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Biological and Water Quality Study of the Sandusky Bay Tributaries, 2009

Watershed Assessment Units 0410001 101, 102, 112, 113, and 114

Erie, Sandusky, and Seneca Counties

OHIO EPA Technical Report EAS/2010-4-6

Ted Strickland, Governor
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Biological and Water Quality Survey of the Sandusky Bay Tributaries 2009

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OEPA Report DSW/EAS 2010-4-6

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SUMMARY

The Sandusky Bay tributaries study area, including the Green Creek, Pickerel Creek, Raccoon Creek, Mills Creek, and Pipe Creek watersheds (Figure 1), was originally part of the lower Sandusky River Total Maximum Daily Load (TMDL) survey area. However, in spring 2009, the decision was made to partition a portion of the survey into a separate study area. Focusing on this smaller area helped Ohio EPA better coordinate with an ongoing investigation regarding a higher than expected number of childhood cancer diagnoses in Eastern Sandusky County. Ohio EPA coordinated with the Ohio Department of Health (ODH) to ensure that the study area and selected parameters for analysis would assist the public health agencies involved in the childhood cancer investigation. Focusing on this smaller area enabled Ohio EPA to provide TMDL results in spring 2010, one year ahead of schedule. This report is the culmination of that work.

All rivers and streams in Ohio are used for various purposes such as recreation or to support aquatic life. Ohio EPA evaluates each stream to determine the appropriate use designation and to determine whether the use meets the goals of the federal Clean Water Act. Twenty-one streams in the study area were evaluated for aquatic life and recreational use potential in 2009 (see Figure 1 and Table 1 for sampling locations). The Warmwater Habitat (WWH) aquatic life use designation was deemed appropriate for eighteen streams in the study area and the Coldwater Habitat (CWH) aquatic life use designation was deemed appropriate for four streams. Two streams, Fishing Creek and Buck Creek, were evaluated for the first time and received the WWH aquatic life use designation. Beaver Creek had historically been assigned the CWH aquatic life use designation without biological sampling. Sampling results in 2009 demonstrated a WWH community in Beaver Creek, and thus the aquatic life use should be WWH and not CWH. The CWH aquatic life use was confirmed for Cold Creek, Green Creek, and Little Pickerel Creek. Raccoon Creek, Mills Creek and Caswell Ditch are also being recommended for Primary Contact Recreation (PCR) rather than the existing Secondary Contact Recreation (SCR) use. All remaining streams in this study should retain the PCR use or SCR use, along with the Agricultural and Industrial uses, and, if applicable, the Public Water Supply use (PWS) (Tables 17 & 18).

Two-thirds of the sites within the Sandusky Bay tributaries study area did not meet the Clean Water Act biological integrity goal, with 30% in full attainment, 28% in partial attainment, and 42% in non-attainment of the assigned/recommended aquatic life use designation (Table 2). While 33% of the Sandusky River mainstem was in full attainment, siltation and eutrophication from the surrounding agricultural activities combined with point sources, such as the Fremont Wastewater Treatment Plant (WWTP), contributed to the partial attainment (17%) and non-attainment (50%) noted in the lower reach of the mainstem. The Ballville Dam impounded a portion of the Sandusky River, resulting in non-attainment within the impounded portion of river. The Sandusky Bay tributaries were negatively influenced by the surrounding agricultural landscape and poor sewage treatment, with only 30% of sites in full attainment, 30% in partial attainment and 40% in non-attainment.

Specific point source and nonpoint source pollution issues which should be addressed to improve water quality throughout the Sandusky Bay tributaries include:

- The Bellevue WWTP and the Clyde WWTP received significant upgrades in 2005 and 2006, respectively. However, the Bellevue WWTP continues to discharge excessive nutrients to Snyder's Ditch, resulting in eutrophication throughout Mills Creek. Nutrients from the Clyde WWTP contributed to eutrophication in Raccoon Creek. Future National Pollutant Discharge Elimination System (NPDES) limits for these facilities should include nutrient limits.

- The Ballville Dam impounds a segment of the Sandusky River to provide drinking water to the city of Fremont. However, this impoundment also results in non-attainment of WWH biocriteria through the impounded reach. The city of Fremont has plans to construct an above ground reservoir for drinking water. The Army Corps of Engineers is currently developing plans to address the fish migration impediment caused by the dam; this may include full dam removal.

- Failing home sewage treatment systems (HSTS) and unsewered areas, such as in the vicinity of Bark Creek, contributed to nutrient and organic enrichment in several areas. The sources should be identified and coordination should occur with the appropriate county health departments to correct the problems.

- Livestock access to Mills Creek and South Creek contributed to organic and nutrient enrichment in these streams. Coordination with local Soil and Water Conservation Districts (SWCDs) should occur to educate the farming community about proper livestock management.

- Crop production with subsurface drainage was the most common nonpoint source of impairment throughout the study area. Increased siltation/sedimentation, nutrient enrichment and channel erosion/incision from crop production contributed to impairment in Mills Creek, Little Pickerel Creek, Pickerel Creek, Raccoon Creek, South Creek, Beaver Creek, Green Creek, Muskellunge Creek, Bark Creek, Little Muddy Creek, and Fishing Creek. Outreach efforts to the local farming community with SWCDs should be undertaken to encourage best management practices (BMPs) aimed at addressing the effects of agricultural activities on water quality.

- The partial attainment of Buck Creek is likely attributable to siltation and embedded substrates from upstream crop production combined with legacy pesticide usage. Historical macroinvertebrate sampling indicated pesticide toxicity, and sediment sampling in 2009 revealed the presence of legacy pesticides. SWCDs should coordinate efforts to address proper pesticide application and disposal throughout the agricultural community.

In addition to the various point and nonpoint source pollution concerns identified during the survey, several streams exhibited unique aquatic assemblages due to strong ground water influences. Cold Creek is artificially aerated by Ohio Department of Natural Resources' (ODNR) Castalia State Fish Hatchery. This supports raising trout and hosts several trout clubs, while Little Pickerel Creek has a private trout hatchery and trout club. The presence of trout within these streams provides unique recreational opportunities for local residents.

Table 1. Sandusky Bay tributaries sampling locations, 2009. Site number corresponds to sampling location on Figure 1.

Site Number	River	River Mile	Location	Drainage Area (mi2)	Latitude	Longitude
46	Albright Ditch	0.60	State Route 228	3.8	41.220204	-83.015308
1	Bark Creek	3.20	Kelley Road (CR 245)	10.0	41.381420	-83.070420
2	Beaver Creek	4.00	State Route 101	20.9	41.225100	-83.025100
3	Beaver Creek	3.48	State Route 101	43.4	41.229650	-83.020920
63	Beaver Creek Reservoir	0.00	Beaver Creek Reservoir	10.0	41.237720	-83.020747
4	Buck Run	0.20	Twp. Road 223	4.5	41.328650	-82.983220
5	Caswell Ditch	0.85	Bogart Road	3.9	41.397550	-82.747410
6	Cold Creek	0.36	Bardshar Road	2.9	41.443060	-82.772720
8	Emerson Creek	1.83	Twp. Road 179	22.0	41.229850	-82.994810
9	Emerson Creek (Royer Ditch)	10.12	County Road 46	6.4	41.190000	-82.894700
7	Emerson Creek (Royer Ditch)	6.85	Roy Meyers Road	15.2	41.220800	-82.917900
10	Fishing Creek	0.20	Weickert Road	7.0	41.437430	-83.096670
11	Green Creek	18.80	County Road 34	53.0	41.241250	-83.084320
12	Green Creek	12.85	Dewey Road	73.0	41.306750	-83.057720
13	Green Creek	9.08	County Road 229	74.0	41.341700	-83.060600
14	Green Creek	3.90	Twp. Road 239 (Balsizer Road)	78.3	41.378300	-83.029100
15	Little Muddy Creek	2.50	Kline Road	25.0	41.438570	-83.086950
16	Little Pickerel Creek	2.00	Yetter Road	5.5	41.409400	-82.882490
17	Mills Creek	10.40	Portland Road	21.0	41.341950	-82.808810
18	Mills Creek	6.03	State Route 99	29.0	41.391750	-82.770710
19	Mills Creek	5.20	Bogart Road	29.0	41.397800	-82.757900
20	Mills Creek	3.70	Strub Road	35.0	41.409450	-82.736810
21	Mills Creek	1.35	Perkins Avenue	41.0	41.433300	-82.732710
57	Mills Creek	0.07	Monroe Street	42.0	41.446183	-82.735980
22	Muddy Creek	1.23	East side of State Route 53	110.0	41.452090	-83.053720
23	Muskellunge Creek	5.40	Near Fremont at Spieldenner Road	37.0	41.356950	-83.159620
24	Muskellunge Creek	1.23	Near Fremont at Fangboner Road	44.0	41.390650	-83.121620
25	Pickerel Creek	6.26	Reinicke Road (Twp. Road 233)	9.5	41.357700	-82.968700
26	Pickerel Creek	3.35	Twp. Road 247	43.7	41.387010	-82.958690
27	Pipe Creek	10.81	Harris Road	9.4	41.338400	-82.748900
28	Pipe Creek	8.18	Patten Tract Road	14.7	41.365300	-82.727900
29	Pipe Creek	6.66	Schenk Road	18.4	41.379100	-82.707700
30	Pipe Creek	2.32	Columbus Avenue	22.8	41.429100	-82.695800
60	Pipe Creek	0.90	US 6	28.6	41.441246	-82.679394
52	Plum Brook	1.00	Perkins Road	6.8	41.420289	-82.640421
31	Raccoon Creek	13.26	Upst. Limerick Road	9.9	41.288050	-82.981790
32	Raccoon Creek	11.32	US 20	12.7	41.312550	-82.985520
54	Raccoon Creek	11.01	Clyde WWTP mix zone	13.2	41.317622	-82.985652
55	Raccoon Creek	10.76	Adjacent Clyde Dump	13.3	41.320143	-82.986562
33	Raccoon Creek	10.18	Twp. Road 223	13.8	41.328650	-82.987520
34	Raccoon Creek	5.45	Twp. Road 244 (Karbler Road)	23.6	41.379350	-82.992120
61	Raccoon Creek	1.10	Brugger Road	35.1	41.429361	-82.979381
62	Raccoon Creek Reservoir	0.00	Limerick Road	10.0	41.290053	-82.978434

