96	3.94
(WWH)			B	25.9	**28.15**	**29.9**	4.02	7.44	7.63	7.82	0.38	980	993	1003	23	5.02	6.56	8.35	3.33
			C	26.0	**28.26**	**29.9**	3.94	7.39	7.62	7.82	0.43	956	988	1003	47	4.75	6.47	8.35	3.60
Mill Creek	3.9	V03W11	A	26.2	**27.85**	**29.5**	3.28	7.59	7.77	8.00	0.41	932	975	991	59	5.12	6.95	9.33	4.21
(WWH)			B	26.2	**28.44**	**30.9**	4.73	7.59	7.75	7.98	0.39	977	994	1008	31	5.12	6.73	9.42	4.30
			C	26.2	**28.51**	**30.9**	4.75	7.56	7.75	7.98	0.42	982	999	1008	26	4.78	6.59	9.42	4.64
Mill Creek	1.57	601260	A	25.6	**27.82**	**30.0**	4.37	7.57	7.84	8.27	0.70	884	896	916	32	4.59	6.79	10.41	5.82
WWH			B	25.6	**28.49**	**31.4**	5.79	7.57	7.84	8.27	0.70	884	911	942	58	4.38	6.64	10.16	5.78
			C	25.6	**28.50**	**31.4**	5.85	7.60	7.85	8.27	0.67	891	923	942	51	**3.83**	6.43	10.16	6.33
Blues Creek	0.6	V03P25	A	24.4	25.77	27.53	3.05	7.62	7.74	7.86	0.24	816	820	827	11	4.79	6.90	9.51	4.72
(WWH)			B	24.4	26.37	29.19	4.71	7.62	7.75	7.92	0.30	821	830	842	21	4.79	6.59	9.01	4.22
			C	24.6	26.46	29.19	4.59	7.63	7.76	7.92	0.29	824	837	849	25	4.43	6.47	9.01	4.58
Crosses Run	0.8	V03W06	A	24.0	25.26	26.49	2.45	7.61	7.72	7.88	0.27	833	845	858	25	**3.60**	**4.96**	6.90	3.30
(WWH)			B	24.0	25.77	27.73	3.69	7.57	7.71	7.90	0.33	832	835	843	11	**0.25**	**4.45**	6.78	6.53
			C	23.8	25.78	27.73	3.89	7.52	7.68	7.90	0.38	832	834	835	3	**0.25**	**4.14**	6.78	6.53
Town Run	0.21	V03G02	A	22.0	25.08	**30.3**	**8.30**	7.24	7.70	8.91	1.67	996	1074	1117	121	**0.05**	5.64	18.41	18.36
(WWH)			B	22.0	26.55	**33.2**	**11.17**	7.23	7.66	8.79	1.56	1096	1120	1155	59	**0.05**	5.01	15.50	15.45
			C	22.6	26.70	**33.2**	**10.62**	7.23	7.65	8.79	1.56	1096	1136	1172	76	**0.04**	**4.93**	15.50	15.46

***Three 24-hour cycles capture unique ranges between critical values during a 48-hour Datasonde® deployment. Range A is from 7/03/12 at 14:00 to 7/04/12 at 13:00. Range B is from 7/04/12 at 04:00 to 7/05/12 at 03:00. Range C is from 7/04/12 at 11:00 to 7/04/12 at 10:00.**

Table 14. Summary of Datasonde data from the August 2013 survey as three separate diel cycles (A, B, & C).

				Temperature (°C)				pH (SU)				Sp Conductivity (µS/cm)				Dissolved Oxygen (mg/L)			
Stream (ALU)	**River Mile**	**Storet**	**Range***	**Min**	**Ave**	**Max**	**Range**	**Min**	**Ave**	**Max**	**Range**	**Min**	**Ave**	**Max**	**Range**	**Min**	**Ave**	**Max**	**Range**
Dates sampled: Aug. 27 - 29, 2013																			
Mill Creek	9.2	301872	A	23.1	23.84	24.08	0.89	7.98	8.08	8.17	0.19	753	759	768	15	5.17	6.81	8.67	3.50
(WWH)			B	23.6	24.31	24.89	1.24	7.98	8.04	8.10	0.12	758	763	773	15	5.17	6.58	8.09	2.92
			C	23.6	24.31	24.89	1.22	7.93	8.03	8.10	0.17	758	762	773	15	**4.76**	6.46	8.09	3.33
Mill Creek	6.89	V03P23	A	21.5	21.75	21.92	0.34	7.19	7.26	7.35	0.16	1675	1710	1734	59	8.25	8.38	8.49	0.24
(WWH)			B	21.6	21.89	22.14	0.47	7.15	7.25	7.35	0.20	1642	1668	1701	59	8.25	8.34	8.46	0.21
			C	21.7	21.96	22.14	0.42	7.15	7.24	7.35	0.20	1642	1669	1703	61	8.19	8.30	8.45	0.26
Mill Creek	3.9	V03W11	A	22.5	22.96	23.59	1.05	7.44	7.53	7.65	0.21	1130	1237	1290	160	6.15	7.39	9.10	2.95
(WWH)			B	22.5	23.15	23.94	1.40	7.38	7.46	7.55	0.17	1177	1267	1316	139	6.15	7.31	8.86	2.71
			C	22.4	23.11	23.94	1.46	7.37	7.45	7.55	0.18	1177	1263	1316	139	5.93	7.23	8.86	2.93

***Three 24-hour cycles capture unique ranges between critical values during a 48-hour Datasonde® deployment. Range A is from 8/27/13 at 13:00 to 8/28/13 at 12:00. Range B is from 8/28/13 at 04:00 to 8/29/13 at 03:00. Range C is from 8/28/13 at 12:00 to 8/28/13 at 11:00.**

Table 15. Summary of Datasonde data from September 2013 survey as three separate diel cycles (A, B, & C).

				Temperature (°C)				pH (SU)				Sp Conductivity (µS/cm)				Dissolved Oxygen (mg/L)			
Stream (ALU)	**River Mile**	**Storet**	**Range***	**Min**	**Ave**	**Max**	**Range**	**Min**	**Ave**	**Max**	**Range**	**Min**	**Ave**	**Max**	**Range**	**Min**	**Ave**	**Max**	**Range**
Dates sampled: Sept. 10 - 12, 2013																			
Mill Creek	9.3	203153	A	23.3	24.34	25.48	2.13	7.86	7.97	8.07	0.21	918	927	930	12	5.07	6.59	8.07	3.00
(WWH)			B	23.3	24.22	25.02	1.67	7.86	7.91	7.96	0.10	920	925	930	10	5.07	5.86	6.83	1.76
			C	22.8	24.17	25.02	2.19	7.84	7.90	7.96	0.12	872	921	930	58	4.76	5.75	6.83	2.07
Mill Creek	9.2	301872	A	22.1	22.82	23.65	1.53	7.34	7.43	7.53	0.19	1420	1503	1547	127	6.67	7.78	9.98	3.31
(WWH)			B	22.1	22.81	23.65	1.53	7.34	7.43	7.55	0.21	1412	1486	1531	119	6.56	7.44	9.37	2.81
			C	21.9	22.78	23.65	1.69	7.36	7.44	7.55	0.19	1412	1477	1531	119	6.16	7.33	9.37	3.21
Mill Creek	6.89	V03P23	A	23.5	24.68	25.97	2.38	7.68	7.84	8.04	0.36	1367	1385	1404	37	5.18	7.18	9.76	4.58
(WWH)			B	23.5	24.66	26.18	2.59	7.68	7.80	7.98	0.30	1382	1409	1427	45	5.18	6.83	9.10	3.92
			C	22.8	24.54	26.18	3.33	7.66	7.80	7.98	0.32	1322	1412	1427	105	5.05	6.82	9.10	4.05
Mill Creek	4.21	V03W14	A	23.5	24.41	25.33	1.82	7.52	7.69	7.86	0.34	1424	1446	1471	47	5.37	7.00	8.98	3.61
(WWH)			B	23.5	24.57	25.83	2.32	7.52	7.62	7.74	0.22	1406	1420	1436	30	5.37	6.64	8.21	2.84
			C	23.1	24.56	25.83	2.66	7.41	7.59	7.74	0.33	1363	1412	1427	64	5.07	6.58	8.21	3.14
BMY Trib	0.01	V03P22	A	22.6	25.52	29.54	6.90	7.64	7.78	7.93	0.29	1518	1534	1552	34	**3.28**	6.19	10.18	6.90
(WWH)			B	22.6	24.75	27.67	5.03	7.64	7.77	7.92	0.28	1481	1522	1551	70	**3.28**	5.79	9.24	5.96
			C	21.4	24.50	27.67	6.27	7.58	7.76	7.92	0.34	1389	1512	1551	162	**2.74**	5.68	9.24	6.50
Marysville	N/A	301924	A	21.6	21.93	22.11	0.46	6.76	7.01	7.15	0.39	1645	1666	1702	57	8.28	8.34	8.44	0.16
(N/A)			B	21.8	22.00	22.21	0.39	6.89	7.14	7.27	0.38	1645	1665	1690	45	8.23	8.31	8.42	0.19
			C	21.8	22.01	22.21	0.39	6.89	7.18	7.27	0.38	1649	1678	1714	65	8.17	8.28	8.42	0.25

***Three 24-hour cycles capture unique ranges between critical values during a 48-hour Datasonde® deployment. Range A is from 9/10/13 at 14:00 to 9/11/13 at 13:00. Range B is from 9/11/13 at 04:00 to 9/12/13 at 03:00. Range C is from 9/11/13 at 10:00 to 9/12/13 at 09:00.**

Data Interpretation

Temperature: Mill Creek is a generally small shallow stream and is prone to warming quickly and having significant temperature variations. Datasonde® data from the July 2012 survey showed the stream had the potential to exceed temperature criteria when nearing summer, low flow critical conditions. Nearly every site was prone to exceedences and the only sites that never had an exceedence captured were areas with the most intact riparian corridors with mature trees in place. The open channel of Town Run was the only tributary with observed exceedences. The other tributaries benefitted from intact, mature riparian zones at the Datasonde® sampling locations.

pH: No exceedences were observed within Mill Creek or any tributaries for pH. Also no trends appeared in the data leading to insight of important dynamics taking place in the stream.

Specific Conductivity: Wastewater treatment plants are often significant sources of dissolved solids to streams. Specific conductivity being a strong indicator of dissolved solids concentration is often used as a surrogate for this purpose. As expected at the point where the Marysville WRF discharged the conductivity of the creek increased. While no water quality violations were noted the specific conductivity acts as a good indicator of changes in water chemistry after the Marysville WRF discharge.

Dissolved Oxygen: Dissolved oxygen has a direct impact on aquatic life and is often the most useful tracked by Datasonde® sampling. All small tributaries (excludes Blues Creek) sampled had failed to meet minimum and average dissolved oxygen criterion for multiple 24-hour cycles. These tributaries were specifically monitored because problems were expected from historical impacts. The mainstem of Mill Creek was generally performing well with regards to dissolved oxygen. However dissolved oxygen was depressed at river mile 16.8 downstream of the city of Marysville. The local data suggested some level of organic enrichment at the site. Further downstream after the discharge of the Marysville WRF the dissolved oxygen ranges began to amplify. The ranges were indicative of high algal production. The dissolved oxygen minimum appeared to be buffered by the Marysville WRF high effluent near the plant. Further downstream from the Marysville WRF the gradient increased and the dissolved oxygen minimums were buffered by reaeration. Because of these phenomenon minimum and average criteria were achieved downstream of the Marysville WRF.

Recreation Use

Water quality criteria for determining attainment of recreation uses are established in the Ohio Water Quality Standards (Table 7-13 in OAC 3745-1-07) based upon the presence or absence of bacteria indicators (*Escherichia coli*) in the water column.

Escherichia coli (*E. coli*) bacteria are microscopic organisms that are present in large numbers in the feces and intestinal tracts of humans and other warm-blooded animals. *E. coli* typically comprises approximately 97 percent of the organisms found in the fecal coliform bacteria of human feces (Dufour, 1977). The analytical method used by this study does not differentiate between human and animal sources of coliform bacteria in surface waters. These microorganisms can enter water bodies where there is a direct discharge of human and animal wastes, or may enter water bodies along with runoff from soils where these wastes have been deposited.

Pathogenic (disease causing) organisms are typically present in the environment in such small amounts that it is impractical to monitor them directly. Fecal indicator bacteria by themselves, including *E. coli*, are usually not pathogenic. However, some strains of *E. coli* can be pathogenic, capable of causing serious illness. Although not necessarily agents of disease, fecal indicator bacteria such as *E. coli* may indicate the potential presence of pathogenic organisms that enter the environment through the same pathways. When *E. coli* are present in high numbers in a water sample, it invariably means that the water has received fecal matter from one source or another. Swimming or other recreational-based contact with water having a high fecal coliform or *E. coli* count may result in ear, nose, and throat infections, as well as stomach upsets, skin rashes, and diarrhea. Young children, the elderly, and those with depressed immune systems are most susceptible to infection.