Site Number	River	River Mile	Location	Drainage Area (mi2)	Latitude	Longitude
35	Sandusky River	18.05	Upstream Ballville dam	1255.0	41.326050	-83.136620
36	Sandusky River	17.70	Fremont upstream Roger Young	1255.0	41.326950	-83.130220
37	Sandusky River	15.40	Fremont at State Street	1260.0	41.346850	-83.111820
38	Sandusky River	12.96	Opposite Fremont Yacht Club	1264.0	41.370400	-83.098500
39	Sandusky River	4.70	Upstream Wightmans Grove	1330.0	41.429960	-83.061260
40	Sandusky River	1.00	Upstream bay confluence	1335.0	41.451900	-83.023500
41	Sawmill Creek	1.10	West of Huron Boos Road	13.5	41.402400	-82.598000
53	Snyder Ditch	5.00	Railroad Tracks	1.5	41.267707	-82.824167
49	Snyder Ditch	3.85	Goodrich Road	3.1	41.283424	-82.823898
56	Snyder Ditch	2.46	Knauss Road	4.3	41.302250	-82.814368
59	South Creek	11.70	Limerick Road	4.9	41.292539	-83.010056
58	South Creek	11.30	1672 CR 236 (Spayd Rd aka Sherman Rd)	5.1	41.297714	-83.012964
42	South Creek	7.92	County Road 229	7.1	41.342250	-83.018020
43	South Creek	4.04	Near Riley Center at Whitmore Road	18.1	41.391700	-83.009500
48	Strong Creek	2.90	Twp. Road 272	4.0	41.380019	-82.925870
47	Strong Creek	2.00	Twp. Road 268	4.6	41.388591	-82.935138
50	Taylor Ditch	2.70	Bogart Road	1.5	41.396071	-82.685499
51	Taylor Ditch	0.80	DeWitt Avenue	2.9	41.420227	-82.685817
44	Westerhouse Ditch	3.25	Snavely Road	9.6	41.183700	-83.006600
45	Westerhouse Ditch	0.63	Northeast of Lowell at State Route 19	16.2	41.213000	-83.022900

*The color of the site number corresponds to the narrative biological score (blue is exceptional to very good (meets EWH goals), green is good to marginally good (meets WWH goals), yellow is fair, orange is poor, and red is very poor (fair, poor, and very poor do not meet the goals of WWH). Gray sites were not assessed for biology or aquatic life use performance.

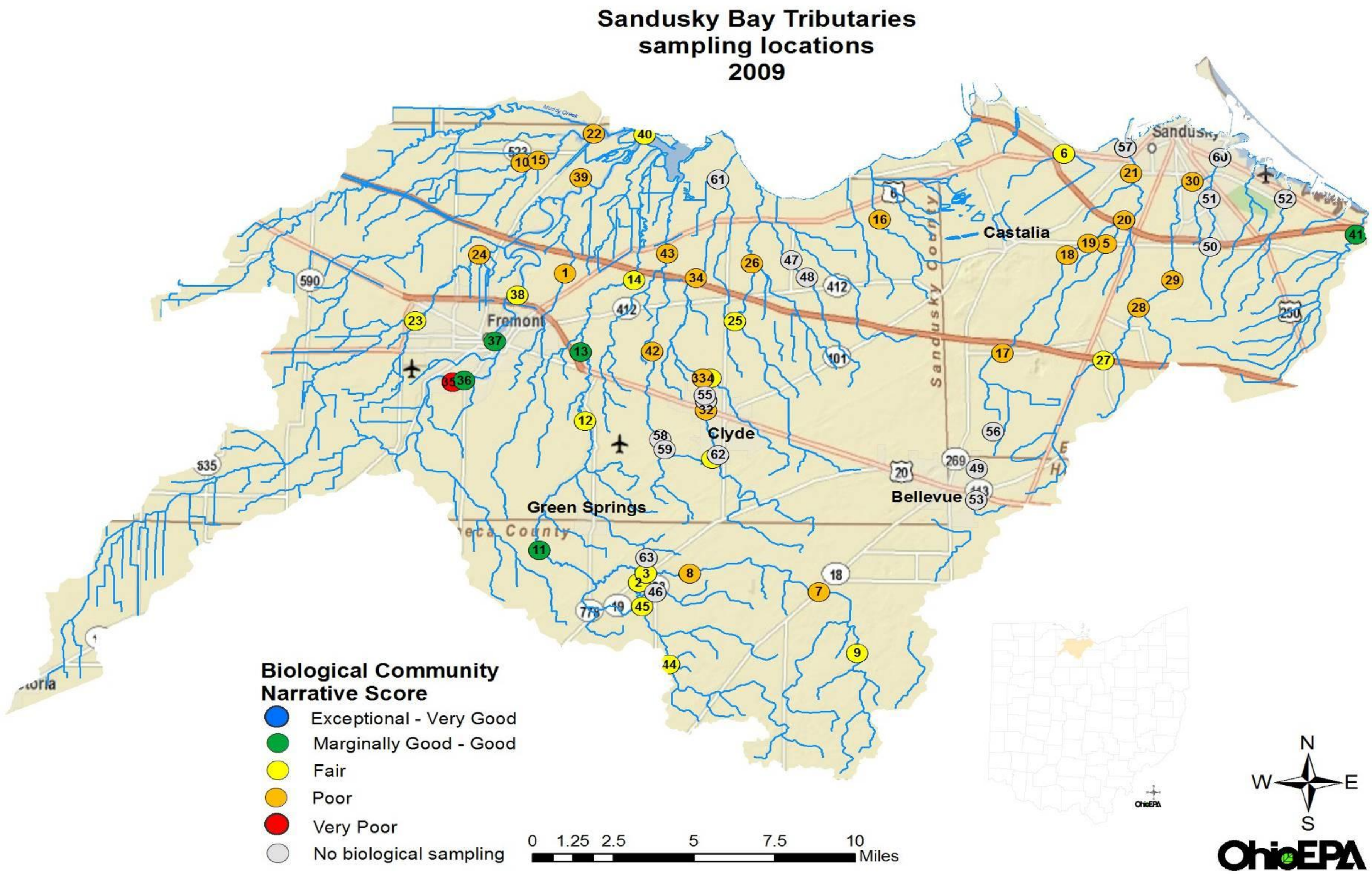


Figure 1. Sandusky Bay tributaries sampling locations and biological community performance, 2009. Site numbers correspond to Table 1.

Table 2. Aquatic life use attainment status for stations sampled in the Sandusky Bay tributaries basin based on data collected June-October 2009. 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 biotic community. The Qualitative Habitat Evaluation Index (QHEI) is a measure of the ability of the physical habitat to support a biotic community. Blue fill indicates sites assessed with lacustuary metrics and breakpoints; biocriteria are not applicable so attainment status is based on a narrative determination of the designated use using IBI, MIwb, ICI scores adapted to lacustuary and other attributes of the fish and macroinvertebrate community samples. All sites are within the Huron Erie Lake Plain ecoregion. If biological impairment has occurred, the cause(s) and source(s) of the impairment are noted. NA = not applicable.

Stream Name	RM[a] (STORET)	Drain. (mi²)	IBI	MIwb[b]	ICI[c]	QHEI	Status[d]	Causes	Sources
Sandusky River (05-001-000) ***Tributary to Lake Erie***				**WWH Existing**					
SANDUSKY RIVER UST. BALLVILLE DAM	18.05 [B] (U04T02)	1255	35	7.2*	6*	52	NON	Siltation Direct habitat alteration	Dam
SANDUSKY RIVER AT FREMONT UPSTREAM ROGER YOUNG PARK	16.8 [B] (U04S23)	1256	41	9.9	34	93	FULL		
SANDUSKY RIVER AT FREMONT @ STATE ST.	15.4 [B] (U04W11)	1260	38	9.7	G	67	FULL		
SANDUSKY RIVER OPPOSITE FREMONT YACHT CLUB	12.8 [B] (500890)	1264	26*	9.2	--	67	NON	Siltation Nutrient eutrophication (biological indicators)	Fremont WWTP Crop production with subsurface drainage
SANDUSKY RIVER UPSTREAM WIGHTMANS GROVE	5.5 [B] (U04S17)	1330	32*	8.7*	14*	60	NON	Nutrient eutrophication (biological indicators) Siltation Embedded substrates	Upstream crop production with subsurface drainage
SANDUSKY RIVER UPSTREAM BAY CONFLUENCE	1.3 [B] (201314)	1335	31*	7.5*	--	64.5	NON	Siltation Embedded substrates	Upstream crop production with subsurface drainage
HUC 10 – 0410001113 ***Muskellunge Creek – Sandusky River***									
HUC 12 – 041000111303 (Mouth Sandusky River)									
Bark Creek (05-002-000) ***Tributary to Sandusky River at RM 5.88***								**WWH Existing**	
BARK CREEK AT KELLEY RD. (CR 245)	3.20[H] (300671)	10.0	20*	N/A	F*	32.0	NON	Direct habitat alteration/ Hydromodification (ditched below water table) Organic enrichment (sewage) biological indicators Nutrient eutrophication (biological indicators) Siltation Embedded substrates Phosphorus (Total)	Crop production with subsurface drainage Channelization Unsewered communities
HUC 12 – 041000111301 (Muskellunge Creek)									
Muskellunge Creek (05-003-000) ***Tributary to Sandusky River at RM 9.37***					**WWH Existing**				
MUSKELLUNGE CREEK NEAR	5.40[W]	37	37	6.9[NS]	G	58.5	FULL		

Stream Name	RM[a] (STORET)	Drain. (mi²)	IBI	MIwb[b]	ICI[c]	QHEI	Status[d]	Causes	Sources
FREMONT @ SPIELDENNER RD.	(201332)								
MUSKELLUNGE CREEK NEAR FREMONT @ FANGBONER RD.	1.23 [B] (U04P08)	44	37	9.1	10*	69	NON	Nutrient eutrophication (biological indicators) Phosphorus (Total) Siltation	Crop production with subsurface drainage
HUC 10 – 0410001102 *Pickerel Creek – Frontal Sandusky Bay*									
HUC 12 – 041000110205 (South Creek)									
South Creek (05-044-000) *Tributary to Lake Erie*					**WWH Existing**				
SOUTH CREEK @ CO. RD. 229	7.92[H] (U05G01)	7.1	20*	N/A	LF*	48.5	NON	Organic enrichment (sewage) biological indicators Nutrient eutrophication (biological indicators) Phosphorus (Total)	On-site treatment systems (septic systems and similar decentralized systems) Crop production with subsurface drainage
SOUTH CREEK NEAR RILEY CENTER @ WHITMORE RD. (TWP. RD. 247)	4.04 [H] (U05K05)	18.1	24[NS]	N/A	LF*	33.5	PARTIAL	Nutrient eutrophication (biological indicators) Phosphorus (Total) Siltation Embedded substrates	Channelization Livestock
HUC 12 – 041000110204 (Raccoon Creek)									
Raccoon Creek (05-045-000) *Tributary to Lake Erie*					**WWH Existing**				
RACCOON CREEK UPST. CLYDE @ LIMERICK RD.	13.26[H] (U05S01)	9.9	28	N/A	MG[NS]	49.5	FULL		
RACCOON CREEK AT CLYDE @ U.S. RT. 20	11.32 [H] (U05P04)	12.7	32	N/A	P*	42	NON	Organic enrichment (sewage) biological indicators Nutrient eutrophication (biological indicators) Phosphorus (Total) Siltation Habitat alteration	Active CSOs Urban run-off Channelization
RACCOON CREEK N OF CLYDE @ TWP. RD. 223	10.18 [H] (U05W10)	13.8	34	N/A	P*	51.5	NON	Nutrient eutrophication (biological indicators) Phosphorus (Total) Embedded substrates Siltation	Clyde WWTP
RACCOON CREEK DST. OHIO TURNPIKE @ TWP. RD. 244	5.45[W] (U05W17)	23.6	29[NS]	5.5*	34	66	PARTIAL	Organic enrichment (sewage) biological indicators Nutrient eutrophication (biological indicators) Phosphorus (Total)	Clyde WWTP Crop production with subsurface drainage
Buck Creek (05-045-003) *Tributary to Raccoon Creek at RM 10.06*					**WWH Recommended**				
BUCK CREEK N OF CLYDE @	0.2 [H]	4.5	30	N/A	LF*	45.5	PARTIAL	Embedded substrates	Crop production with

Stream Name	RM[a] (STORET)	Drain. (mi^2)	IBI	MIwb[b]	ICI[c]	QHEI	Status[d]	Causes	Sources
TWP. RD. 223	(U05S03)							Siltation Nutrient eutrophication (biological indicators) Pesticides	subsurface drainage Specialty crop production
HUC 12 – 041000110203 (Pickerel Creek)									
Pickerel Creek (05-046-000) *Tributary to Lake Erie*				**WWH Existing**					
PICKEREL CREEK @ REINICKE RD. (TWP. RD. 233)	6.26 [H] (U05K10)	9.5	32	N/A	MG[NS]	48	FULL		
PICKEREL CREEK @ TWP. RD. 247	3.35 [H]* (U05S04)	43.7	<u>27</u>[NS]	N/A	LF*	45	PARTIAL	Embedded substrates Siltation	Crop production with subsurface drainage Channel erosion/incision from upstream hydromodifications; bank destabilization
HUC 12 – 041000110201 (Frontal South Side of Sandusky Bay)									
Little Pickerel Creek (05-049-000) *Tributary to Lake Erie*				**CWH Existing**					
LITTLE PICKEREL CREEK @ YETTER RD.	2.00 [H] (201385)	5.5	26[NS]	N/A	LF*	50.5	PARTIAL	Embedded substrates Siltation	Crop production with subsurface drainage
Cold Creek (05-050-000) *Tributary to Lake Erie*				**CWH Existing**					
COLD CREEK @ BARDSHAR RD.	0.36 [H] (300670)	2.9	34	N/A	F*	47	PARTIAL	Natural	Natural
HUC 10 – 0410001101 *Mills Creek – Frontal Lake Erie*									
HUC 12 - 041000110103 Mills Creek									
Mills Creek (05-051-000) *Tributary to Lake Erie*				**WWH Existing**					
MILLS CREEK W OF PARKERTOWN @ PORTLAND RD.	10.40[W] (U05S07)	21	26[NS]	<u>5.3*</u>	LF*	28.5	NON	Embedded substrates Siltation Organic enrichment (sewage) biological indicators Nutrient eutrophication (biological indicators) Phosphorus (Total)	Crop production with subsurface drainage Bellevue WWTP
MILLS CREEK SE OF CASTALIA @ ST. RT. 99	6.03 [W] (U05S06)	29	<u>21*</u>	<u>4.9*</u>	28*	49	NON	Organic enrichment (sewage) biological indicators Nutrient eutrophication (biological indicators) Phosphorus (Total) Siltation	Crop production with subsurface drainage Bellevue WWTP Livestock
MILLS CREEK NEAR CASTALIA @ BOGART RD.	5.20 [W] (U05P07)	29	<u>23*</u>	<u>5.7*</u>	38	61.5	NON	Organic enrichment (sewage) biological indicators Nutrient eutrophication (biological indicators) Phosphorus (Total) Embedded substrates	Livestock On-site treatment systems (septic systems and similar decentralized systems) Bellevue WWTP

Stream Name	RM[a] (STORET)	Drain. (mi^2)	IBI	MIwb[b]	ICI[c]	QHEI	Status[d]	Causes	Sources
								Siltation	
MILLS CREEK S OF SANDUSKY @ STRUB RD.	3.70[W] (U05S18)	35	25[NS]	6.9[NS]	30[NS]	42.5	FULL	Comment – Total phosphorus continues to exceed expectations and the macroinvertebrate community has signatures of nutrient enrichment. Sources are likely the Bellevue WWTP and upstream livestock operations	
MILLS CREEK AT SANDUSKY @ PERKINS AVE.	1.35[W] (U05P05)	41	19*	4.9*	18*	46.5	NON	Siltation Organic enrichment (sewage) biological indicators Nutrient eutrophication (biological indicators) Phosphorus (Total)	Active CSOs Urban run-off Bellevue WWTP
Caswell Ditch (05-051-004) *Tributary to Mills Creek at RM 3.95* **WWH Existing**									
CASWELL DITCH (TRIB TO MILLS CREEK 3.95) @ BOGART RD.	0.85[H] (U05W37)	3.9	22*	N/A	30[NS]	34.5	PARTIAL	Siltation	Crop production with subsurface drainage Loss of riparian habitat (no trees)
HUC 12-041000110102 (Pipe Creek – Frontal Sandusky Bay)									
Pipe Creek (05-052-000) *Tributary to Lake Erie* **WWH Existing**									
PIPE CREEK JUST UPST. TURNPIKE @ HARRIS RD.	10.81 (U05K18)	9.4	--	--	F*	--	N/A		
PIPE CREEK N OF BLOOMINGVILLE @ PATTEN TRACT RD.	8.18[H] (U05K17)	14.7	20*	N/A	G	46.5	PARTIAL	Siltation	Channelization
PIPE CREEK S OF SANDUSKY @ SCHENK RD.	6.7[H] (U05K16)	18.4	24[NS]	N/A	F*	30	PARTIAL	Siltation	Channelization
PIPE CREEK AT SANDUSKY @ COLUMBUS AVE.	2.32[W] (U05K15)	22.8	23*	4.6*	22*	41.5	NON	Siltation Other flow regime alterations (Hydromodification)	Channelization Urban run-off
HUC 12-0410001101 (Mills Creek-Frontal Lake Erie)									
Sawmill Creek (12-004-000) *Tributary to Lake Erie* **WWH Existing**									
SAWMILL CREEK W OF HURON @ BOOS RD.	1.10[H] (K01K21)	13.5	44	N/A	MG[NS]	50.5	FULL		
HUC 10 – 0410001112 *Green Creek*									
HUC 12 041000111203 (Green Creek)									
Green Creek (05-100-000) *Tributary to Lake Erie* **CWH Existing**									
GREEN CREEK @ CO. RD. 34	18.80[H]* (U04G24)	53	42	N/A	36	67	FULL		
GREEN CREEK SE OF FREMONT @ DEWEY RD.	12.85[H]* (U04S10)	71	27[NS]	N/A	26*	73	PARTIAL	Sedimentation/Siltation	Channel erosion/incision from upstream hydromodifications Crop production with

Stream Name	RM[a] (STORET)	Drain. (mi^2)	IBI	MIwb[b]	ICI[c]	QHEI	Status[d]	Causes	Sources
									subsurface drainage
Green Creek (05-100-000) *Tributary to Lake Erie*				**WWH Existing**					
GREEN CREEK @ CO. RD. 229	9.08 H* (U04G20)	74	36	N/A	36	67.5	FULL		
GREEN CREEK NE OF FREMONT @ TWP. RD. 239	5.06 H* (U04K01)	78.3	33	N/A	22*	64	PARTIAL	Sedimentation/Siltation	Channel erosion/incision from upstream hydromodifications Crop production with subsurface drainage
HUC 12 – 041000111202 (Beaver Creek)									
Beaver Creek (05-103-000) *Tributary to Green Creek at*				**CWH Existing**					
BEAVER CREEK DST. LEAFY OAKS MHP	4.00 H* (U04K03)	20.9	29	N/A	G	68	FULL		
BEAVER CREEK @ ST. RT. 101	3.48 H* (U04G25)	43.4	31	N/A	44	62.5	FULL	Comment – Chemical water quality sampling indicates nitrate-nitrite concentrations occasionally exceed drinking water criterion near Beaver Creek reservoir intake. See Public Water Supply section of this report for additional information.	
Emerson Creek (05-108-000) *Tributary to Beaver Creek at RM 3.60*				**WWH Existing**					
EMERSON CREEK @ TWP. RD. 179	1.83 H* (U04G26)	22	25*	N/A	F*	67	NON	Siltation	Crop production with subsurface drainage
Emerson Creek a.k.a. Royer Ditch (05-109-000)				**WWH Existing**					
EMERSON CREEK (ROYER DITCH) @ CO. RD. 46	10.12 (U04K08)	6.4	--	--	LF*	--	N/A	Comment – Stream was interstitial as a result of channelization and subsurface drainage for crop production.	
EMERSON CREEK (ROYER DITCH) NEAR FIRESIDE @ RON MEYERS RD.	6.85 H (U04K07)	15.2	18*	N/A	P*	30.5	NON	Siltation Direct habitat alterations	Channelization
HUC 12 – 041000111201 (Westerhouse Ditch)									
Westerhouse Ditch (05-105-000) *Tributary to Beaver Creek at RM 4.73*				**WWH Existing**					
WESTERHOUSE DITCH @ SNAVELY RD.	3.25 H (U04K05)	9.6	30	N/A	G	52.5	FULL		
WESTERHOUSE DITCH NE OF LOWELL @ ST. RT. 19	0.63 H (U04K04)	16.2	34	N/A	VG	57	FULL		
HUC 10 – 0410001114 *Muddy Creek – Frontal Sandusky Bay*									
HUC 12 – 041000111404 (Town of Lindsey - Muddy Creek)									
Muddy Creek (05-219-000) *Tributary to Lake Erie*				**WWH Existing**					
MUDDY CREEK @ EAST SIDE OF ST. RT. 53	1.23 B (U04Q13)	110	21*	6.7*	12*	50.5	NON	Direct habitat alterations Other flow regime alterations Phosphorus (Total)	Channelization (including extensive levees and armored banks)
HUC 12 – 041000111403 (Little Muddy Creek)									
Little Muddy Creek (05-220-001) *Tributary to Muddy Creek at RM 1.31*				**WWH Existing**					