The streams of the Mill Creek watershed evaluated in this survey are designated as a Primary Contact Recreation (PCR) use in OAC Rule 3745-1-24. Water bodies with a designated recreational use of PCR "…are waters that, during the recreation season, are suitable for one or more full-body contact recreation activities such as, but not limited to, wading, swimming, boating, water skiing, canoeing, kayaking and SCUBA diving" [OAC 3745-1-07 (B)(4)(b)]. Three classes of PCR are used to reflect differences in the potential frequency and intensity of use. Streams designated PCR Class A typically have identified public access points and support primary contact recreation. Streams designated PCR Class B support, or potentially support, occasional primary contact recreation activities. The Mill Creek mainstem and all tributaries are designated PCR Class B. The *E. coli* concentration criteria that apply to PCR Class B streams include a geometric mean of 161 colony forming units (cfu) per 100 ml, and a single sample maximum value of 523 cfu/100 ml. The geometric mean is used as the basis for determining attainment status when more than one sample is collected, as is the case in this study (Table 16).

Land use surrounding Town Run, particularly in the present-day Eljer Park area near the Walnut Street sampling location, has changed over the years to allow for greatly increased stream access and recreation use potential. This report recommends a re-designation of Town Run to PCR Class B from the prior designation of SCR. The less-protective SCR designation is no longer appropriate based on the establishment of a park adjacent to the stream as well as potential and observed summertime recreation use of Town Run.

Summarized bacteria results are listed in Table 16. Downloadable bacteria results are also available from the Ohio EPA GIS interactive maps by zooming to the watershed or site of interest at the following link: http://www.epa.ohio.gov/dsw/gis/index.aspx .

Table 16. Recreation use attainment status in the Mill Creek watershed. Attainment status is based on sampling conducted during the 2012 recreation season (May 1 through October 31). Primary Contact Recreation (PCR) class B applies to all sites. Geometric mean *E. coli* bacteria concentrations were compared to the WQS criterion (161 cfu/100 ml). An asterisk next to PCR Class in the table below indicates a recommended PCR classification.

Location	River Mile	PCR Class	n	Geo. mean	Max	Attainment	Sources
Upper Mill Creek (0506000106-01)							
Mill Cr NE of E. Liberty @ CR-142	39.20	B	7	767	2600	NON	Small scale livestock, agriculture, Unsewered area
Middle Mill Creek (050600010602)							
Mill Cr S. of Lunda @ Ben.-Newland Rd.	36.05	B	5	588	1200	NON	Small scale livestock, agriculture, Unsewered area
Mill Ck. near Peoria @ Wheeler-Green Rd.	28.13	B	5	236	440	NON	Unsewered area, small scale livestock, and agriculture
Mill Ck. UPST Marysville @ Cotton Slash Rd.	24.74	B	5	309	470	NON	Unsewered area, small scale livestock, and agriculture
Town Run at Marysville @ Walnut St.	0.75	B*	4	461	850	NON	Illicit sewage discharges
Town Run at Marysville @ 5th St. DST Culvert	0.21	B*	2	727	2200	NON	Illicit sewage discharges
Mill Ck. at Marysville @ Cherry St.	18.20	B	7	531	1600	NON	Illicit sewage discharges
Blues Creek (050600010603) Tributary to Mill Creek at RM 3.98							
Blues Ck. DST Ostrander @ Ostrander Rd.	0.60	B	7	83	270	FULL	
Lower Mill Creek (050600010604)							
Mill Ck. DST Marysville @ Hinton Mill Rd.	12.17	B	5	680	9300	NON	Unsewered area and agriculture
Mill Ck. NE of Watkins @ Hinton Mill Rd.	6.89	B	5	131	270	FULL	
Mill Creek UPST Bellpoint @ USGS Gage	1.57	B	6	62	220	FULL	

Eleven locations in the Mill Creek study area were sampled for *E. coli* bacteria 5 to 7 times apiece between May and October, 2012. Town Run at Walnut Street was sampled twice. Evaluation of *E. coli* results revealed that 6 of the 11 total sampling locations were in excess of the applicable geometric mean criterion, indicating an impairment of the recreation use at these locations (Table 16 and Figure 21). Elevated bacteria concentrations were nearly ubiquitous with the exception of the lower approximately 10 river miles. The most probable source of bacteria varies depending on the site location and surrounding land use.

In the Mill Creek mainstem upstream from Marysville (CR-142 at RM 39.2 to Cotton Slash Road Bridge at RM 24.7), agricultural activities and failing home sewage treatment systems (HSTSs) are likely to be the most predominant sources of bacteria to streams. Agricultural sources include land application of manure and biosolids and small scale livestock production. A visual survey of the watershed indicated that cattle, horses, sheep, goats or chicken are raised in dozens of locations spread throughout the watershed. Improper manure management or unrestricted livestock access to waterways can contribute to pathogen concentrations in surface waters.

Unsewered areas can also be a source of bacteria. Within the Blues Creek drainage, the unincorporated community of Broadway is unsewered. In the remainder of the Mill Creek watershed, unsewered areas include the census-designated places of East Liberty and Raymond, and unincorporated community of Peoria. At the time of this report, a regional wastewater treatment plant is planned for the Raymond and Peoria area. It is expected that *E. coli* loading in the nearby downstream portion of Mill Creek will be diminished once this plant is operational.

Within the City of Marysville, during routine stream sampling Ohio EPA staff noticed two small potential wastewater leaks entering Mill Creek. One leak was coming through an old tile drain in the area downstream from Main Street and another via a stormwater catchment east of McCarthy Park. These instances were reported to the city of Marysville who promptly followed up in each case. Similar leaks are suspected within Town Run based on high *E. coli* concentrations, field observations of occasional grayish stream flow and periodic 'sewage fungus' on the stream bottom. Periodic stream walks or other leak detection activities are recommended to ensure this type of discharge is not ongoing or more widespread.

Bacterial contamination in most streams was present during both mid-range summer flow and dry weather periods. As a result, effective strategies to reduce bacteria levels in streams could include both nonpoint source and point source control measures. At the time of this study, the sources of impairment listed in Table 16 have not necessarily been confirmed nor are they exclusive of other possible sources.

Figure 21. Recreation use attainment map for the Mill Creek watershed, 2012. All sites are designated or recommended Primary Contact Recreation Class B.

Sediment Quality

Sediment samples were collected from four sites in the Mill Creek study area in September, 2012 - two locations on the Mill Creek mainstem (RMs 39.2 and 18.14) and one site in Crosses Run near the mouth (RM 0.8) and one in Blues Creek near the mouth (0.6). A sample from each site was analyzed for nutrients, total organic carbon (TOC), common metals and 130 organic parameters including polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs) and various pesticides. Analytical results are summarized in Table 17.

Sample collection focused on depositional areas of fine grain material (silts and clays), and one spatial composite sample was created for each sampling location. Sampling staff walked a zone of each stream site within approximately 100 feet downstream and/or upstream from the designated bridge crossing, collecting scoops of soft depositional material wherever it could be found and mixing all subsamples together in a stainless steel pan. Fine grained material found in depositional areas of a stream typically exhibit higher contaminant levels compared to sands and gravels.

All sediment sampling occurred within the wetted stream perimeter or directly adjacent to the wetted perimeter, which were represented at times by sparse deposits of fine grained material. It should be noted that depositional areas comprised a small proportion of the bottom substrates in each of the stream sites surveyed. Bottom substrates at several sites surveyed were dominated by cobble, gravel, and/or sand.

Mill Creek sediment samples were analyzed based upon the Ohio EPA January 2010 *Guidance on evaluating sediment contaminant results* document. The results were compared to published guidelines from *Development and Evaluation of Consensus-Based Sediment Quality Guidelines for Freshwater Ecosystems* (MacDonald et. al. 2000) and those established by the Ontario Ministry of the Environment (Persaud et al. 1993). Not every pollutant type is included in each of these studies, while some pollutant types are included in both studies. Where sediment pollutants were found in concentrations above published threshold values, the highest exceeded threshold is highlighted and these results are discussed below in a site by site fashion (Table 17).

Mill Creek at CR-142 (RM 39.2), Upper Mill Creek HUC-12 (050600010601)

Three chemicals were elevated slightly above their respective Lowest Effect Level (LEL) thresholds: arsenic, at 6.93 mg/kg, nickel, at 17.3 mg/kg, and total organic carbon (TOC), at 2.1%. The LEL is defined by *Persaud,* et al. as "a level of contamination which has no effect on the majority of the sediment-dwelling organisms. The sediment is clean to marginally polluted." Arsenic was in excess of the 6 mg/kg LEL at most sampling locations, and this is likely explained by naturally occurring background levels (up to 30 mg/kg) commonly found in central Ohio soils (Ohio EPA 1998). The LEL concentrations for nickel and TOC are 16 mg/kg for nickel and 1% for TOC. No organic pollutants (PCBs, PAHs, pesticides) were detected at this site. Sediment nutrients were not measured.

Mill Creek Upstream from Cherry St. in Marysville (RM 18.14), Middle Mill Creek HUC-12 (050600010602)

Total phosphorous (690 mg/kg) and TOC (4.8%) were above LEL concentrations at this site, as well as several metals: arsenic (7.72 mg/kg), cadmium (0.732 mg/kg), nickel (22.5 mg/kg), and copper (27.3 mg/kg). These concentrations of arsenic, cadmium and nickel, while slightly elevated, are not significantly higher than levels found elsewhere in the Mill Creek watershed. The concentration of

copper, however, is approximately twice what was found in other locations. Various organic compounds were detected at concentrations above background levels at this site; however, none was present in a concentration that exceeds the ecological thresholds referenced by this report.

With a few exceptions, most metals were detected in slightly higher concentrations in the stream sediment at this location relative to the other three sediment sampling locations in the study area (one Mill Creek headwaters site and two tributary sites). Urban nonpoint source runoff is a plausible source of elevated metals concentrations in any densely populated area such as this; however some sediment metals contamination, in particular copper, in this reach of Mill Creek has been historically linked to specific legacy point sources. The 1998 *Mill Creek Geographic Initiative* by the Ohio EPA Division of Emergency and Remedial Response (DERR) identified the former Eljer Plumbingware facility on Town Run as a source of copper contamination and determined that localized ecological effects were likely to be occurring within that tributary, upstream from this sampling location. In 1995, DERR measured sediment copper concentrations in Town Run at approximately 200 times the concentrations detected in downstream 2012 Mill Creek samples (cited in Ohio EPA 1998). Remedial actions at the Eljer site and within Town Run may have eliminated this source of metals contamination; however this cannot be stated definitively because sediment sampling was not carried out within Town Run as a part of the 1995 DERR study.

Other potential legacy sources of metals and other pollutants to this reach of Mill Creek were highlighted by the 1998 DERR Geographic Initiative and the 1995 Mill Creek Biological and Water Quality Report, and those include: the former Ray Lewis metal plating facility and landfill, upstream along Mill Creek, and the property where the Marysville WWTP was formerly located (west from the Cherry Street bridge, on the left edge of water) which was historically used as a city landfill.

Sediment concentrations of all heavy metals except cadmium were lower in 2012 than they were in the 1995 biosurvey, and this corresponds to source elimination efforts and thereby an improvement in local stream quality. A variety of sediment metals that remain above the LEL, combined with low-level amounts of several organic compounds may be working in concert with diminished habitat quality and elevated concentrations of water column nutrients to depress local fish and macroinvertebrate communities.

Crosses Run downstream of Watkins Road (RM 0.8), Lower Mill Creek HUC-12 (050600010604)

Crosses Run sediments were collected along the upper half of the 0.8 mile reach that extends from Watkins Road to the downstream confluence of Crosses Run and Mill Creek. Sediments from this location had the greatest number of pollutants in excess of ecological thresholds, and the highest degree of threshold exceedance, among all sediment sampling locations in the Mill Creek study area. Of particular note are the pesticide related compounds alpha- and gamma-chlordane, which were present in concentrations greater than the Severe Effect Level (SEL), which is defined as a concentration at which sediments are considered to be “heavily polluted and likely to affect the health of sediment dwelling organisms” (Persaud 1993). Alpha-chlordane was measured at 202 µg/kg and gamma-chlordane was present at 180 µg/kg, and the SEL threshold for chlordane is 60 µg/kg. Metabolites of chlordane cis-nonachlor and trans-nonachlor were present in concentrations (21.4 µg/kg and 59.3 µg/kg, respectively) that exceed the Probable Effect Concentration (PEC) for chlordane, defined as “contaminant concentrations above which harmful effects on sediment-dwelling organisms were expected to occur frequently’’ (MacDonald 2000).

Additional pesticides were found in excess of their respective Threshold Effect Concentrations (TEC), defined as “contaminant concentrations below which harmful effects on sediment dwelling organisms

were not expected" (MacDonald et al 2000). These compounds include heptachlor epoxide (9 µg/kg, TEC = 2.47 µg/kg), and DDT metabolites 4,4'-DDD (15.7 µg/kg, TEC = 4.88 µg/kg) and 4,4'-DDT (13.5 µg/kg, TEC = 4.16 µg/kg).

Mercury was in excess of the TEC (0.203 mg/kg, TEC = 0.18), while three other metals were in excess of the less-conservative threshold: arsenic (9.52 mg/kg), cadmium (0.608 mg/kg) and nickel (19.3 mg/kg). Total phosphorous (695 mg/kg) and TOC (2.7%) were above LEL concentrations at this site (Table 17).