Stream Name	RM[a] (STORET)	Drain. (mi^2)	IBI	MIwb[b]	ICI[c]	QHEI	Status[d]	Causes	Sources
LITTLE MUDDY CREEK @ KLINE RD.	2.5 [B] (300676)	25	20*	6.9[NS]	20*	47.5	NON	Nutrient enrichment (biological indicators) Siltation Phosphorus (Total)	Upstream crop production with subsurface drainage
Fishing Creek (05-220-001) *Tributary to Little Muddy Creek at RM 2.36* **WWH Recommended**									
FISHING CREEK @ WEICKERT RD.	0.20 [H] (300678)	7	32	N/A	P*	21.5	NON	Nutrient enrichment (biological indicators) Siltation Phosphorus (Total)	Upstream crop production with subsurface drainage

a - River Mile (RM) represents the Point of Record (POR) for the station, not the actual sampling RM.

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

c - 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. VP=Very Poor, P=Poor, LF=Low Fair, F=Fair, MG=Marginally Good, G=Good, VG=Very Good, E=Exceptional

d - Attainment is given for the proposed status when a change is recommended.

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.

B - Boat site.

H - Headwater site.

W - Wading site.

H* - Sites with strong ground water resulting in fish communities representative of headwater systems, though drainage area is >20mi^2. Headwater biocriterion were used to evaluate the fish community.

Index – Site Type	Biological Criteria			Lacustuary Benchmarks[1]				
	Huron Erie Lake Plain							
	EWH	WWH	MWH (Channelized)	Exceptional	Good	Fair	Poor	Very Poor
IBI – Headwaters	50	28	20	N/A	N/A	N/A	N/A	N/A
IBI – Wading	50	32	22	N/A	N/A	N/A	N/A	N/A
IBI – Boat	48	34	20	50	42	31	17	<17
MIwb – Wading	9.4	7.3	5.6	N/A	N/A	N/A	N/A	N/A
MIwb – Boat	9.6	8.6	5.7	10	8.6	5.6	2.8	<2.8
ICI	46	34	22	52	42	25	12	<12

1- Proposed Lacustuary scoring breakpoints. These have not been adopted into rule.

INTRODUCTION

Originally, the Sandusky Bay tributaries study area was part of the lower Sandusky River study area and was scheduled to be sampled as part of that TMDL survey. In January 2009 the decision was made to place additional focus on the area in which a childhood cancer investigation is underway. This smaller study area, referred to as the Sandusky Bay tributaries study area, included 3 United States Geologic Survey (USGS) ten-digit Hydrologic Unit Codes (HUC 10s): Pickerel Creek–Frontal Sandusky Bay (0410001102), Green Creek (0410001112), and Mills Creek–Frontal Lake Erie (0410001101). The first two HUC 10s were within the area ODH identified as having a higher than expected rate of childhood cancer, while the Mills Creek – Frontal lake Erie HUC 10 did not. However, the latter was included for comparison to the affected areas. Focusing on this smaller area also would allow Ohio EPA to provide results in spring 2010, a year ahead of schedule.

In late May 2009, ODH published a spatial analysis of the childhood cancer cases. The analysis extended the area of concern westward to include portions of Fremont and northward into Ottawa County (ODH 2009). As depicted in Figure 2, several sites within the proposed lower Sandusky River study area fell within the newly defined boundaries. To ensure adequate coverage and efficiency, results from sampling locations within the lower Sandusky River study area which overlapped into the cancer investigation extent as identified by the spatial analysis were incorporated into both the Sandusky Bay tributaries report and the lower Sandusky River report. The overlapping sites are within two HUC 10s: Muskellunge Creek–Sandusky River (0410001113) and Muddy Creek–Frontal Sandusky Bay (0410001114).

In addition to ensuring adequate spatial coverage within the bounds of the childhood cancer investigation, coordination with ODH occurred to ensure that the water, fish tissue and sediment samples collected would be analyzed for all appropriate potential contaminants. The only additional analysis beyond Ohio EPA's standard parameter list requested by ODH was for a gross Alpha radiation and gross Beta radiation count on sediment samples. These results are presented in the Sediment section of this report.

The Sandusky River and Sandusky Bay tributaries, delineated by USGS as the 8-digit HUC 04100011 are located in portions of Sandusky, Erie and Seneca counties in north central Ohio along the southern shore of Lake Erie. The watersheds are bordered by the Portage River on the west and the Huron River on the east. The study area comprises five HUC 10 watersheds with fourteen HUC 12 watersheds and includes twenty named creeks and tributaries. The study area encompassed approximately 595 square miles, and all streams in the study area except Sawmill Creek flowed to Sandusky Bay (Figure 1).

In 2009, Ohio EPA conducted a water resources assessment of the Sandusky Bay tributaries using standard Ohio EPA protocols as described in Appendix A. Included in the study are assessments of the biological, surface water, sediment and recreational (bacteria) conditions. A total of 47 biological, 56 water chemistry and 7 sediment stations were sampled within the study area.

Specific objectives of the evaluation were to:

- monitor and assess the chemical, physical, and biological integrity of the water bodies within the Sandusky Bay tributaries study area;
- assess physical habitat influences on stream biotic integrity;
- determine recreational water quality;
- evaluate the appropriateness of existing use designations and assign uses to undesignated streams;
- characterize the amount of aquatic resource degradation attributable to various land uses, including agricultural practices and urbanization;
- assess physical habitat influences on stream biotic integrity;
- identify the relative levels of organic, inorganic, and nutrient parameters in the sediments and surface water;
- compare present results with historical conditions;
- determine any aquatic impacts from known potential sources, including point source dischargers, and from unsewered communities; and,
- collect fish samples for the Ohio Sport Fish Tissue Monitoring Program (used to assess chemical contaminant levels in fish).

The entire TMDL study area is located in the Huron-Erie Lake Plain (HELP) ecoregion and the majority of streams are currently assigned the Warmwater Habitat (WWH) aquatic life use designation in the Ohio Water Quality Standards (WQS), as well as Primary Contact Recreation (PCR), Secondary Contact Recreation (SCR), Agricultural Water Supply (AWS) and Industrial Water Supply (IWS). Little Pickerel Creek, Cold Creek, Green Creek and Beaver Creek have the Coldwater Habitat (CWH) designation.

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, TMDLs and the biennial Integrated Water Quality Monitoring and Assessment Report (305[b] and 303[d] report).

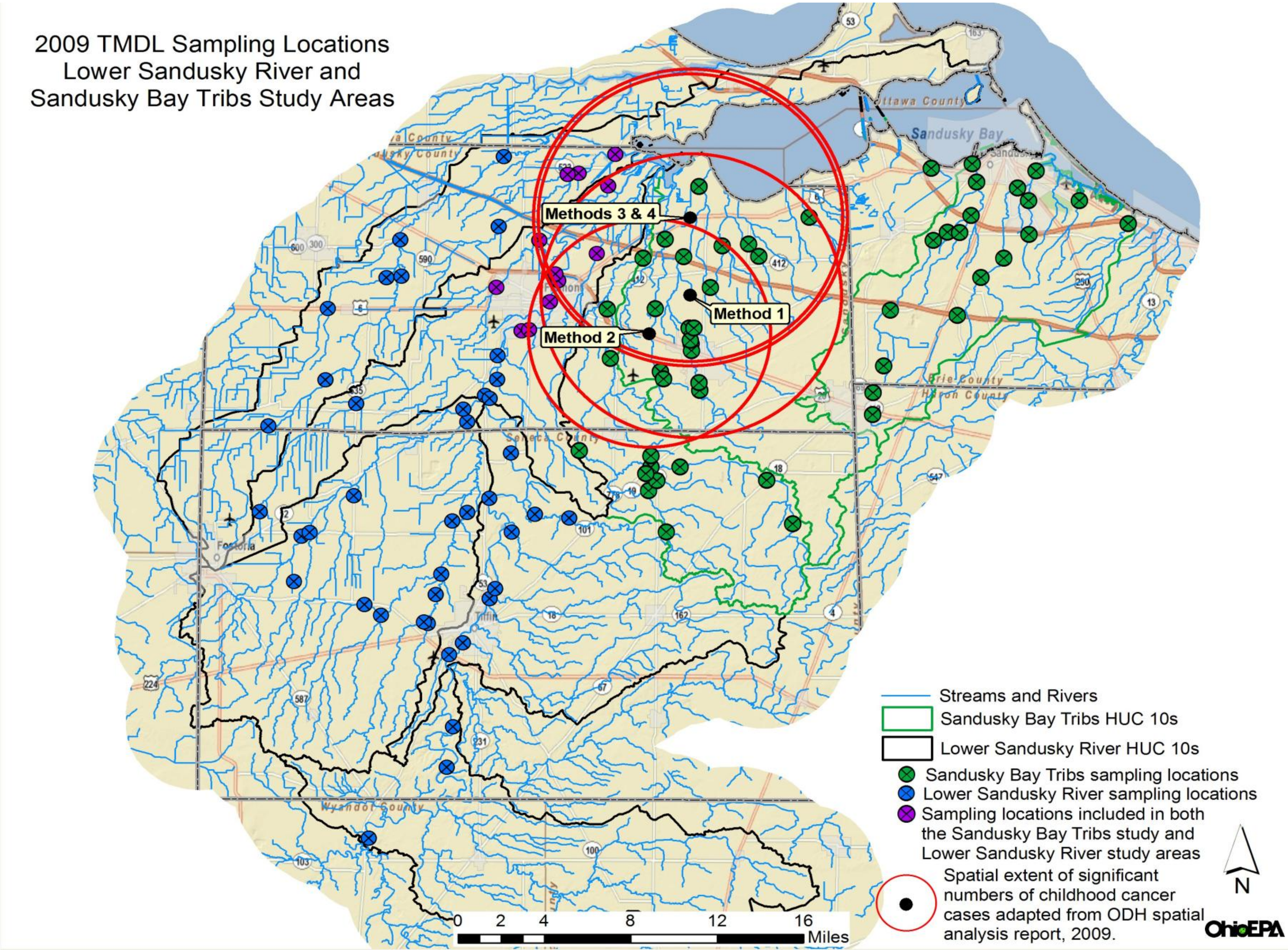


Figure 2. Sampling locations for lower Sandusky River and Sandusky Bay tributaries study areas, 2009. Circles represent the spatail extent of significant nubmers of childhood cancer cases identified by Ohio Department of Health, 2009.

STUDY AREA DESCRIPTION

Hydrology

The Sandusky Bay tributaries study area is contained entirely within the Huron-Erie Lake Plain ecoregion and specifically the Marblehead Drift/Limestone Plain, which went through several glacial periods. The most recent Late Wisconsinan glaciation formed the lakes and bays of the north coast region. The watershed is characterized by lake plain and till plain physiography having relatively uniform, level topography, with beach ridges and some rock ridges on the eastern and southern boundaries of the watersheds. Unique features include the sand dunes at Cedar Point, marl prairies near Castalia and sink holes, the most prominent of which is the Blue Hole, near Castalia. The springs surrounding Castalia contribute a significant amount of water to Cold Creek. However, the ground water has little oxygen. Early pioneers established mills along Cold Creek as the stream never froze nor appeared affected by drought. The artificial aeration provided by these mills oxygenated the waters sufficiently to support stocking trout (Ver Steeg and Yunck, 1932). Over time, trout clubs were established and today ODNR's Castalia State Fish Hatchery aerates the water to increase oxygen levels enough to support rearing various trout species (Dave Insley, personal communication). In addition to Cold Creek, there are other numerous distinct watersheds in the study area; mostly small creeks that flow directly to the bay and are usually fewer than 15 miles long. Some of the eastern tributaries, such as Pipe and Sawmill Creeks, often flow on carbonate bedrock, while Muddy and Muskellunge Creeks to the west tend to have more clayey channels (USDA Soil Survey, 2006).

Every stream in the study area has been negatively impacted by siltation and nutrient enrichment from agricultural activities. At some locations siltation is caused by upstream channelization or habitat alteration for drainage, such as in Bark Creek, South Creek, Pipe Creek, Emerson Creek, Muddy Creek and Caswell Ditch. Embedded substrates were especially noted in the lower segments of Sandusky River near Wightman's Grove and at the confluence with Sandusky Bay. Sources of nutrient enrichment include the Bellevue, Clyde and Sandusky WWTPs discharges, and general agricultural activities throughout the watershed. Failing home sewage systems, especially in rural areas southwest of Sandusky, were contributing to organic enrichment in South Creek and Mills Creek.

The Pickerel Creek-Sandusky Bay watershed unit also exhibited destabilized banks and severe erosion in Pickerel Creek, South Creek, and Raccoon Creek. Stream bank erosion was worsened by livestock access to South Creek. The Mills Creek-Sandusky Bay watershed assessment unit had impacts from Combined Sewer Overflows (CSOs) and urban runoff in addition to specific segments of stream bank erosion in Mills, Sawmill and Pipe Creeks and Caswell Ditch that were worsened by livestock access. Green Creek was impacted by channel incision and stream bank erosion from upstream hydromodification. Beaver Creek supplied surface water for public drinking water to Clyde and Green Springs.

Geology

Ohio's modern Lake Erie shoreline was subjected to many glacial advances during geologic time, followed by subsequent periods of melting and recessions that filled valleys and low bedrock areas with glacial till and lacustrine sand, silt and clay. As the last Wisconsinan glaciers retreated, the high bedrock areas in the eastern and southern edges of the watershed were either exposed or thinly covered with poorly drained drift soils of the Mitiwanga and Millsdale associations. Thicker glacial till soils were deposited in western Erie and Sandusky counties. Clay content was highest near the lake and examples of soils formed in glacial till include Del Rey, Fulton, Toledo and Pewamo silty clays and clay loams. These old lakebed soils comprised very fertile and productive agricultural land when artificially drained and carefully managed. Hydric classifications of soils were found throughout these watersheds where wetlands were filled and drained for agriculture and other development.

Bedrock geology of the area was characterized by predominantly Silurian and Devonian age limestone and dolomite west of Sandusky and Devonian age shale to the east. This major rock type change also marked the eastern edge of the shallower western basin of Lake Erie and the Lake Erie Islands. The most important Devonian rock formation was the Columbus Limestone, which is a nearly pure limestone of high calcite content. These deep deposits are mined throughout the region for building stone, manufacturing cement and as fluxstone for the iron ore refining and steel-making process. Gypsum is another mineral mined from this area for use in production of gypsum board, also known as drywall, used in the building industry.

Other natural processes contributed to unique post-glacial landforms in northern Erie County, near Castalia. Subterranean springs and seepage from limestone produced calcium carbonate charged water which formed calcareous tufa rock over the lake sediments. Directly east and extending to the southwest into Sandusky and Seneca counties was the Bellevue-Castalia Karst Plain. The area was underlain by up to 175 feet of Devonian carbonate bedrock overlying Silurian dolomite, anhydrite and gypsum deposits. This area was believed to have more sinkholes than any other karst region of Ohio. Karst formation was due to the collapse of overlying carbonate rocks into voids created by the dissolution of underlying gypsum beds. Huge irregularly shaped, closed depressions up to 270 acres in size and numerous smaller depressions of 5 to 80 feet diameter pockmark the land between Flat Rock in Seneca County and Sandusky in Erie County (ODNR-Coastal Atlas, 2007).

Surface drainage on the Bellevue-Castalia Karst Plain was very limited and many streams disappear into sinkholes often called "swallow holes". This part of the watershed was primarily used for row crop production, and attempts to provide adequate agricultural drainage were complicated by the elusiveness of sinkholes which come and go in the middle of fields. Another concern was protecting ground water that may be a drinking water source for rural residents.

Land Use

Portions of twelve townships and the municipal areas of Fremont, Green Springs, Clyde, Castalia, Bellevue and Sandusky were located in the Sandusky Bay tributaries study area. Figure 3 depicts land use throughout the study area.

Land use across the study area was approximately 77 percent agricultural and nearly 1 percent pasture, with 8.8 percent developed for urban or residential use. Other land uses included 7.1 percent forest, 4.6 percent wetland and 1.7 percent open water. Today, row crop and livestock production remains the dominant land use, though the long term trend has shown the loss of farmland to urban growth and residential sprawl, particularly along the coast in Erie County where tourism and residential/commercial growth has occurred for the past thirty years.

These coastal watersheds encompass marsh, grassland and forest areas that are a vital resource to migratory birds. Located at the intersection of the Mississippi and Atlantic flyways, Lake Erie represents one of the most diverse flyways in the country. Significant bird habitat and walleye spawning areas are abundant in the western basin of Lake Erie, while Sandusky Bay is a critical nursery habitat for walleye due to shallow depth, low water clarity and proximity to the Sandusky River mouth, which is prime riverine spawning habitat (ODNR-Coastal Atlas, 2007).

Protected Lands

Row crop agriculture is practiced in the lake plain areas of the Sandusky Bay watersheds, but farm fields must be diked and the water table intensively managed to grow crops closer to the shoreline. Some wetlands formerly lost to development or farming, have been restored as private and public hunting preserves. Some landowners are converting diked farm fields to wildlife production areas with incentives from USDA Farm Bill programs.

According to the Ohio Coastal Atlas, ODNR and other conservation organizations own and manage several wildlife areas along the shoreline. State protected lands bordering the bays include Pickerel Creek State Wildlife Area and Willow Point State Wildlife Area in Sandusky County. Additionally, there are large tracts of private land bordering Muddy Creek Bay that are owned by Ottawa Shooting Club and Winous Point Shooting Club. These long-established, exclusive clubs preserve and manage the wetland habitat for waterfowl hunting.

Further east in Erie County, the State of Ohio and Erie Metroparks also manage coastal areas along the Cedar Point Chausée including Pipe Creek State Wildlife Area, Sheldon Marsh State Nature Preserve and Putnam Marsh Nature Preserve.