Previous sampling of Crosses Run and its tributaries from 1994, 1995, and 1998 documented elevated soil and sediment pesticide concentrations at, adjacent to, and downstream from The Scotts Company, a large scale agrochemical manufacturer located upstream on Crosses Run. These findings ultimately resulted in the 2007 *Decision Document for the Remediation of The Scotts Company located in Marysville, Ohio* (Ohio EPA 2007). This document outlined specific actions that The Scotts Company has since undertaken to mitigate the environmental exposure risks posed by high concentrations of compounds including chlordane and DDT. Landfill capping, remediation of field broadcast areas and stream remediation projects including sediment removal and habitat restoration have taken place in portions of Crosses Run and N. Branch Crosses Run that lie upstream from this sampling location. Further remediation requirements for The Scotts Company include sediment, habitat, fish tissue and biological monitoring of this particular reach of Crosses Run at six-year intervals until 2040 in order to document progress toward ecological recovery.

Sediment pesticide concentrations at SEL in Crosses Run function as an ecological stressor. In addition to a nutrient enriched water column and periodic low dissolved oxygen concentrations, sediment pesticides are very likely a cause of the decline in macroinvertebrate community health in Crosses Run and Mill Creek immediately downstream from Crosses Run. Upstream from Crosses Run the macroinvertebrate ICI score was 44 (RM 12.17) and downstream (RM 11.7) the ICI score decreased to 34.

Blues Creek DST Ostrander @ Ostrander Road (RM 0.6), Blues Creek HUC 12 (050600010603)

Two metals, arsenic (5.47 mg/kg) and cadmium (0.685 mg/kg) exceeded LEL in the sediment at this location. Methoxychlor was found to be present in Blues Creek sediments in low concentrations (10.2 µg/kg). Methoxychlor is a pesticide that has historically been used in home, garden and agricultural settings, but its use has been banned in the United States since 2003 (USEPA 2004, 2006). The presence of this compound may be acting as a secondary ecological stressor, in addition to sedimentation and siltation, in the Blues Creek subbasin.

Table 17. Selected results of chemical/physical sediment sampling in the Mill Creek study area, 2012. Compared to the specific guideline established by MacDonald et. al. 2000 and Persuad et. al. 1993.

Parameter	Units	Mill Ck RM 39.20	Mill Ck RM 18.14	Crosses Run RM 0.80	Blues Ck RM 0.60
NUTRIENTS					
Total Phosphorus	mg/kg	--	**690* (600)**	**695* (600)**	--
Ammonia	mg/kg	--	98	38	--
Total Organic Carbon	%	**2.1* (1)**	**4.8* (1)**	**2.7* (1)**	**3.9* (1)**
METALS					
Aluminum	mg/kg	6260	8780	6550	6100
Arsenic	mg/kg	**6.93* (6)**	**7.72* (6)**	**9.52* (6)**	5.47
Barium	mg/kg	55.6	144.0	56.8	44.6
Cadmium	mg/kg	0.546	**0.732* (0.6)**	**0.608* (0.6)**	**0.685* (0.6)**
Calcium	mg/kg	46700	44800	24900	22300
Chromium	mg/kg	8.75	13.9	12.3	9.22
Copper	mg/kg	12.4	**27.3* (16)**	3.9	14.7
Iron	mg/kg	16300	20200	18300	14900
Lead	mg/kg	11.5	23.7	16.1	11.9
Magnesium	mg/kg	15500	17100	11900	8660
Manganese	mg/kg	417	476	310	183
Mercury	mg/kg	0.028	0.057	**0.203** (0.18)**	0.046
Nickel	mg/kg	**17.3* (16)**	**22.5* (16)**	**19.3* (16)**	14.8
Strontium	mg/kg	154	180	105	163
Zinc	mg/kg	57.4	108.0	73.5	56.5
ORGANICS (*Includes PCBs, PAHs, Pesticides*)					
Benzo[a]pyrene	mg/kg	BDL	4.36	BDL	BDL
Benz[a]anthracene	mg/kg	BDL	3.49	BDL	BDL
Benzo[b]fluoranthene	mg/kg	BDL	4.61	BDL	BDL
Benzo[g,h,i]perylene	mg/kg	BDL	3.29	BDL	BDL
Benzo[k]fluoranthene	mg/kg	BDL	2.91	BDL	BDL
Chrysene	mg/kg	BDL	4.28	BDL	BDL
Fluoranthene	mg/kg	BDL	7.89	BDL	BDL
Indeno[1,2,3cd]pyrene	mg/kg	BDL	2.93	BDL	BDL
Phenanthrene	mg/kg	BDL	1.86	BDL	BDL
Pyrene	mg/kg	BDL	6.20	BDL	BDL
4,4'-DDD	µg/kg	BDL	BDL	**15.7** (4.88)**	BDL
4,4'-DDT	µg/kg	BDL	BDL	**13.5** (4.16)**	BDL
Alpha-chlordane	µg/kg	BDL	BDL	**202† (60)**	BDL
Gamma-chlordane	µg/kg	BDL	BDL	**180† (60)**	BDL
Heptachlor epoxide	µg/kg	BDL	BDL	**9** (2.47)**	BDL
cis-Nonachlor††	µg/kg	BDL	BDL	**21.4*** (17.6)**	BDL
trans-Nonachlor††	µg/kg	BDL	BDL	**59.3*** (17.6)**	BDL
Methoxychlor	µg/kg	BDL	BDL	BDL	10.2

* Exceeds Lowest Effect Level (LEL), from Persuad. 1993
** Exceeds Threshold Effect Concentration (TEC), from MacDonald et. al. 2000
*** Exceeds Probable Effect Concentration (PEC), from MacDonald et. al. 2000
† Exceeds Severe Effect Level (SEL), from Persuad. 1993
†† Considered a metabolite of chlordane, criterion for chlordane is applied this compound

Public Drinking Water Supplies

The Public Drinking Water Supply (PDWS) beneficial use in the Ohio WQS [OAC 3745-1-33] currently applies within 500 yards of drinking water intakes and to all publicly owned lakes. Ohio EPA has developed an assessment methodology for this beneficial use which focuses on source water contaminants not effectively removed through conventional treatment methods. Impaired source waters may contribute to increased human health risk or treatment costs. The 2014 Integrated Water Quality Monitoring and Assessment Report describes the assessment methodology. For the case when stream water is pumped to a reservoir, the stream and reservoir will be evaluated separately.

These assessments are designed to determine if the quality of source water meets the standards and criteria of the Clean Water Act. Monitoring of the safety and quality of treated finished drinking water is regulated under the Safe Drinking Water Act and evaluated separately from this assessment. For those cases when the treatment plant processes do not specifically remove a source water contaminant, the finished water quality data may be considered representative of the raw source water directly feeding into the treatment plant.

There is one public water system, the city of Marysville, directly served by surface water sources within the study area. Marysville has an intake on Mill Creek at RM 21.65. Table 18 provides a summary of exceedances for the PWS use while Appendix G contains the water chemistry results.

City of Marysville

The city of Marysville operates a community public water system that serves a population of approximately 22,800 people through 6,959 service connections. The water treatment system obtains its water from both ground water wells (25%) and Mill Creek (75%). Water from Mill Creek is pumped into the 1.36 billion gallon upground Marysville Reservoir, which was constructed in 2008 and put into service in 2009. The system's treatment capacity is approximately 4.3 million gallons per day, but current average production is 2.0 million gallons per day. In addition to conventional surface water treatment (coagulation, flocculation, sedimentation, and rapid filtration), the Marysville treatment plant pre-oxidizes and post-oxidizes with gaseous chlorine for disinfection, has lime-soda softening for hardness removal, and fluoridates. The City has obtained coverage under the pesticide applications general permit to apply algaecides (copper sulfate) to the reservoir to control nuisance algae. Since the City selectively pumps into the reservoir during periods of good water quality (when nitrates, pesticide and turbidity are low) and blends surface water with ground water, the finished water sampling data cannot be used to assess Mill Creek's water quality.

Ohio EPA collected a total of ten water quality samples at Marysville's intake on Mill Creek in 2012 and 2013. To assess the PDWS beneficial use, samples were analyzed for nitrate (9 samples) and pesticides (10 samples). Nitrate ranged from 0.35 mg/l to 11.6 mg/l and averaged 3.7 mg/l. An additional spring sample is needed to complete a full assessment of the PDWS use, but since one sample exceeded the drinking water WQS criterion for nitrate (10.0 mg/L), the waters will at a minimum be placed on the watch list for elevated nitrate. Atrazine concentrations ranged from 0.21 ug/l to 36.2 ug/l. Three individual samples exceeded the criterion and the spring quarterly averages for both 2012 and 2013 exceeded the criterion. Since atrazine is assessed as an annual average, the source water is not impaired, but will be placed on the pesticide watch list (annual average 2.1 ug/l for both years, assuming atrazine concentrations at 0 for quarters not sampled).

Table 18. Summary of available water quality data for parameters of interest at Marysville's PDWS intake, 2012 and 2013.

Location(s)	PDWS Parameters of Interest				
	Nitrate-Nitrite WQS = 10 mg/L[1]		Atrazine WQS = 3.0 ug/L[2]		
	Average (sample count)	Maximum (# samples >WQC)	Average (sample count)	Maximum Quarterly Average	Maximum
Mill Creek at Marysville Intake	3.7 mg/L (n=9)	11.6 mg/L (1)	5.3 ug/L (n=10)	8.5 ug/L	36.2 ug/L

1 Nitrate Water Quality Standards (WQS) criterion evaluated as maximum value not to be exceeded, impaired waters defined as having two or more excursions above the criteria.

2 Atrazine WQS criterion evaluated as annual average.

NPDES Permitted Facilities

There are thirteen individual National Pollution Discharge Elimination System (NPDES) permits issued for sanitary wastewater, industrial process water and/or industrial storm water discharges into streams in the Mill Creek watershed (Table 13). The city of Marysville Water Reclamation Facility (WRF) is the only major NPDES facility in the study area.

In addition to the thirteen individual NPDES permits, there is one general permit for a small sanitary discharge (ODOT Rest Area 6-4) and nine industrial storm water permits in the study area. A majority of the industrial storm water facilities are located in and around the Marysville area and along Industrial Parkway in the lower Mill Creek subwatershed. The discussion below focuses on the facilities with a significant influence on the water quality of Mill Creek.

Marysville WRF (4PE00002)

The new Marysville Water Reclamation Facility (WRF) completed in the spring of 2009 is an advanced secondary treatment facility with an average daily design flow of 8.0 MGD (million gallons per day). Wet stream processes include raw sewage pumping, fine screens, aeration for carbonaceous and nitrification oxidation, chemical precipitation for nutrient removal, secondary clarification, tertiary sand filtration followed by UV disinfection and post aeration. Solids handling consists of aerobic sludge holding, mechanical thickening and centrifuge dewatering. Biosolids are disposed of at a landfill. The sanitary collection system is 100% separate. Final effluent is discharged to Mill Creek at RM 9.25. This new facility replaces the old WWTP that discharged at RM 18.26. A summary of 2012 effluent characteristics for the Marysville WRF is shown in Table 19.

Ohio EPA Effluent Sampling

During the 2012 survey, Ohio EPA collected final effluent grab samples at the Mill Creek WRF. The mean dissolved oxygen level was 8.71 mg/l. BOD5 and TSS results were below detection level. Most nitrate+nitrite results were around 10 mg/l but a measurement of 49.7 mg/l was recorded on 7/12/2013. Total ammonia-nitrogen results averaged 0.95 mg/l with a maximum of 4.52 mg/l recorded. Total phosphorus results averaged 0.8 mg/l. Bacteria (*E.coli*) results were found to be near or below the detection level.

NPDES Compliance Summary

For the three year period 2010 – 2012, Marysville WRF had two NPDES effluent violations for copper in June 2010. There were no NPDES effluent violations in 2011 or 2012.

Facility Loadings

Annual third quarter loadings (kg/day) of selected pollutants for the new Marysville WRF is presented in Appendix H. Flow for the new facility has decreased slightly compared to flow from the old WWTP. In 2012, the median annual third quarter flow was 2.67 mgd. CBOD5, TSS and total ammonia-nitrogen loads have dropped significantly since the new facility went online. For nutrients, total phosphorus loads have also decreased dramatically and recent nitrate+nitrite loading results have trended comparable to historical observations.

Bioassay Testing

Whole effluent toxicity testing performed by the city of Marysville in accordance with the NPDES permit has been negative for the period 2011 to 2013. This data indicates that the effluent does not currently

present a toxicity problem to fathead minnows *Pimephales promelas* and daphnid *Ceriodaphnia dubia*. Ohio EPA toxicity screening of effluent in 2009 and 2010 found no acute toxicity to either organism.

Ostrander WWTP (4PA00007)

The village of Ostrander WWTP, built in 1991, uses a conventional activated sludge treatment system with a design flow of 90,000 gpd. The WWTP serves a population of approximately 500 with no significant industrial or commercial users. The sanitary collection system is 100% separate. There are no reported bypasses or overflows. The treatment process includes flow equalization, primary and secondary treatment, solids handling, chlorine disinfection and post aeration facilities. WWTP biosolids are primarily managed through land application. The final effluent is discharged to Mill Creek at RM 4.05, immediately upstream from the confluence of Blues Creek. A summary of 2012 effluent characteristics for the Ostrander WWTP is presented in Table 19.

Ohio EPA Effluent Sampling 2012

During the 2012 survey, Ohio EPA collected final effluent grab samples at the Ostrander WWTP. The mean dissolved oxygen and BOD5 levels were 7.02 mg/l and 4.1 mg/l respectively. Total ammonia-nitrogen averaged 0.46 mg/l with a maximum of 0.81 mg/l recorded. For nutrients, mean total phosphorus results were 6.8 mg/l and mean nitrate+nitrite results were 7.3 mg/l.

Ohio EPA *E.coli* sampling results on two runs during 2012 were 1,900 and 3,900 cfu/100 ml respectively. These results are extremely elevated for properly treated and disinfected wastewater. Three other bacteria results during the survey were each reported at 10 cfu/100 ml (below detection).

NPDES Compliance Summary

For the three year period 2010 – 2012, the Ostrander WWTP had a single fecal coliform bacteria violation in July 2010. No NPDES effluent violations were noted in 2012 (Table 20).

Facility Loadings

Ostrander WWTP annual third quarter loadings (kg/day) of selected pollutants are presented in Appendix H. Median and 95th percentile flows have remained well below the WWTP average design flow of 0.09 mgd. BOD and TSS loads generally have remained fairly steady over the past 5 years. 95th percentile total phosphorus and total ammonia-nitrogen loads in 2012 have risen compared to previous annual results.

Mill Creek Estates WWTP (4PG00036)

The Mill Creek Estates WWTP was built in 1971 primarily serving approximately 263 homes in the Mill Creek Estates, Pleasant Ridge and Buxton Meadows subdivisions. The original average design flow was 0.105 mgd. The actual treatment capacity has been reduced to 0.072 mgd due to plant modification. The sanitary collection system is 100% separate. The treatment process includes flow equalization, activated sludge (extended aeration), secondary clarification, fixed media clarification, tertiary sand filtration, UV disinfection and post aeration. Biosolids are hauled off-site to the city of Marysville for further management. Final effluent is discharged to Mill Creek at RM 12.57. A summary of 2012 effluent characteristics for the Mill Creek Estates WWTP can be found in Table 19.

Ohio EPA Effluent Sampling 2012

During the 2012 survey, Ohio EPA collected final effluent grab samples at the Mill Creek Estates WWTP. The averaged dissolved oxygen reading was 7.45 mg/l with CBOD5 and TSS results below detection. Nutrient results averaged 5.14 mg/l for nitrate+nitrite and 0.10 mg/l for total phosphorus. Total

ammonia-nitrogen averaged 0.9 mg/l with a maximum of 3.66 mg/l recorded. E.coli bacteria results were all below detection.

NPDES Compliance Summary
An Ohio EPA compliance evaluation inspection (CEI) was conducted at Mill Creek Estates on May 23, 2012. High inflow and infiltration (I&I) was identified as an area needing improvement. NPDES compliance, operations and maintenance and flow measurement were areas rated as marginal by Ohio EPA staff. The collection system was rated as unsatisfactory due to the high I&I concerns. According to Ohio EPA records, actions are currently being taken to address the I&I problem.

For the three year period 2010-2012, the Mill Creek Estates WWTP had 61 NPDES effluent violations. Many of these violations occurred in 2011 for total ammonia-nitrogen and total suspended solids results. During the survey year of 2012, only two total suspended solids violations were recorded.

Facility Loadings
Mill Creek Estates WWTP annual third quarter loadings for selected pollutants are presented in Appendix H. Most recently in 2011, the median flow easily exceeded the WWTP average design flow. Recent TSS median loads have also tripled compared to 2006. BOD5 and total ammonia-nitrogen loads, however, have remained low over that same period.

The Scotts Company (4IF00000)
The Scotts Company (Scotts) is located on a 745 acre complex at the intersection of Industrial Parkway and Scottslawn Road just southeast of Marysville. Production activity at the plant includes the blending of raw materials into fertilizers. Some of these products contain registered pesticides. The facility began production in 1957. The complex includes production areas, warehouse and loading areas, research laboratories, office buildings, product test fields and farm land. The complex is primarily surrounded by agricultural uses. Crosses Run and North Branch Crosses Run provide storm water drainage from the facility property.

Prior to 1984, Scotts disposed of off-specification process materials in five on-site landfills and two on-site field broadcast areas. Scotts also used several ponds to settle solids out of process waters before recycling the water back into the manufacturing processes. On September 23, 2003 Ohio EPA issued a Decision Document selecting initial corrective measures that Scotts was required to implement to address contamination at the facility. In August 2007 a second Decision Document was issued to approve Scotts selected remedies for addressing facility contamination including areas impacting Crosses Run.

This work was primarily performed under the Ohio EPA RCRA corrective actions program. Since 2007, completed actions have included sediment removal, habitat restoration and preservation and natural stream recovery. Scotts also placed multi-layer protective caps on several landfills and broadcast areas as well as implementing a groundwater monitoring and response plan. Periodic biological stream surveys, habitat evaluations, fish tissue and sediment chemistry studies are also part of the action plan (Ohio EPA, 2007 “Decision Document”). http://epa.ohio.gov/dmwm/Home/HWIssuedActions.aspx .
Prior to 1998, Scotts maintained and operated five package-type WWTPs at the facility. From 1990 to 1995, 189 violations were recorded from the permitted outfalls at the facility ((Ohio EPA, 1996) Mill Creek (Scioto River Basin) and Selected Tributaries Study). These plants have subsequently been tied into the city of Marysville WRF.

Scotts currently holds an Ohio EPA Industrial NPDES Permit (4IF0000). The permit includes coverage for thirteen stations including two chiller/condensate discharges and five storm water discharges. East and West plant process areas are included in the storm water discharges as well as warehouse storm water discharges into the fire pond. A summary of 2012 NPDES effluent characteristics for Scotts is presented in Table 19.

NPDES Compliance Summary

From 2010 to 2013, Scotts recorded two NPDES effluent violations (ammonia, 2010). No NPDES effluent violations were reported in 2011 or 2012.

Table 19. Summary of NPDES effluent characteristics for facilities assessed in the Mill Creek watershed, 2012.

FACILITY	PARAMETER	NUMBER OBSERVATIONS	PERCENTILES 50^{TH} / 95TH
MARYSVILLE WRF	FLOW mgd	366	2.95 / 5.50
4PE00002	CBOD mg/l	144	0.67 / 2.29
OUTFALL 001	TSS mg/l	144	1.0 / 2.53
	AMMONIA-N mg/l	144	0.028 / 0.25
	PHOSPHORUS mg/l	48	0.81 / 1.09
	NITRATE+NITRITE mg/l	12	10.35 / 40.01
	TDS mg/l	52	1038 / 1206
MILL CREEK ESTATES WWTP	FLOW mgd	366	0.07 / 0.15
4PG00036	CBOD mg/l	96	0 / 8
OUTFALL 001	TSS mg/l	96	5 / 13.25
	AMMONIA-N mg/l	24	0 / 1.87
OSTRANDER WWTP	FLOW mgd	366	0.036 / 0.065
4PA00007	CBOD mg/l	46	7 / 15.5
OUTFALL 001	TSS mg/l	47	6 / 15
	AMMONIA-N mg/l	26	0.55 / 2.88
	PHOSPHORUS mg/l	12	2.65 / 7.80
SCOTTS COMPANY	FLOW gpd	366	7829 / 309000
4IF00000	BOD mg/l	12	5.4 / 7.4
OUTFALL 102	TOTAL-NITROGEN mg/l	12	3.2 / 6.4
	AMMONIA-N mg/l	12	0.48 / 2.46
	PHOSPHORUS mg/l	12	0.17 / 0.46
	2,4-D ug/l	12	0 / 9.77
SCOTTS COMPANY	FLOW gpd	239	0 / 88950
4IF00000	BOD mg/l	8	7.88 / 22.91
OUTFALL 103	TOTAL-NITROGEN mg/l	8	2.37 / 8.09
(2011 Data)	AMMONIA-N mg/l	8	0.54/ 2.31
	PHOSPHORUS mg/l	8	0.19 / 0.87
	2,4-D ug/l	8	16.2 / 46.65
SCOTTS COMPANY	FLOW gpd	366	9704 / 296500
4IF00000	BOD mg/l	12	6.48 / 9.37
OUTFALL 106	TOTAL-NITROGEN mg/l	12	4.18 / 13.08
	AMMONIA-N mg/l	12	1.51 / 3.69
	PHOSPHORUS mg/l	12	0.31 / 0.47
	2,4-D ug/l	12	1.19 / 17.25
SCOTTS COMPANY	FLOW gpd	28	24240 / 26800
4IF00000	BOD mg/l	11	12 / 17
OUTFALL 107	TOTAL-NITROGEN mg/l	9	8.7 / 23.2
	AMMONIA-N mg/l	10	3.45 / 9.65
	PHOSPHORUS mg/l	10	0.18 / 0.51
	2,4-D ug/l	11	1.2 / 8.75

Table 20. Summary of NPDES effluent violations for selected facilities in Mill Creek watershed over a 3-year period (2010 – 2012).

FACILITY	NO. VOLATIONS	SUMMARY
MARYSVILLE WRF 4PE00002	2	COPPER (JUNE 2010). NO VIOLATIONS 2012.
MILL CREEK ESTATES 4PG00036	61	AMMONIA-N (DEC. 2010, JAN. 2011, FEB. 2011, MAR. 2011, APR. 2011, MAY 2011, JUNE 2011). 2 TSS VIOLATONS ONLY IN 2012 (MAY).
OSTRANDER WWTP 4PA00007	1	FECAL COL. (JULY 2010). NO VIOLATIONS 2012.
SCOTTS CO. 4IF00000	2	AMMONIA-N (MAR. 2010, NOV. 2010). NO VIOLATIONS 2012.

Stream Physical Habitat

Stream habitat was evaluated using the Qualitative Habitat Evaluation Index (QHEI) at 24 fish sampling locations throughout the Mill Creek study area in 2009, 2012, and 2013. As measured by QHEI scores, the Mill Creek study sites consisted mainly (83%) of good to excellent stream habitats (Table 21). Good to excellent stream habitat was recorded at 20 sites with only four sites scoring fair to poor quality stream habitats – Town Run and the headwaters of Blues Creek. The average QHEI score for the Mill Creek watershed was 69.7 which showed the overall good habitat quality in the study area (Table 15 and Appendix A). Covering over twelve river miles, the lower eight sampling sites on Mill Creek had some of the best available habitat for fish communities (Figure 22). However, algae blooms manifested by eutrophic conditions smothered high quality gravel and coble substrates in the riffles at the lower sampling site (Mills Road, RM 1.57). This limited the quality of the macroinvertebrate community which dropped ten ICI points from the site upstream (Figure 23 and Table 2). The overall habitat quality in the watershed as assessed by the QHEI is generally unchanged since the previous 1995 survey with the exception of the areas around the low head dams in the city of Marysville (Figure 22 Ohio EPA 1996).

The physical habitat and flow in Mill Creek adjacent to Waldo Road (RM 16.8) was heavily influenced by the upstream CSO in 1995 (QHEI = 63.0, good) with trash noted instream and restricted flow and dewatering of the creek by a low head dam and drinking water intake located just upstream of the CSO. Instream trash was not encountered during the 2012 (QHEI = 74.5, excellent) sampling as the CSO is no longer discharging and the Marysville WWTP has been upgraded and relocated downstream several miles. Upstream of Cherry Street (RM 18.3) the low head dam used to impound Mill Creek for a drinking water intake is also gone. This has been replaced by an inflatable dam and up ground drinking water reservoir located adjacent to Mill Valley Park and Raymond Road (Appendix A and Figure 26). Low flow and drought like conditions were encountered in most places during the 2012 sampling season and maximum depths (>1m) recorded for 2012 were still greater than those from 1995 (0.7-1m).

Figure 22. Exceptional physical habitat pictured above in Mill Creek (RM 1.57) upstream from Bellpoint Road.

Figure 23. Pictured above, algae mats in the riffles in Mill Creek at Bellpoint Road (RM 1.57) limited the quality of the macroinvertebrate community.

The fair (RM 10.15, QHEI = 47.0) and poor (RM 16.3, QHEI = 41.0) habitat quality at two Blues Creek sites was related to upstream and adjacent agricultural land use practices. Stream substrates at the sites were almost entirely comprised of silt and fine sediment (Figure 24 and Appendix A). At Taylor Claiborne Road (RM 16.3), Blues Creek is channelized and incised with no woody riparian corridor. A narrow CRP type buffer has been planted or allowed to grow along the tops of both incised banks; however, it doesn't appear to be filtering much of the surface water runoff as the adjacent field was tiled. Unstable instream substrates were evidence of flashy stormwater events. Further evidence of these flashy storm events was noted downstream at Leeper Perkins Road (RM 10.15). Despite a more natural woody riparian buffer and channel sinuosity, the instream substrates found at this site continued to reflect storm water impacts from flashy flows and sediment transport.

Figure 24. Two Blues Creek sites pictured above show examples of both poor (RM 16.3) and fair (RM 10.15) quality habitats, 2012.

Fair quality habitat in Town Run (QHEI scores of 44 and 50 at RMs 0.7 and 0.2, respectively) was attributed to raw sewage, sedimentation from urban stormwater runoff and major habitat modifications. For part of its length, Town Run flows in an underground concrete culvert through the city of Marysville. The substrates in both sampling locations were covered in raw sewage from illicit discharges which turned the channel margins black and grey. While the upstream site had more natural features as it flowed through a city park, the downstream site was incised and channelized with riprap and surrounded by concrete and blacktop parking lots (Figure 25). Regardless of whether physical habitat quality is improved in daylighted reaches of Town Run, WWH use attainment will likely not be attained unless the illicit discharges are eliminated.

Figure 25. Fair quality habitat (QHEI = 50) at Town Run RM 0.20.

Table 21. Summarized results of QHEI scores for the Mill Creek study area, 2009, 2012, & 2013.