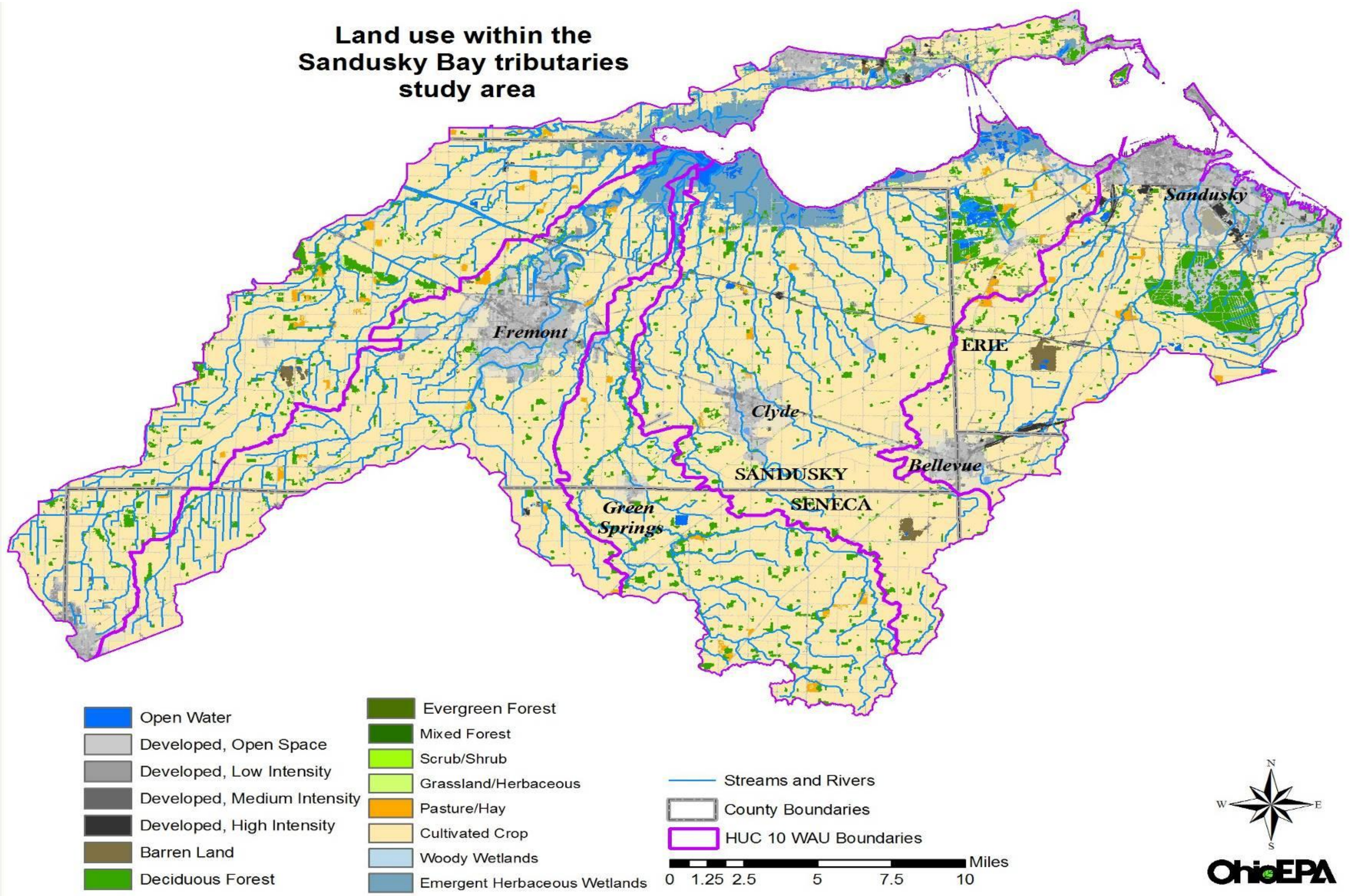


Figure 3. Land use throughout the Sandusky Bay tributaries study area.

Other protected lands in the watershed include several inland preserves that are managed for wildlife production and habitat protection. They include Pickerel Creek Wildlife Area, Blue Heron Reserve and Miller's Blue Hole Wildlife Area in Sandusky County, plus Castalia State Fish Hatchery, Resthaven State Wildlife Area, Castalia Quarry Reserve and Erie Sand Barrens State Nature Preserve in Erie County (ODNR-Coastal Atlas, 2007)

National Aeronautic and Space Administration (NASA) Plum Brook Station is located south of Sandusky on 6,400 acres of land in Perkins Township. A former War Department munitions plant during World War II, it was idle until the late 1950s and 1960s when NASA acquired the land for a nuclear reactor research site. This was the first of fifteen test facilities built at Plum Brook Station for materials and aircraft components used in space flight. Since the end of the moon/space flight program in the mid-1970s, most of the smaller test sites on the property have been decommissioned, including the test reactor. Today, Plum Brook Station is an active testing and research installation housing some of the world's most advanced space environment simulation facilities. There are private research projects being conducted with oversight from NASA at four of the test sites. More history on the NASA Plum Brook Station can be found at http://www.grc.nasa.gov/WWWpbrf/fact-sheets/nasa%20history%20fact.pdf .

Ground Water Supply

Many rural residents in Ohio depend on ground water wells as their source of drinking water. The area along the lakeshore in the Sandusky Bay region has moderate to high vulnerability to ground water contamination from a variety of sources, including spills and over-application of chemicals. This is primarily due to the shallow bedrock, sandy glacial deposits and the presence of sinkholes, which ironically are the highest-yielding geologic formations in this region (ODNR-Coastal Atlas, 2007).

In response to the high threat of contamination, the Karst Unified Source Water Protection Plan was developed in 2001. The project itself was unique within Ohio due to the vastness and vulnerability of the project area. Following the source water delineation conducted by Ohio EPA, the Great Lakes Rural Community Assistance Program (RCAP), public water suppliers, Ohio EPA, and Stakeholder Committee completed the potential contaminant source inventory. The team, along with other key stakeholders, including the agricultural community and local health departments, identified management strategies to protect drinking water supplies. A contingency plan and monitoring section are also included (Great Lakes RCAP, 2001).

Surface Water Supply and Drinking Water Quality Issues

For public health safety, most rural homes in the study area are now served by Northern Ohio Rural Water (NORW). NORW has expanded into the northwest corner of Erie County and into Sandusky County. The project involved more than 20 miles of new water line construction to approximately 400 customers along the south shoreline area of Sandusky Bay. The distribution system includes a new elevated water storage tank and booster pump station. The finished water supply for this expansion is provided under a cooperative agreement with the Erie County Sanitary District. An additional Sandusky County project involved more than 36 miles of new water line construction in Green Creek, York, Sandusky and Riley Townships. NORW purchases water from the City of Sandusky Big Island Water Treatment Plant, which in turn draws water from Lake Erie (http://www.norw.org/content.aspx?PID=5).

Residents of the Clyde vicinity get drinking water from two surface water sources. The NORW, as described above, purchases water from the city of Sandusky water treatment facility and the Margaretta Water District. The Clyde public water system gets water from Beaver Creek via two reservoirs. Beaver Creek reservoir is a 110 acre lake in Adams Township, Seneca County. In conjunction with Raccoon Creek reservoir, it provides drinking water to the Clyde and Green Springs. Source water for the lake is Beaver Creek. Raw water is fed by gravity to Raccoon Creek Reservoir located in the Clyde's municipal limits. The Raccoon Creek pump station was eliminated in 2001.

Bellevue area residents are also served by surface water from several local streams, which is pumped to a series of 5 reservoirs. Big Ditch, Miller Ditch and Berry Ditch in the Sandusky River watershed, and Frink Run in the Huron River Watershed supply raw water for these reservoirs. More information about the Ohio EPA Source Water Protection Program is available at
http://www.epa.ohio.gov/ddagw/swap_publications.aspx.

Sampling results from drinking water supplies within the study area are provided in the results section of this report. Additional results of drinking water sampling conducted in January and February 2009 as part of the cancer investigation can be found in the report linked below
http://www.epa.state.oh.us/portals/47/citizen/clyde/Final_Clyde_WQ_Report_041609.pdf

Point Source Issues

The city of Sandusky and portions of Margaretta Township in Erie County, including Bay View, are designated a Phase 2 Storm Water community. They are required to prepare and implement storm water pollution prevention plans to address construction sediment and erosion control measures and urban runoff issues.

The Bellevue wastewater treatment plant negatively impacts Snyder's Ditch downstream into Mills Creek. The Clyde WWTP also has a negative influence on Raccoon Creek. The city of Clyde has one combined sewer overflow (CSO), and the city of Sandusky has 15 CSOs, with one discharging to Mills Creek and another to Pipe Creek. The remaining 13 CSOs discharge to Sandusky Bay. The city has a long term control plan to eliminate overflows and has completed Phase I of an expansion to the WWTP. Phase 2 of the WWTP expansion is currently under construction.

There are several industrial facilities in Sandusky that have connected their process wastewater to the sanitary sewer but they still maintain NPDES permitted discharges of cooling water and/or storm water to area streams. Other entities such as quarries and mobile home parks operate package treatment plants, and two water treatment plants have lime settling lagoons, all with permitted discharges.

Nonpoint Source Issues

Within all sub-watersheds of the study area, most of the water quality impairments could be linked to nonpoint sources such as fertilizer runoff, failing home sewage systems, sedimentation from agricultural crop production and urban storm runoff. Agricultural practices including channelization and routine maintenance of streams and ditches and the drainage of farm fields through subsurface tiles caused habitat and flow alteration impairments in the headwater and small tributary streams. Drainage alterations were also found where floodplains and wetlands were crossed by numerous highways and railroads, as well as in urban areas where development has encroached or filled in natural wetlands. All of the counties in the study area had programs for drainage maintenance (ODNR- Division of Soil and Water Conservation, 2008).

The Ballville Dam in Fremont was a barrier to fish spawning/migration in the Sandusky River. It may be removed during the next five years after the Fremont drinking water reservoir is completed. The restoration of free-flowing water should restore the habitat and water quality in this impounded length of the lower Sandusky River.

Recreational use impairment from pathogens was found in all of the watershed assessment units. Sources of bacteria included combined sewer overflows from Clyde and Sandusky. Livestock access to streams likely also contributed to impairment in Mills Creek. Another source of bacteria was failing home sewage systems. Individual rural homes and unsewered communities such as Vickery, Wightman's Grove and Bay View contributed to unsanitary conditions. In pockets around the edge of Fremont, and along the lower main stem of the Sandusky River there were areas without centralized sewage collection and treatment. The county health departments in Erie, Seneca, and Sandusky have identified critical areas for replacement of failed systems.

Water quality improvement projects

A Section 319 grant awarded in 2004 provided cost share funding for home sewage treatment system replacements in critical areas identified by the wastewater committee of the Sandusky River Watershed Coalition. Five local health departments participated in the project which replaced 144 failing systems. Previous 319 grants were awarded to the Akron University Geology Department to delineate the southern boundary of the Bellevue-Castalia karst plain, and to Ducks Unlimited for the restoration of 105 acres of wetlands in the coastal areas of the Sandusky, Portage and Toussaint watersheds.

Watershed Groups

The Sandusky River Watershed Coalition was founded in 1997. The Coalition is a diverse group of individuals and organizations providing leadership for the conservation and enhancement of the Sandusky River watershed and its natural resources through community based planning, education and action. Supported by more than 100 local private organizations, government entities and individual citizens, the steering committee meets regularly to discuss restoration plans and projects which range from replacement of failing home sewage systems, to implementing agricultural best management practices (BMPs) to developing watershed action plans. For more information, go to www.sanduskyriver.org (ODNR-Coastal Atlas, 2007 and Sandusky River Watershed Coalition 2001).

The Firelands Coastal Tributaries Watershed project was a newly formed local watershed group in 2007. Friends of Old Woman Creek and the Erie Soil and Water Conservation District partnered to sponsor and employ the first watershed coordinator, supported by a four-year ODNR planning grant in 2008. Supported by dozens of local interests, the first watershed action plan, covering Old Woman Creek, received state endorsement in November 2009. The other coastal tributaries will be characterized for restoration and protection goals as the TMDL progresses. For more information, visit http://www.firelandstributaries.net/index.html.