	RM	QHEI	Sample Type
Mill Creek (02-109-000)			
	42.60	61	Headwater
	39.20	61.5	Wading
	36.10	66.5	Wading
	24.80	72.8	Wading
	21.70	76.8	Wading
	19.00	68.8	Wading
	18.20	64.5	Wading
	16.80	74.3	Wading
	14.60	66.5	Wading
	12.20	75.3	Wading
	11.70	76.8	Wading
Sampled in 2013 →	9.42	79.0	Wading
	9.20	81.5	Wading
	6.90	83.3	Wading
	4.20	91.3	Wading
	3.90	91.8	Wading
	1.57	87	Wading
Blues Creek (02-109-001)			
	16.50	41	Headwater
	10.15	47	Headwater
	1.90	66	Wading
	0.70	71.5	Wading
Crosses Run (02-109-005)			
	0.90	75.3	Headwater
Town Run (02-109-015) Samples Collected in 2009*			
	0.20	50	Headwater
	0.70	44	Headwater

General narrative ranges assigned to QHEI scores.			
Narrative Rating		QHEI Range	
		Headwaters (≤20 sq. mi)	Larger Streams
Excellent		≥70	≥75
Good		55 to 69	60 to 74
Fair		43 to 54	45 to 59
Poor		30 to 42	30 to 44
Very Poor		<30	<30

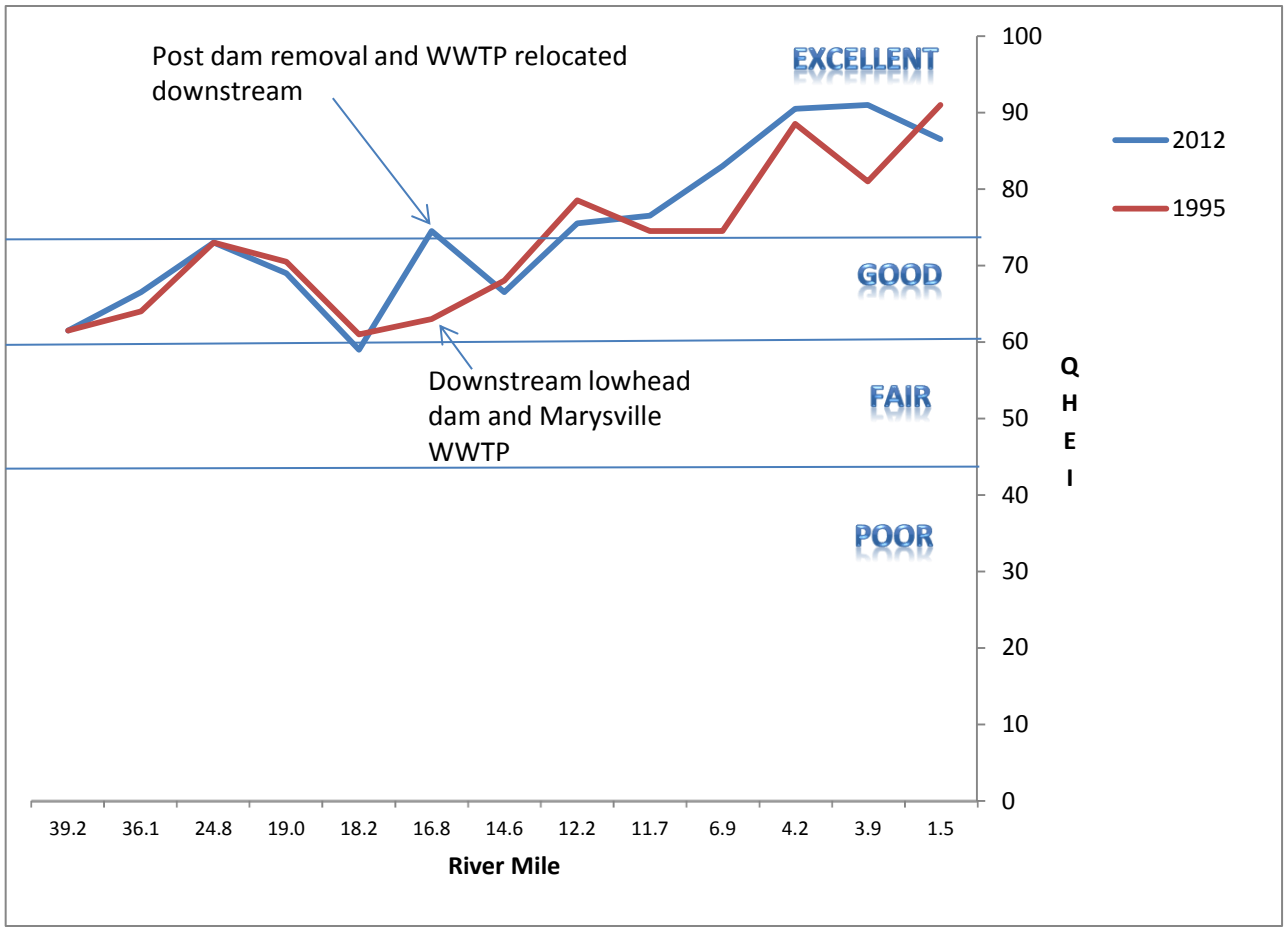


Figure 26. Comparison of QHEI trends for Mill Creek, 1995-2012.

Spills and Fish Kills

A total of fourteen spills which resulted in 7 fish kills were reported in the Mill Creek watershed between 1987 and 2007 (Table 22). No evidence or reports of fish kills occurred during the 2012 study and the most recent past incident occurred in 2007. Based on 2012 survey results, there did not appear to be any long-term residual impacts attributable to these events.

Table 22. Documented fish kills in the Mill Creek watershed, 1987-2007.

River	Date	RM	Length Affected (miles)	# Fish Killed	Operation	Pollutant	Source
Crosses Run	2/7/07	2.23	0.34	0	industrial	nitrogen/ammonia	The Scotts Company
Trib. to Mill Creek (32.90)	5/27/02	0.12	0.12	0	farms and feedlots	manure	William S. Keck farm
Mill Creek	7/31/01	27.22	8.12	0	agribusiness	manure	Larry D. Hobbs
Mill Creek	7/16/00	38.10	19.85	0	farms and feedlots	manure (chicken)	Dalay Egg Farm
Mill Creek	7/5/99	18.00	6.02	0	unknown	unknown	unknown
Blues Creek	7/26/98	15.55	1.27	2811	farms and feedlots	manure (cow)	Lloyd Martino farm
Blues Creek	6/29/98	13.23	1.33	0	farms and feedlots	manure (hog)	Rinehart Farm Partnership
North Branch Crosses Run	8/28/98	0.30	0.06	2000	chemical industries	ammonia fertilizer	O.M. Scott
Trib. to Mill Creek (27.22)	4/2/98	0.55	0.55	0	farms and feedlots	manure (cow, liquid)	George Beeson Farms
Town Run	8/12/97	0.55	0.15	75	petroleum	water runoff from extinguishing fire	Penn Oil Co.
Trib. to Mill Creek	2/8/93	3.65	2.00	907	mining and minerals	#2 fuel oil	Northwood Stone and Asphalt Co.
Beech Ditch	5/19/91	13.84		0	chemical industries	fertilizer	Terra International, Inc.
Blues Creek	10/30/91	2.70	0.00	0		low dissolved oxygen	natural
Mill Creek	5/6/87			8047		fertilizer	

Mill Creek Fish Tissue Contamination

Ohio has been sampling streams annually for sport fish contamination since 1993. Fish are analyzed for contaminants that bioaccumulate in fish and that could pose a threat to human health if consumed in excessive amounts. Contaminants analyzed in Ohio sport fish include mercury, PCBs, DDT, mirex, hexachlorobenzene, lead, selenium, and several other metals and pesticides. Other contaminants are sometimes analyzed if indicated by site-specific current or historic sources. Fish contaminant data are primarily used for three purposes: 1) to determine fish advisories; 2) to determine attainment with the water quality standards; and 3) to examine trends in fish contaminants over time.
For more information about the chemicals analyzed, how fish are collected, or the history of the fish contaminant program, see State Of Ohio Cooperative Fish Tissue Monitoring Program Sport Fish Tissue Consumption Advisory Program, Ohio EPA, January 2010 (http://www.epa.state.oh.us/portals/35/fishadvisory/FishAdvisoryProcedure10.pdf).

Fish advisories

Fish contaminant data are used to determine a meal frequency that is safe for people to consume (e.g., two meals a week, one meal a month, do not eat), and a fish advisory is issued for applicable species and locations. Because mercury mostly comes from nonpoint sources, primarily aerial deposition, Ohio has had a statewide one meal a week advisory for most fish since 2001. Most fish are assumed to be safe to eat once a week unless specified otherwise in the fish advisory, which can be viewed at http://www.epa.state.oh.us/dsw/fishadvisory/index.aspx.

Prior to the 2012 sampling, the only fish advisory in place for Mill Creek was a two meals per week advisory for saugeye, indicating that mercury contamination in this species was low. For all other species, the statewide advisories were in effect (two meals a week for sunfish and yellow perch, one meal a week for most other fish, one meal a month for flathead catfish 23" and over, and northern pike 23" and over).

The minimum data requirement for issuing a fish advisory is 3 samples of a single species from within the past 10 years. For Mill Creek, five species met this requirement. Three species (channel catfish, common carp, and rock bass) had contaminant concentrations indicating that the statewide advisories were appropriate, and no advisories specific to Mill Creek are being proposed for those species. Saugeye also meet the data requirement, but no new data (i.e., 2012) has been collected since the last advisory was posted and no change in the existing two meals per week advisory is being recommended.

Table **23** *lists the only change, smallmouth bass now warrant a one meal per month advisory due to mercury contamination*.

Fish tissue/human health use attainment

In addition to determining safe meal frequencies, fish contaminant data are also used to determine attainment with the human health water quality criteria pursuant to OAC Rules 3745-1-33 and 3745-1-34. The human health water quality criteria are presented in water column concentrations of µg/l, and are then translated into fish tissue concentrations in mg/kg. [See Ohio's 2012 Integrated Report, Section E (http://epa.ohio.gov/dsw/tmdl/OhioIntegratedReport.aspx) for further details of this conversion.]

In order to be considered in attainment of the water quality standards, the sport fish caught within a HUC12 in the Ohio River basin must have a weighted average concentration of the geometric means for all species below 1.0 mg/kg for mercury, and below 0.054 mg/kg for PCBs.

Within the Mill Creek study area, fish tissue data were adequate to determine attainment status in one HUC-12. At least 2 samples from each trophic level 3 and 4 are needed, and the lower reaches of the Mill Creek mainstem were sampled for fish tissue and met that data requirement. PCBs were only detected in one fish sample (reporting limit of 0.05 mg/kg) from Mill Creek (HUC 050600010604), and the average level of contamination was well below the attainment threshold. No fish had mercury levels above the criterion of 1.0 mg/kg (reporting limit of 0.024 mg/kg). Therefore, this HUC-12 is considered in full attainment of the human health use based on overall contamination levels in ambient fish communities.

Fish contaminant trends

Fish contaminant levels can be used as an indicator of pollution in the water column at levels lower than laboratory reporting limits for water concentrations but high enough to pose a threat to human health from eating fish. Most bioaccumulative contaminant concentrations are decreasing in the environment because of bans on certain types of chemicals like PCBs, and because of stricter permitting limits on dischargers for other chemicals. However, data show that PCBs continue to pose a risk to humans who consume fish, and mercury concentrations have been increasing in some locations because of increases in certain types of industries for which mercury is a byproduct released to air and/or surface water.

For this reason, it is useful to compare the results from the survey presented in this document with the results of the previous survey(s) done in the study area. Recent data can be compared against historical data to determine whether contaminant concentrations in fish tissue appear to be increasing, decreasing, or staying the same in a water body or watershed.

Fish tissue had previously been collected from Mill Creek in 1994, 1995, and 2010. Average mercury concentrations were slightly higher in 2010 and 2012 compared to 1994 and 1995 (0.177 vs. 0.141 mg/kg), but given the large variation in concentrations between individual samples, this difference may not be statistically significant.

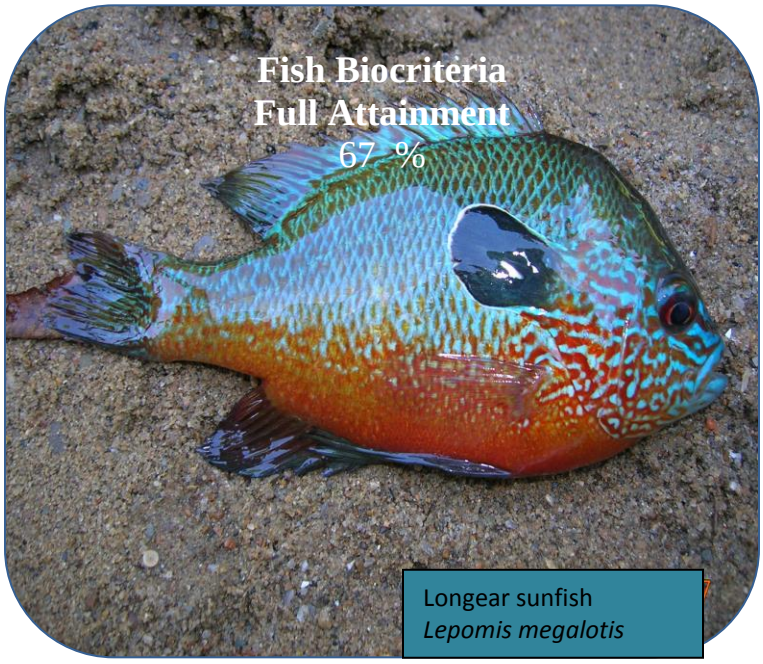
PCBs have generally not been detected in fish in Mill Creek. A total of three samples (two in 1995, one in 2010) have tested positive for PCBs out of a total of 51 samples analyzed. The 1995 samples were well below (average 0.02 mg/kg) any consumption advisory threshold and the 2010 sample was barely above (0.063 mg/kg) the one meal per week threshold (0.05 mg/kg). Owing to the very low number of PCB detections, trends in PCB contamination are not clear but the current and historical results are well within the desirable range.

Table 23. Fish tissue data (mg/kg) from Mill Creek sampling locations, 2012. All contaminant levels in the table were in the unrestricted consumption range except for mercury. The shading indicates the advisory category that would apply. Blue = one meal per week, yellow = one meal per month. No PCBs or pesticides were detected.

Year	Location	River Mile	Species	Arsenic	Cadmium	Lead	Mercury
2012	Mill Creek @ Hinton Mill Rd.	6.9	COMMON CARP	0.108	<0.0039	<0.039	0.240
2012	Mill Creek @ Mills Rd.	1.6	COMMON CARP	<0.049	<0.0039	<0.039	0.365
2012	Mill Creek @ Hinton Mill Rd.	6.9	ROCK BASS	<0.050	<0.0040	<0.040	0.215
2012	Mill Creek @ Mills Rd.	1.6	ROCK BASS	<0.048	<0.0038	<0.038	0.126
2012	Mill Creek @ Hinton Mill Rd.	6.9	SMALLMOUTH BASS	0.056	<0.0040	<0.040	0.353
2012	Mill Creek @ Mills Rd.	1.6	SMALLMOUTH BASS	0.051	<0.0039	<0.039	0.349

Fish Community

Fish sampling was conducted at 24 sites in the Mill Creek study area, 2009, 2012, and 2013. Relative numbers of fish species collected per location are presented in Appendix C. IBI and MIwb scores are presented in Table 2, and Table 18 and the IBI metric breakdowns can be found in Appendix B. Sampling locations were evaluated using WWH biocriteria with the exception of the upstream site on Blues Creek which is designated MWH. Various summary attributes of the fish data are presented in Table 24.



Mill Creek watershed sites sampled achieved the applicable fish biocriteria at 16 of the 24 sites evaluated (67%). Fish communities partially achieved the applicable biocriteria at three wading (>20 sq. mi.) sites or 13% (Mill Creek RMs 18.14 and 14.54 and Blues Creek RM 0.60). Five sites (wading and headwater) were not achieving the applicable biocriteria, representing 21% of the fish sites (Blues Creek RMs 10.15 and 2.00, Crosses Run RM 0.80 and Town Run RMs 0.7 and 0.2). The average IBI score among the Mill Creek sites was 39.6.

Fish communities only partially met WWH expectations in Mill Creek at RMs 18.14 and 14.54 and Blues Creek at Ostrander Road (RM 0.60) due to fine sediment and silt accumulations (Table 2). The two Mill Creek sites were also impacted by organic enrichment discharging from illicit connections and hook-ups to storm sewers within the Marysville city limits. Direct habitat alteration due to channelization was also found to be a cause for impacting fish communities at Cherry Street (RM 18.14). The stream banks upstream from Cherry Street are steeply incised and the channel has been widened, creating a depositional area for silts and other fines to accumulate from storm runoff. Sediment runoff at the other Mill Creek site and Blues Creek site was attributed to upstream and adjacent agricultural land use practices.

The two Blues Creek and one Crosses Run sites not achieving fish biocriteria in the watershed had stream substrates covered with silt from sediment runoff coming off the adjacent agricultural landscape (Table 2). Crosses Run was also found to have toxic levels of pesticides and metals in the sediments and elevated levels of nutrients in the water column. These pollutants likely originated from past poorly treated waste water from the Scotts Company. Although big improvements have been made to the Scotts' effluent, the contaminated sediments are thought to be from legacy pollutant releases of contaminants with long half-lifes in the environment. The Scotts' production waste water is now tied in and treated by the Marysville WRF. Currently, only storm water from the Scotts' property drains into the North Branch and mainstem of Crosses Run. Please see the NPDES section for additional information about the Scotts Company.

The IBI in Crosses Run was 34 (just two IBI points from meeting the WWH biocriterion) in 2012 with 404 fish caught among 12 species; in 1995 there were only 13 total fish caught among 3 species (IBI=18). Improvements in water quality can also be seen in Mill Creek downstream from Crosses Run. In 1995 this site (Mill Creek RM 11.7) scored an IBI=34 (non-attainment) while the site upstream from Crosses Run (RM 12.2) was in full attainment. Downstream from Crosses Run in 2012, Mill Creek (RM 11.7) was found to have an exceptional fish community, scoring an IBI=47.

The two Town Run sites not achieving WWH expectations for fish were impacted by direct habitat alterations and raw sewage discharging into the stream from illicit connections. Poor quality fish communities were found at both sampling locations (RMs 0.75 and 0.21). For part of its length, Town Run flows through a restricted underground culvert under the city of Marysville before emerging for approximately 110 meters and flowing through a channelized section buffered by concrete, asphalt, city streets and parking lots before flowing into Mill Creek.

Narrative fish community evaluations, based on IBI and MIwb scores, are provided in Table 24. Descriptive evaluations allow for the comparison of fish communities from site to site. Three (13%) sites scored exceptional fish communities out of the 24 total sites. Fifty-seven percent of fish sites scored within the narrative very good to marginally good range. Sites that were scored within the exceptional, very good, good and marginally good categories would meet WWH expectations for fish. Thirty percent were found to have only fair to poor fish communities which were found to be degraded predominately from habitat alterations, siltation due to agricultural or urban storm water runoff and organic enrichment due to illicit discharges (Table 2 and Table 24).

Table 24. Fish community status for stations sampled in the Mill Creek basin based on data collected in 2009, 2012 and 2013. The Index of Biotic Integrity (IBI) and Modified Index of well-being (MIwb) are scores based on the performance of the fish community. The narrative fish evaluations (Exceptional, Very Good, etc.) were based upon the corresponding IBI and MIwb relative to the drainage area, ecoregion, and the assigned aquatic life use. The Qualitative Habitat Evaluation Index (QHEI) is a measure of the ability of the physical habitat to support a biotic community. Relative numbers and weights are per 0.3 km for wading and headwater sites, and per 1.0 km for boat sites.

River Mile		Number of Species	Relative Weight (kg)	Rel. No. minus tolerants	(all) Relative Number	QHEI	IBI	MIwb	Narratives			Drainage Area (mi^2)
02-109-000 Mill Creek												
Warmwater												
42.56	H	25.00	NA	1232.00	1940.00	61.00	50	NA	Exceptional	:	NA	11.20
39.20	W	23.00	18.50	637.50	1311.00	61.50	43	8.60	Good	:	Good	21.90
36.05	W	24.00	17.90	860.30	1611.00	66.50	43	9.10	Good	:	Very Good	38.00
24.74	W	25.00	21.30	845.30	1254.80	72.80	46	9.30	Very Good	:	Very Good	62.00
21.65	W	22.00	11.20	234.00	357.80	76.80	44	8.60	Good	:	Good	73.00
19.00	W	27.00	15.00	357.80	513.00	68.80	49	9.10	Very Good	:	Very Good	80.00
18.14	W	20.00	23.90	193.50	408.00	64.50	36	7.20	Marginally Good	:	Fair	88.00
16.80	W	25.00	4.30	345.80	475.50	74.30	48	8.30	Very Good	:	Good	89.00
14.54	W	24.00	2.70	435.80	1220.30	66.50	34	7.80	Fair	:	Marginally Good	94.70
12.17	W	28.00	13.60	259.50	476.30	75.30	42	8.90	Good	:	Very Good	102.00
11.70	W	28.00	39.50	334.50	470.30	76.80	47	9.60	Very Good	:	Exceptional	106.00
9.42	W	32.00	44.60	456.60	871.20	79.00	41	9.40	Good	:	Exceptional	109.00
9.20	W	28.00	29.30	631.50	1188.40	81.50	40	9.00	Good	:	Very Good	115.00

River Mile		Number of Species	Relative Weight (kg)	Rel. No. minus tolerants	(all) Relative Number	QHEI	IBI	MIwb	Narratives			Drainage Area (mi^2)
02-109-000 Mill Creek												
6.89	W	26.00	48.30	533.80	958.00	83.30	41	9.20	Good	:	Very Good	118.00
4.21	W	26.00	64.30	762.80	996.00	91.30	49	9.70	Very Good	:	Exceptional	130.00
3.90	W	26.00	93.00	965.30	1270.50	91.80	52	10.10	Exceptional	:	Exceptional	167.00
1.57	W	25.00	109.50	522.80	613.50	87.00	51	9.70	Exceptional	:	Exceptional	178.00
02-109-001 Blues Creek												
Modified Channel Modified												
16.30	H	14.00	NA	690.00	8586.00	41.00	30	NA	Fair	:	NA	8.90
Warmwater												
10.15	H	12.00	NA	88.00	256.00	47.00	30	NA	Fair	:	NA	17.50
2.00	H	14.00	1.50	188.00	666.00	66.00	33	5.70	Fair	:	Poor	34.10
0.60	H	18.00	2.00	265.00	653.00	71.50	39	7.20	Marginally Good	:	Fair	37.10
02-109-005 Crosses Run												
Warmwater												
0.80	H	12.00	NA	180.00	808.00	75.30	34	NA	Fair	:	NA	4.30
02-109-015 Town Run												
Warmwater												
0.20	H	5.00	NA	24.00	240.00	50.00	20	NA	Poor	:	NA	4.30
0.70	H	5.00	NA	18.00	159.00	44.00	22	NA	Poor	:	NA	4.30

Narrative ranges and WWH biocriteria (bold) for the ECBP ecoregion. Exceptional (EWH biocriteria), very good (EWH nonsignificant departure), poor and very poor evaluations are common statewide. For WWH, the ranges of marginally good and nonsignificant departure are the same.

IBI			**MIwb**		**Narrative Evaluation**
Headwater	Wading	Boat	Wading	Boat	
50-60	50-60	48-60	≥9.4	≥9.6	Exceptional
46-49	46-49	44-47	8.9-9.3	9.1-9.5	Very Good
Eastern Corn Belt Plains					
40-45	**40**-45	**42**-43	**8.3**-8.8	**8.5**-9.0	Good
36-39	36-39	38-41	7.8-8.2	8.0-8.4	Marginally Good
28-35	28-35	26-37	5.9-7.7	6.4-7.9	Fair
18-27	18-27	16-25	4.5-5.8	5.0-6.3	Poor
12-17	12-17	12-15	0-4.4	0-4.9	Very Poor

NA - Headwater site, MIwb is not applicable
H - Headwater site
W - Wading site

Fish Community Trends

Thirteen Mill Creek basin fish sites previously sampled in 1995 were analyzed for trends. Comparisons for selected sites yielded both positive and negative IBI trends between 1995 and 2012 (Figure 27). Two Mill Creek sites (RMs 16.8 and 11.7) displayed significant improvements in fish community IBI scores between the seventeen years of assessment. The sample site adjacent to Waldo Road (RM16.8) was not attaining its designated aquatic life use in 1995, scoring a poor MIwb (5.2) and a low IBI (36) with only 189 total fish captured among 18 species (66% of the catch were pollution tolerant individuals). This was the first site sampled downstream from Marysville city limits. During the 1995 study there were two low-head dams on Mill Creek relatively close together (at Maple Street and Cherry Street), both just upstream from where the old WWTP discharged poorly treated effluent. The combination of dewatering and poor water quality resulted in impairment at RM 16.8. The city of Marysville has effectively dealt with these issues by removing the dams and updating and relocating the WWTP further upstream to RM 9.25. The city has also installed an inflatable dam and pump house leading to an upground reservoir for drinking water further downstream at RM 21.65. The inflatable dam appears to be having little to no lasting ecological effect on Mill Creek. An exceptional IBI (48) was scored at RM 16.8 in 2012 with 351 total fish captured (30 species) of which only 30% were found to be pollution tolerant (Appendix C and Table 2).

The fish community inhabiting Crosses Run and in Mill Creek (RM 11.7) downstream from Crosses Run displayed big improvements from historical collections. Crosses Run improved from having a poor quality fish community in 1995 (IBI=18, 3 species and 13 total fish) to narrowly missing WWH ALU attainment in 2012 (IBI=34, 12 species and 404 total fish); however, the quality of the macroinvertebrate community was still poor due to toxic levels of pesticides and metals found in the sediments and elevated levels of water column nutrients downstream from the Scotts Company. In 1995 an IBI of 34 was scored in Mill Creek at RM 11.7 downstream from Crosses Run with about 50% of the biomass tolerant of pollution. An IBI of 47 was scored in 2012 with only about 27% of the fish community being pollution tolerant individuals, reflecting a substantial swing towards a higher quality fish community (Appendix B).