RESULTS

Point Source Pollutant Loadings - NPDES

Facilities within the study areas that are regulated by an individual NPDES permit are listed in Table 3. These facilities are required to conduct routine self-monitoring of effluent quality and quantity. Results are reported monthly to Ohio EPA as Discharge Monitoring Report (DMR) data. Each permit includes a detailed list of each parameter to be monitored and the specific limits for both concentration and loading rate. The facility also includes monthly average limits and daily or weekly maximum limits, depending on the monitoring requirements. DMR data can be used to track compliance as well as to evaluate historical trends. Facilities classified as major dischargers are summarized below. Facilities or sites within the study area that are regulated by a general NPDES permit may be found by visiting http://www.epa.ohio.gov/dsw/permits/gpfact.aspx#background.

Ohio EPA conducts 48-hour acute screening bioassays to evaluate toxicity during the permit compliance and renewal process for Major NPDES permitted facilities [discharge >1.0 Million Gallons per Day (MGD)] and occasionally minor facilities if time permits. Grab and composite samples of the effluents are collected along with samples of the receiving stream upstream and in the near field mixing zone. The fathead minnow *Pimephales promelas* and daphnid *Ceriodaphnia dubia* are used as test organisms.

Village of Bellevue WWTP

The village of Bellevue WWTP (Permit No. 2PD00037) located at 3000 Seneca Industrial Parkway, Bellevue discharges to Snyder's Ditch at RM 3.80. The existing facility was built in 1966 and major modifications occurred in 2005. The system is designed to treat 2.4 MGD utilizing a primary sedimentation unit, activated sludge-contact stabilization, secondary clarification, trickling filters and UV disinfection. The collection system has 100% separated sewers with 15 lift stations and a post-primary bypass to the trickling filters.

Acute bioassays performed by Ohio EPA staff at the Bellevue WWTP in 2009 indicated no toxicity to aquatic test organisms. A review of monthly self-monitoring data revealed 13 permit limit violations in 2009. Permit limit parameters exceeded included fecal coliform, total phosphorus, nitrogen ammonia, pH and chronic toxicity. Annual loadings (kg/day) of total phosphorus, nitrate+nitrite and total dissolved solids were evaluated using the Liquid Effluent Analysis Processing (LEAP) system and are presented in Figures 4-6.

City of Clyde WWTP

The city of Clyde WWTP (Permit No. 2PD00004) located at 749 West McPerson Highway, Clyde discharges to Raccoon Creek at RM 11.02. The existing system was built in 1986 and major modifications occurred in 2006. The system is designed to treat an average flow of 1.9 MGD and consists of primary and secondary aerobic digesters, a pair of oxidation ditches with clarifier, tertiary lagoons and UV disinfection. The collection system consists of a 65% separated sewers system; the remaining 35% is combined with one CSO discharge to Raccoon Creek. The city of Clyde submitted a revised Combined Sewer System Long-Term Control Plan to Ohio EPA on July 23, 2007. The plan describes improvements to the system and maintenance operations with the goal of reducing CSO events to four or less a year.

Acute bioassays performed by Ohio EPA staff at the Clyde WWTP in 2009 indicated no toxicity to aquatic test organisms. A review of monthly self-monitoring data revealed no permit limit violations in 2009. Annual loadings (kg/day) of total phosphorus and nitrate+nitrite were evaluated using the LEAP system and are presented in Figures 7 & 8.

Fremont WWTP

The Fremont WWTP (2PD00007) located at 1019 Sand Road, Fremont discharges to the Sandusky River at RM 13.85. The existing facility was built in 1949 and the latest major modification occurred in 1998. The system is designed to treat 7.6 MGD and utilizes conventional activated sludge with primary sedimentation and sand filters with chemical disinfection. The collection system is 25% separated sewers with 9 lift stations, the remaining 75% is combined sewers with 11 lift stations and 13 permitted CSOs, of which only four are currently active and includes a primary and secondary bypass. The City of Fremont submitted a Combined Sewer System Long-Term Control Plan to Ohio EPA on July 26, 2005. The plan includes improvements to the treatment facility and collection system during the next 20 years.

Acute bioassays performed by Ohio EPA staff at the Fremont WWTP in 2005 indicated no toxicity to aquatic test organisms. A review of monthly self-monitoring data revealed one permit limit violation for total residual chlorine in 2009. Annual loadings (kg/day) of total phosphorus and nitrate+nitrite were evaluated using the LEAP system and are presented in Figures 9 & 10.

City of Sandusky WWTP

The city of Sandusky WWTP (Permit No. 2PF00001) which discharges directly to Sandusky Bay was not evaluated as part of this study. However, the collection system for this facility includes numerous CSOs, two of which discharge to streams that were evaluated as part of the survey. One CSO discharges to Mills Creek downstream of Anderson Street and the other to Pipe Creek near East Perkins Ave. Pursuant to a Consent Order dated February 17, 1995, the city of Sandusky has adopted a General Plan for Wastewater Improvements and Disinfection. The plan establishes treatment and compliance goals through 2040. Currently, the City of Sandusky is in the second phase of improvements to the facilities and treatment systems.

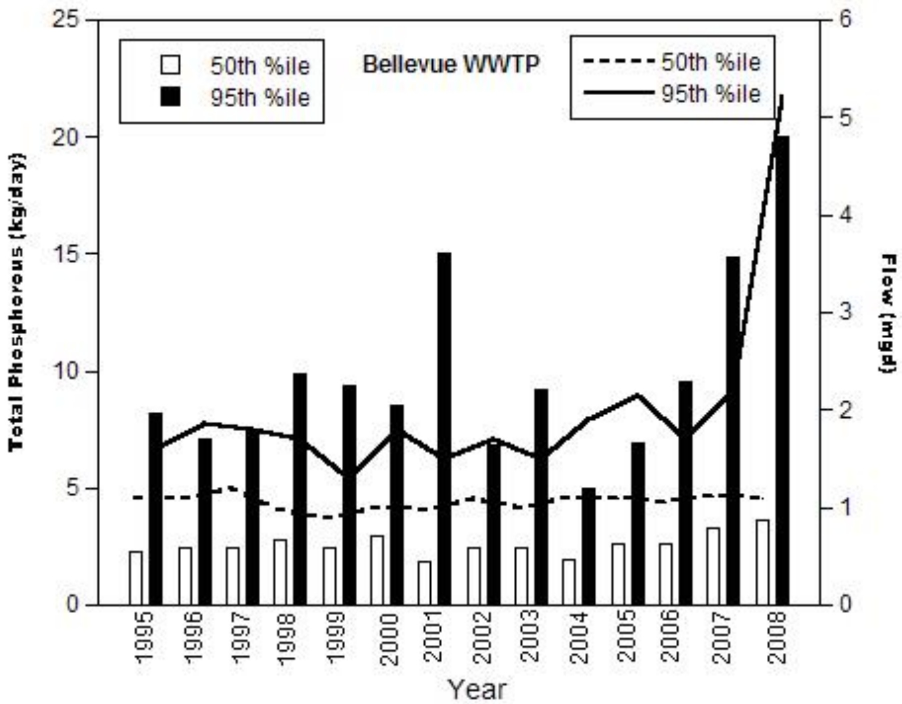


Figure 4. Annual total phosphorus loadings (kg/day) and flow from the Bellevue WWTP, 1995 to 2008.

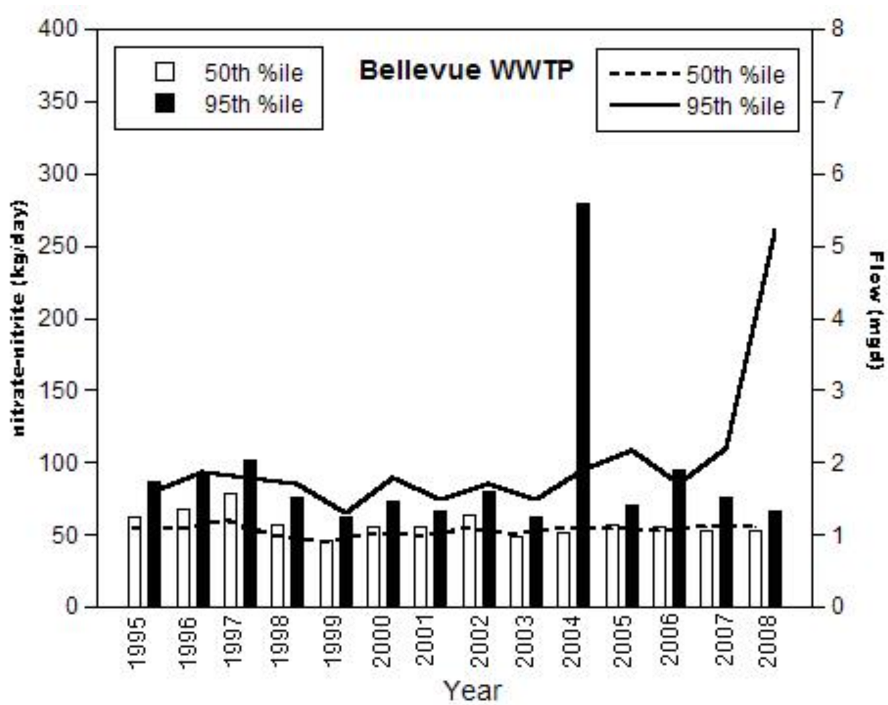


Figure 5. Annual nitrate+nitrite loadings (kg/day) and flow from the Bellevue WWTP, 1995 to 2008.

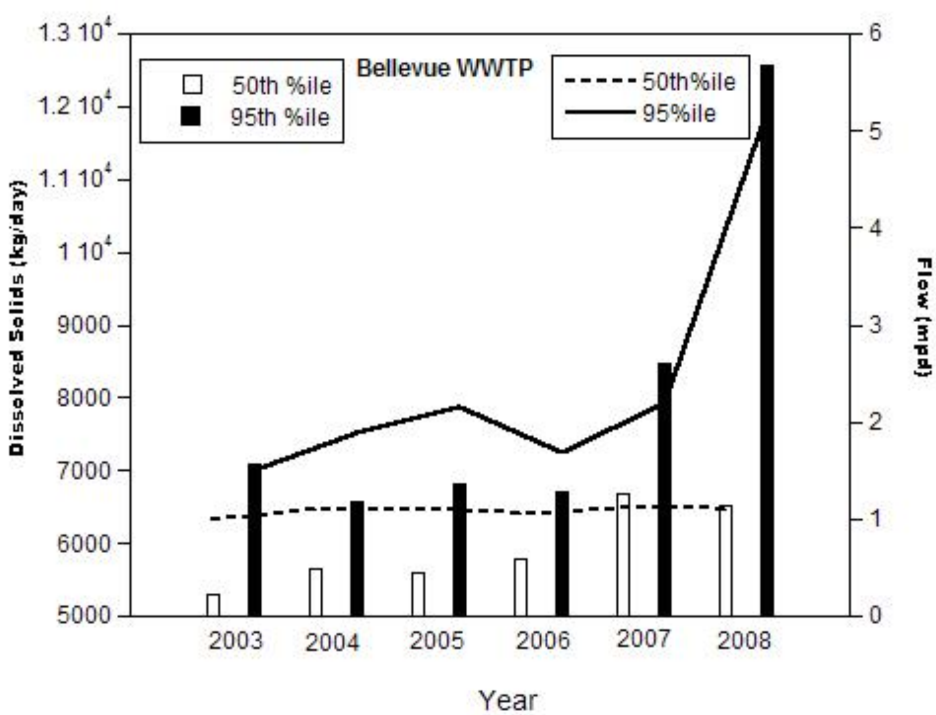


Figure 6. Annual Total Dissolved Solids loadings (kg/day) and flow from the Bellevue WWTP, 2003 to 2008.