At State Route 36 (RM 14.54), substrates in Mill Creek are silt laden and the overall depth is much shallower than other sections up and downstream (Appendix A). Drought conditions during 2012 exacerbated an already silty and shallow section of Mill Creek. Habitat conditions remained similar to what was encountered during the 1995 survey with moderate to heavy amounts of silt throughout the sampling zone (Figure 22). IBI scores in this section decreased from 42 in 1995 to 34 in 2012. The percentage of pollution tolerant fish collected increased from an average of 43% between sample passes in 1995 to 62% in 2012 (Appendix C).

Species richness, as shown by similar IBI scores between survey years in the upper and lower ends of Mill Creek indicate little or no change in those areas (Figure 27). However, when looking at the weighted balance of those species within the fish community through MIwb trends analysis, a larger overall improvement can be seen in Mill Creek (Figure 24). Numbers of individual species sensitive to pollution, such as golden redhorse (*Moxostoma erythrurum*) and banded darter (*Etheostoma zonale*),

reflected significant increases in abundance between 1995 and 2012, representing more tangible evidence of improved water quality throughout Mill Creek (Figure 29 and Figure 30).

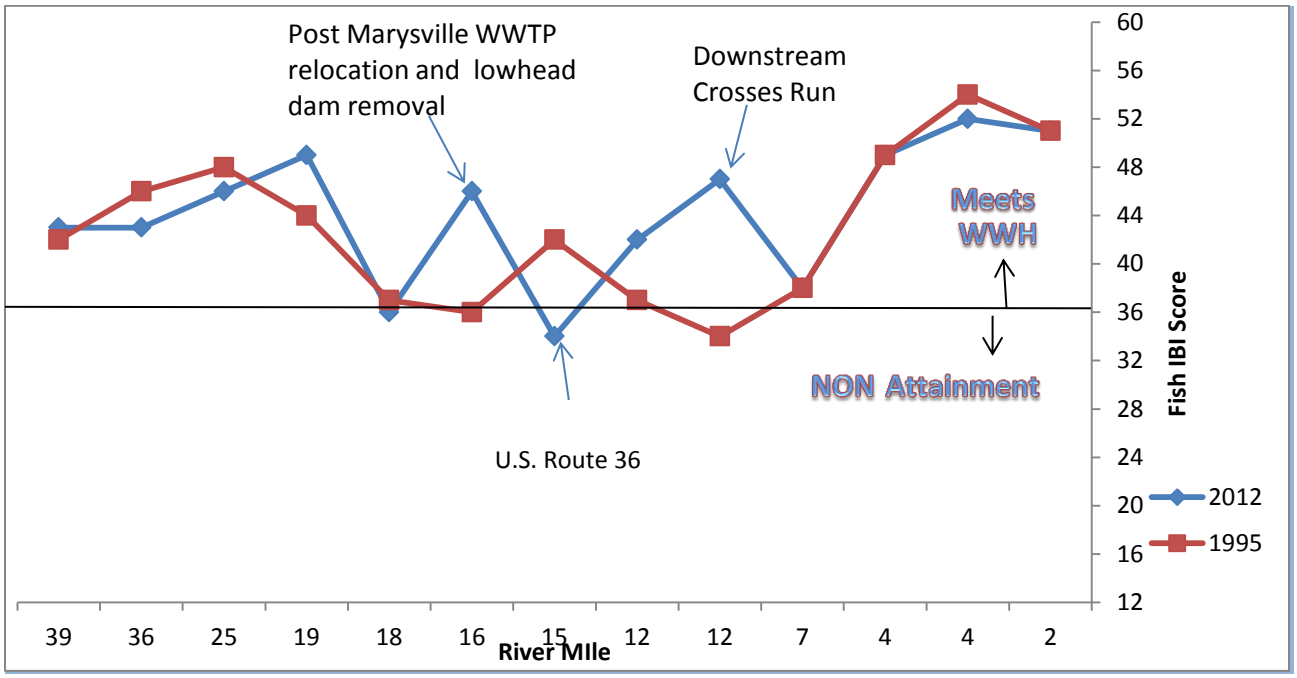


Figure 27. Mill Creek IBI trends listed by RM, 1995 and 2012.

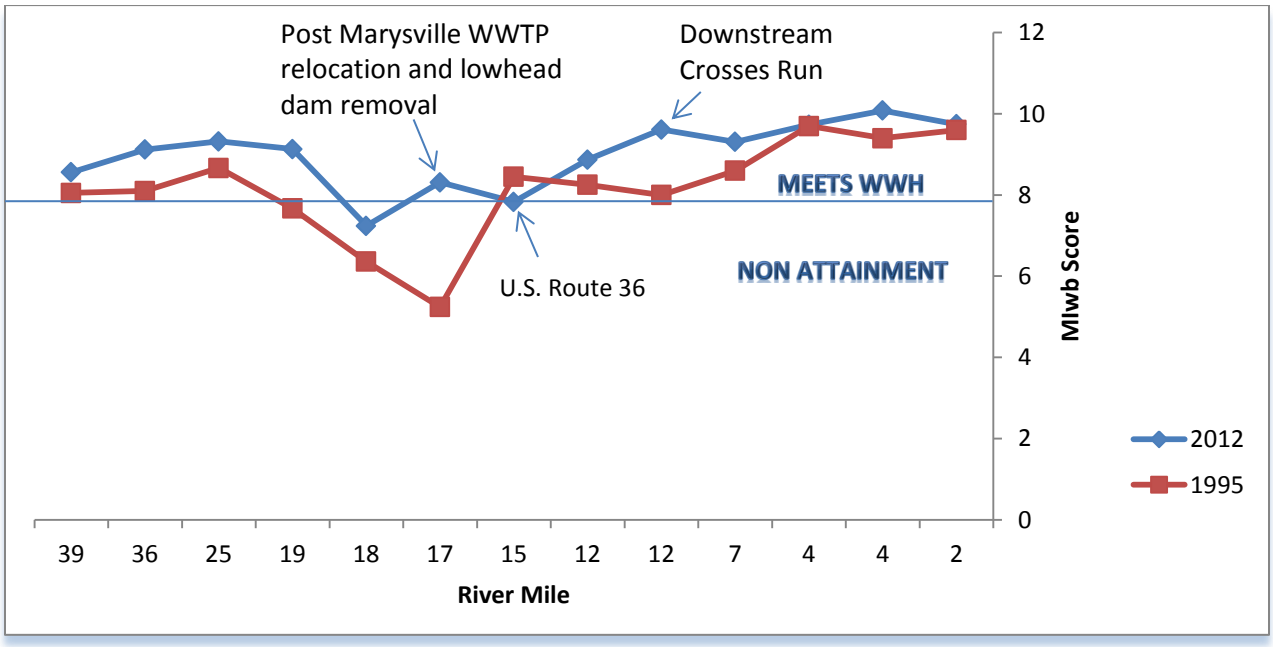


Figure 28. Mill Creek MIwb trends listed by RM, 1995 and 2012.

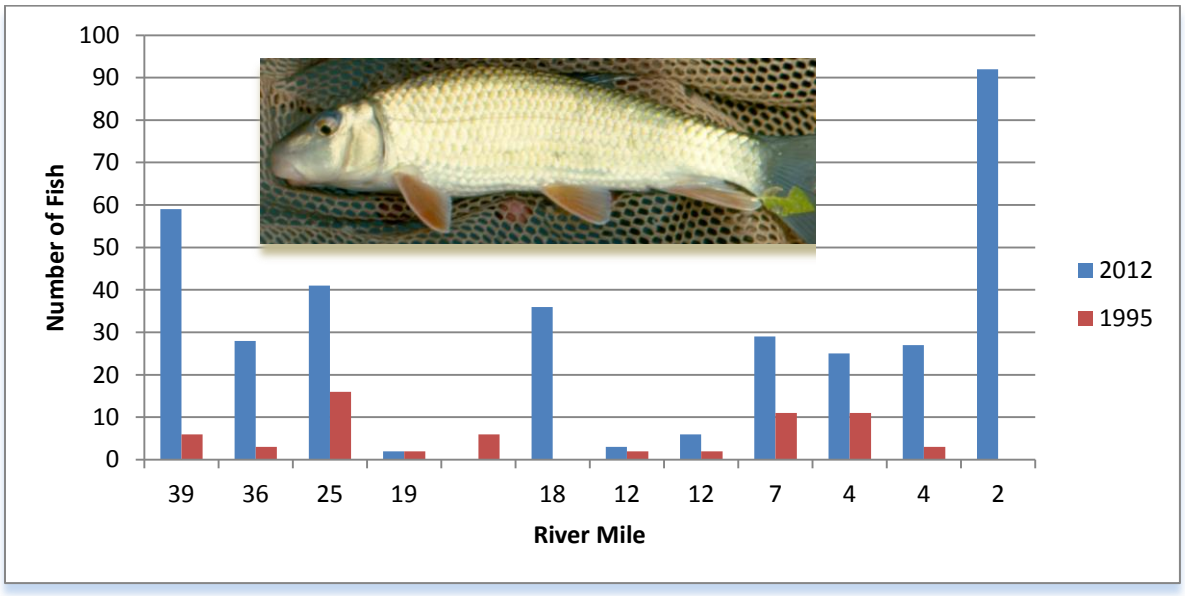


Figure 29. Number of golden redhorse suckers caught per greatest sample pass at sites replicated from 1995 and 2012.

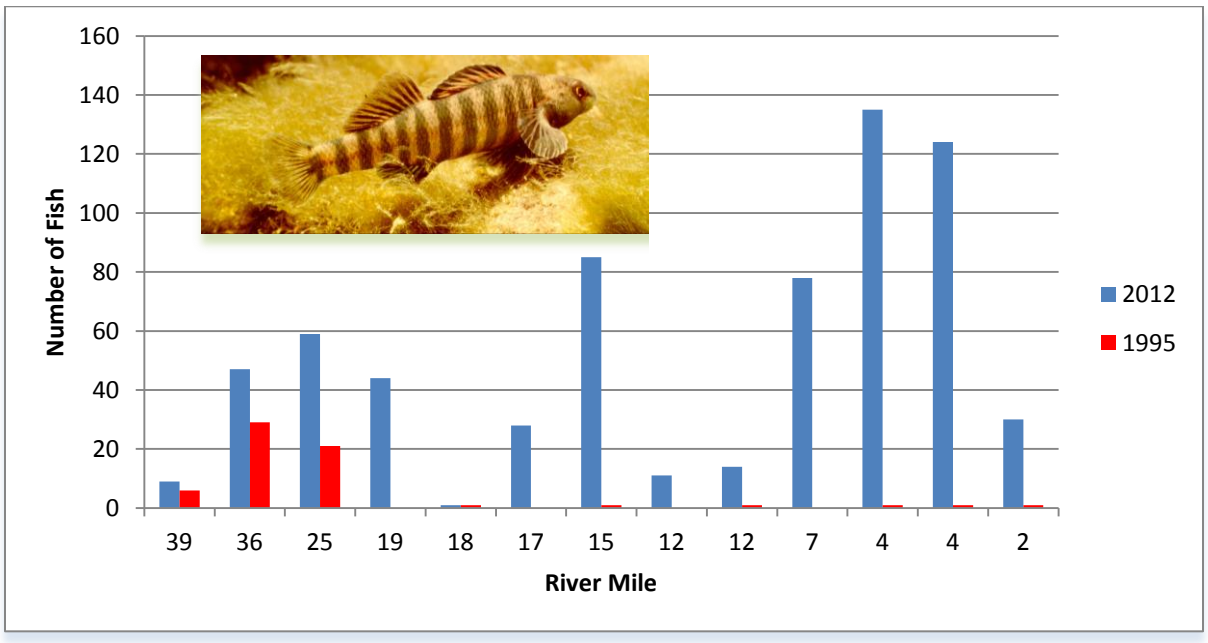


Figure 30. Number of banded darters caught per greatest sample pass at sites replicated from 1995-2012.

Macroinvertebrate Community

Macroinvertebrate communities were evaluated at 24 stations in the Mill Creek study area during 2009, 2012 and 2013 (Table 1 and Appendices D and E). Seventeen of 24 locations at least marginally supported benthic communities consistent with ecoregional expectations (71%). Community performance was evaluated as exceptional at 6 stations, very good at 3, good at 4, marginally good at 4, fair at 3, poor at 3, and very poor at 1. Seven sites were not achieving the applicable biocriterion; Blues Creek RMs 16.30 and 10.15, Crosses Run RM 0.80, Mill Creek RMs 18.2 and 9.2, and Town Run RMs 0.75 and 0.21.

At the Mill Creek sites, the longitudinal trend in sensitive taxa mirrored the ICI and was illustrative of macroinvertebrate community condition where an ICI score was not available (Figure 31). In particular, the sensitive taxa showed declines within the city of Marysville followed by significant recovery before declining again downstream from Crosses Run and the Marysville WRF.

Urban storm water runoff and illicit discharges, particularly via Town Run, were likely contributors to a decline in macroinvertebrate community condition within the Marysville city limits. A marginally good community was present at RM 19.00, where ten Ephemeroptera, Plecoptera and Trichoptera (EPT) and five sensitive taxa were collected. At the next site (RM 18.20), the macroinvertebrate community was negatively affected by degraded water quality, slow current and heavy sedimentation. Just twenty-five taxa and three sensitive taxa were collected from natural substrates. The macroinvertebrate community met or exceeded WWH expectations at the next three sites (RMs 16.80, 14.54 and 12.17) downstream from the city of Marysville. The ICI score at RM 16.80 was in the excellent range (ICI= 46), but the collection of just five sensitive taxa suggested a lingering impact related to upstream pollution sources noted previously. Additional improvement was evident in the qualitative natural substrate sampling at RM 14.54, which was reflective of a good community condition. Eleven sensitive taxa were recorded and the total number of taxa (63) was the highest number collected from natural substrates at a single site for the entire survey.

The macroinvertebrate community was in very good condition (ICI = 44) at RM 12.17, upstream from Crosses Run but only marginally met expectations (ICI =34) downstream at RM 11.70. The ten point decline in the ICI score at RM 11.70 indicated an impact related to the legacy pollutants in the sediment in Crosses Run likely from the Scotts Company manufacturing facilities. Qualitative sampling also showed a decline in overall macroinvertebrate community condition.

Downstream from the Marysville WRF (RM 9.20), the macroinvertebrate community declined further and yielded an ICI score in the fair range (ICI = 28) with just six sensitive taxa in the qualitative sample. A high percentage of pollution tolerant taxa, principally limpets and aquatic worms, collected from the artificial substrates suggested the Marysville WRF effluent was negatively affecting the macroinvertebrate community. Potential causes included nutrient enrichment and elevated TDS contained in the effluent. It should be noted that the WRF discharge may have exacerbated a lingering impact from Crosses Run.

The macroinvertebrate community at the four remaining Mill Creek sites produced ICI scores in the good to exceptional range beginning at RM 6.89. While WWH expectations were met at these sites, the taxa diversity at RM 1.57 was markedly reduced compared to RMs 4.05 and 3.90 (Table 25). The variability in this reach indicated that land use stressors affected the stability of macroinvertebrate communities in Mill Creek.

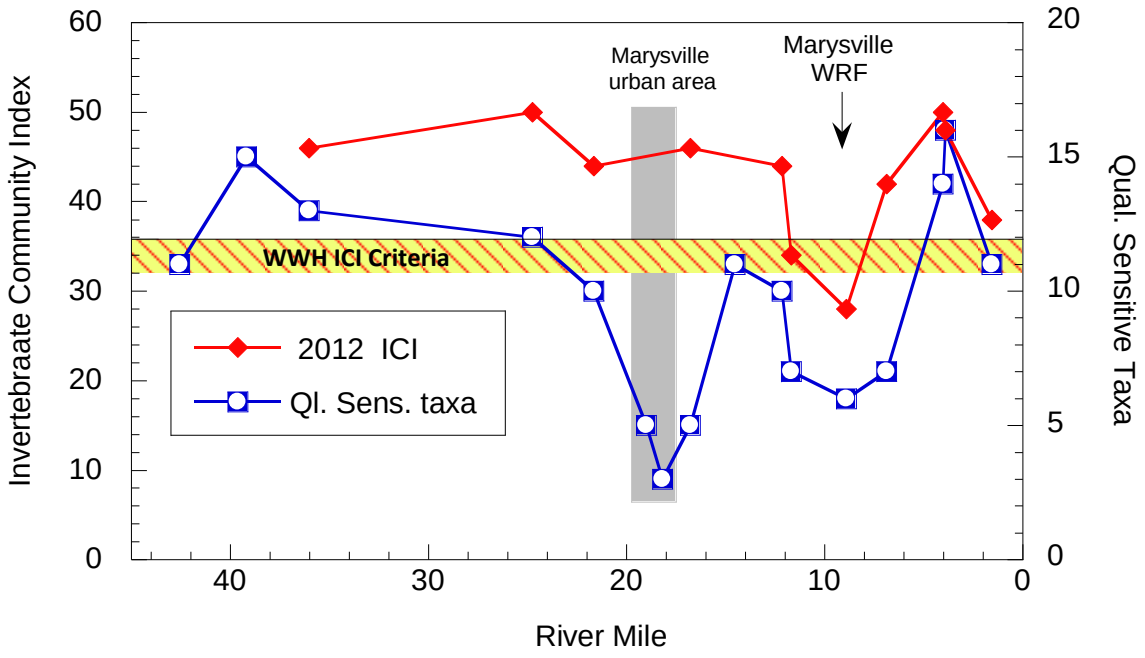


Figure 31. Longitudinal trend of Invertebrate Community Index (ICI) scores and number of sensitive taxa collected from Mill Creek, June- October, 2012.

In 2009, poor quality macroinvertebrate communities were documented in Town Run. Septic conditions were encountered at both sampling locations (RMs 0.21 and 0.75); additionally, the habitat at the downstream site was severely degraded. No sampling was conducted in Town Run during 2013 owing to intermittence at the uppermost location (RM 0.75) and severely degraded/septic conditions encountered at RM 0.21.

Crosses Run at RM 0.8 showed the effects of previous channelization in the predominantly fine sediments and occasional rubble at the site. Qualitative sampling yielded a poor quality community assemblage. A few heptageniid mayflies and hydropsychid caddisflies were collected, but no other EPT taxa were recorded despite acceptable, but limited microhabitats. A lingering toxic impact from operations at the Scott's Company could not be ruled out; however, low flow conditions and less than optimal habitat appeared to be the principle restrictions on development of a more diverse macroinvertebrate community.

The headwater portion of Blues Creek produced fair and poor macroinvertebrate assemblages at RMs 16.30 and 10.15, respectively. The upper site had shallow stream flow confined within a channelized waterway. Multiple factors were reflective of a highly enriched condition and suggested wide diurnal dissolved oxygen range. Filamentous algae lined the stream margins and large numbers of flatworms were present. Eight EPT taxa were recorded but included just one pollution sensitive taxon (*Procloeon* sp.).

A severe habitat impact precluded an assessment of water quality effects on the macroinvertebrate community at RM 10.15. The stream was channelized with non-discernible current, and in-stream habitat was comprised of mud and woody debris. A low density and diversity macroinvertebrate community was reflective of the limiting habitat. Qualitative sampling produced 27 taxa with just one EPT taxon.

The macroinvertebrate community was in marginally good condition at the two remaining Blues Creek sites (RMs 2.00 and 0.60), due to improved habitat and assimilation of agricultural nutrients contributed in the upper watershed. There was no impact from the Ostrander WWTP discharge since it discharges directly to Mill Creek. Qualitative sampling of the two sites produced similar diversities of taxa, including 11 and 10 EPT taxa at RMs 2.00 and 0.60, respectively.

Table 25. Summary of macroinvertebrate data collected from artificial substrates (quantitative sampling) and natural substrates (qualitative sampling) in the Mill Creek study area, June to October, 2012.

Stream RM	Dr. Ar. (sq. mi.)	Quant. Taxa	Qual. Taxa	EPT Ql. / Total	Sensitive Taxa Ql. / Total	Density Ql. / Qt.	Predominant Organisms on the Natural Substrates With Tolerance Category(ies)	ICI	Narrative Evaluation
Mill Creek (02-109-000)									
42.56	11.1	-	61	16	11	H	Caddisflies (F,MI), midges (F), mayflies (F)	-	Good
39.20	22.5	-	52	15	15	L	Midges (F)	-	Good
36.05	38.0	45	57	17 / 20	13 / 20	M / 3629	Midges (F), mayflies (F)	46	Excellent
24.74	62.0	36	40	14 / 15	12 / 14	H / 2783	Mayflies (F), water penny beetles (MI)	50	Excellent
21.65	65.0	30	35	12 / 13	10 / 11	M / 965	Baetid mayflies (F), hydropsychid caddisflies (F)	44	Very Good
19.00	80.0	-	43	10	5	M	Caddisflies (MI), mayflies (F)	-	Marginally Good
18.20	82.0	29	25	7	3	M	Mayflies (F)	-	Fair
16.80	88.0	38	43	10 / 11	5 / 6	M / 1810	Baetid mayflies (F), hydropsychid caddisflies (F)	46	Excellent
14.54	94.7	54	63	14	11	M	Midges (F)	-	Good
12.17	102.0	45	48	12 / 12	10 / 11	M / 2154	Caddisflies (F), mayflies (F)	44	Very Good
11.70	107.0	31	49	11 / 12	7 / 8	L / 1021	Mayflies (F), midges (F)	34	Marginally Good
9.20	115.0	37	45	11 / 12	6 / 8	M / 2769	Aquatic worms (T), mayflies (F), hydropsychid caddisflies (F), midges (F), limpets (F)	28	Fair
6.89	120.0	40	48	12 / 13	7 / 10	M / 2139	Hydropsychid caddisflies (F), river snails (MI)	42	Very Good

Stream RM	Dr. Ar. (sq. mi.)	Quant. Taxa	Qual. Taxa	EPT Ql. / Total	Sensitive Taxa Ql. / Total	Density Ql. / Qt.	Predominant Organisms on the Natural Substrates With Tolerance Category(ies)	ICI	Narrative Evaluation
4.21	130.0	46	53	17 / 20	14 / 17	M / 2898	Caddisflies (F), midges (F), mayflies (F)	50	Excellent
3.90	167.0	41	57	18 / 21	16 / 18	M / 2945	Caddisflies (F), midges (F), baetid mayflies (F)	48	Excellent
1.57	178.0	30	43	14 / 18	11 / 14	M / 1416	Hydropsychid caddisflies (F), midges (F)	38	Good
Blues Creek (02-109-001)									
16.30	8.4	-	45	8	1	H	Flatworms (F)	-	Fair
10.15	16.7	-	27	1	0	L	Fingernail Clams (F)	-	Poor
2.00	33.8	-	45	11	7	L	Midges (F)	-	Marginally Good
0.60	37.1	-	42	10	8	M	Midges (F)	-	Marginally Good
Crosses Run (02-109-005)									
0.80	4.4	-	42	3	1	M	Midges (F)	-	Poor

RM: River Mile.
Dr. Ar.: Drainage Area
Sensitive Taxa: Taxa listed on the Ohio EPA Macroinvertebrate Taxa List as MI (moderately intolerant) or I (intolerant).
Qt.: Quantitative sample collected on Hester-Dendy artificial substrates, density is expressed in organisms per square foot.
Density Ql./Qt.: Qualitative sample relative density where: L=Low, M=Moderate, H=High.
Tolerance Categories: VT=Very Tolerant, T=Tolerant, MT=Moderately Tolerant, F=Facultative, MI=Moderately Intolerant, I=Intolerant

Macroinvertebrate Trends

The 2011 replacement of the Maryville WWTP with the Maryville WRF was evident in comparing results of a 1995 Mill Creek survey and the 2012 macroinvertebrate sampling results. The effect of treated effluent on the macroinvertebrate community was modestly reduced; however, significant impairment was present nine miles downstream from the original treatment facility where the WRF now discharges (RM 18.2) (Figure 32). ICI scores from thirteen duplicated mainstem sampling sites averaged 40.7 and 38.5 during the 2012 and 1995 surveys, respectively (Table 26). Both ICI averages were in the warmwater habitat range and within the range of acceptable variability (i.e., +/- 4 ICI points) for the index. Like the ICI trend, comparison of the qualitative sampling results from the two surveys revealed similar diversities in the average number of total taxa and EPT taxa collected from the natural substrates. Overall, macroinvertebrate community performance throughout Mill Creek was similar between surveys.

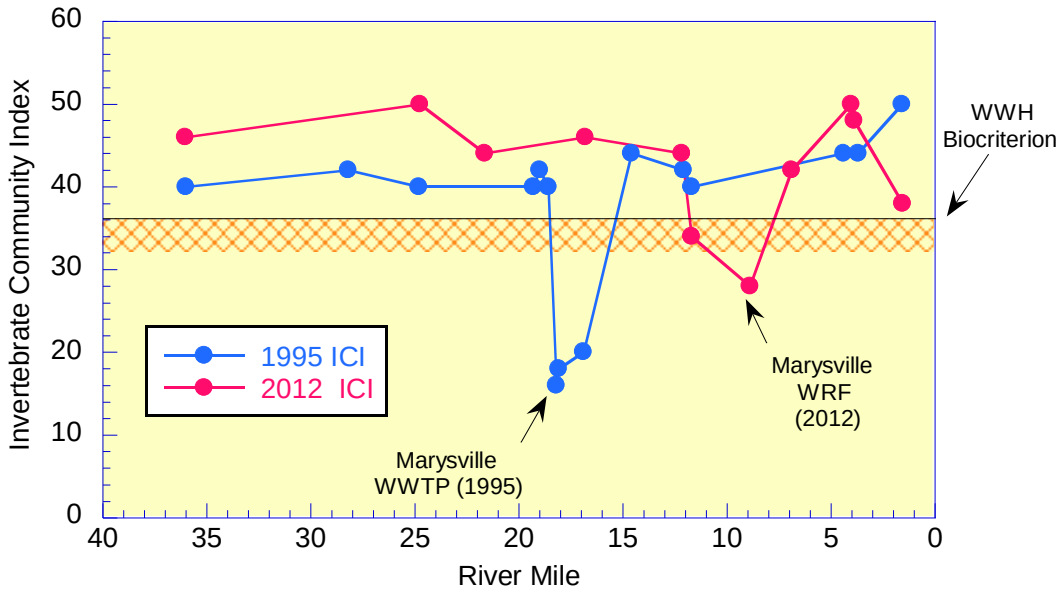


Figure 32. ICI scoring trends in Mill Creek, 1995 and 2012.

Table 26. Average ICI scores and average number of qualitative taxa and EPT taxa collected from the natural substrates from thirteen similar Mill Creek mainstem sites in 1995 and 2012.

Year	ICI score	# Qual taxa	# EPT taxa
2012	**40.7**	47.8	13.2
1995	**38.5**	46.2	11.8

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