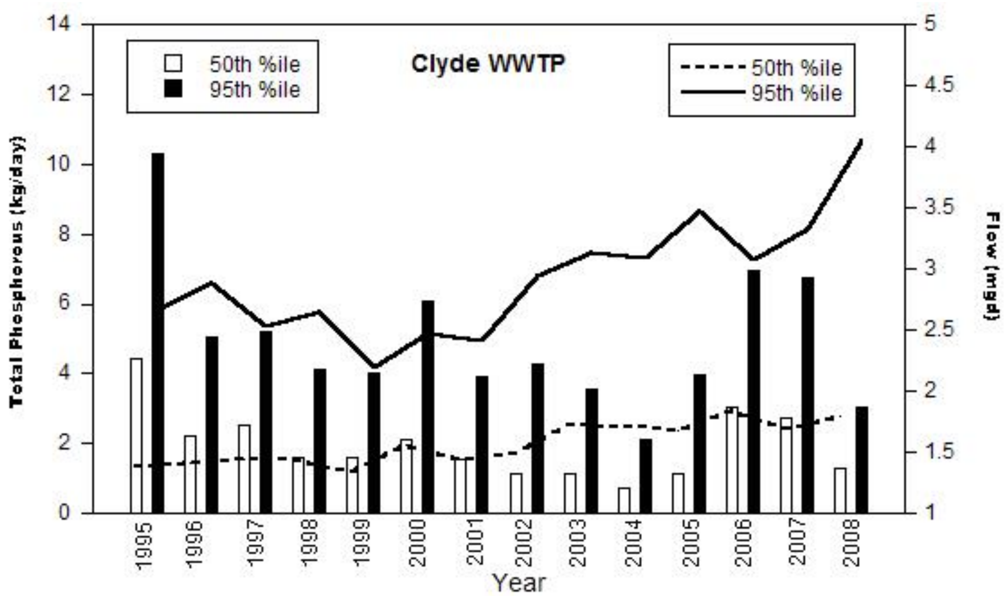


Figure 7. Annual total phosphorus loadings (kg/day) and flow from the Clyde WWTP, 1995 to 2008.

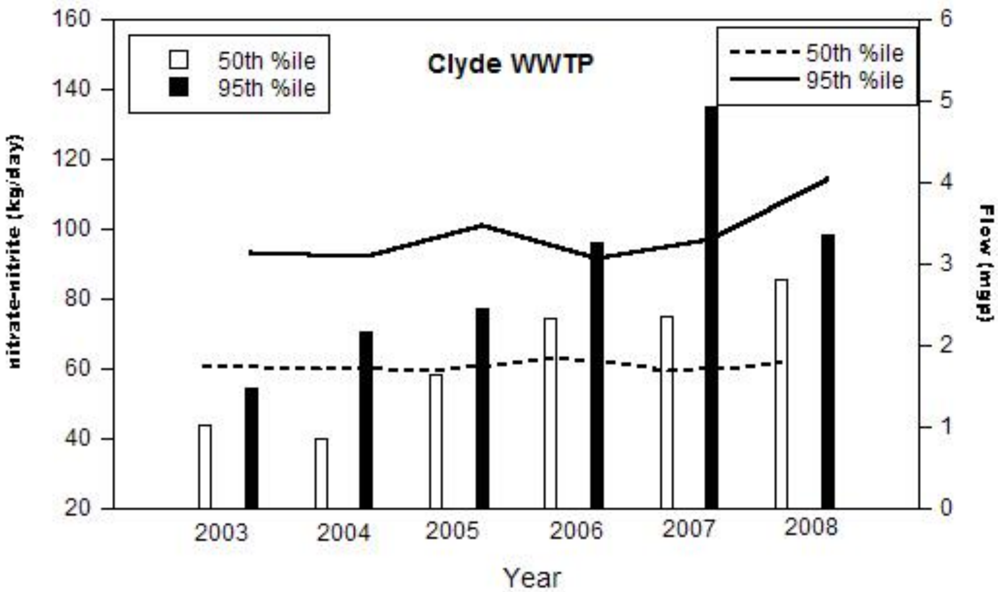


Figure 8. Annual nitrate+nitrite loadings (kg/day) and flow from the Clyde WWTP, 2003 to 2008.

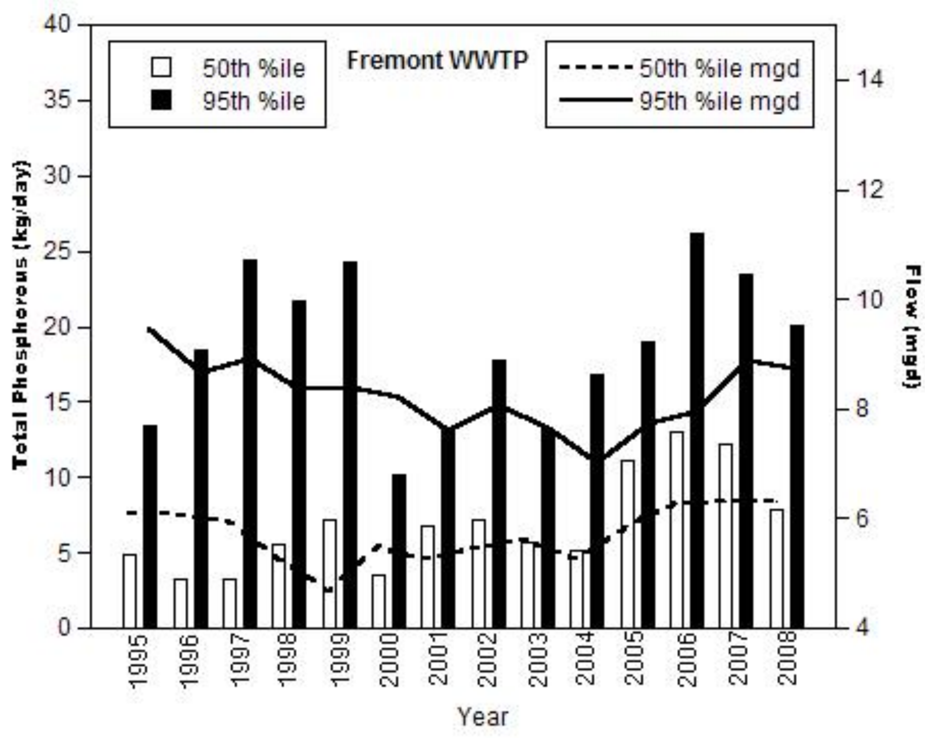


Figure 9. Annual total phosphorus loadings (kg/day) and flow from the Fremont WWTP, 1995 to 2008.

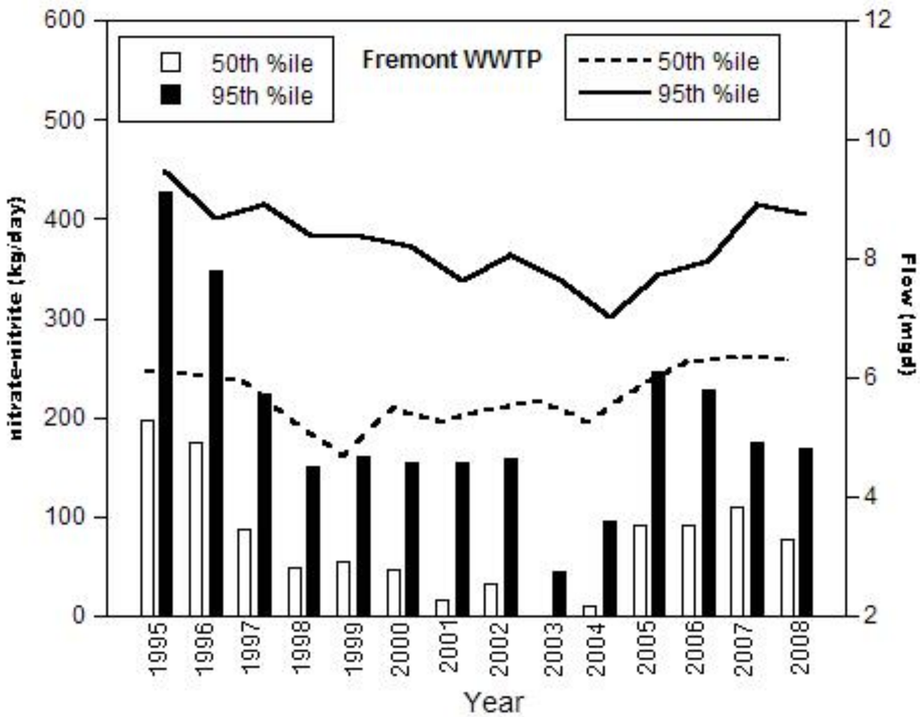


Figure 10. Annual nitrate+nitrite loadings (kg/day) and flow from the Fremont WWTP, 1995 to 2008.

Table 3. Facilities within the Sandusky Bay tributaries study area regulated by an individual NPDES permit.

Facility Name Permit Number	Outfall	Receiving Stream	River Mile	Description
City of Sandusky 2PF00001	019 021	Mills Creek Pipe Creek	0.95 1.60	combined sewer overflow combined sewer overflow
Wagner Quarries 2IJ00006	001 002	Taylor Ditch Hemminger Ditch	1.59	sedimentation sedimentation
Thakar Aluminum 2IE00007	001	Mills Creek	0.22	heat exchanger
NASA Plum Brook 2IO00002	001 002 003 005 010 014 016	Kuebler Ditch Ransom Brook Plum Brook Kuebler Ditch Lindsey Ditch Pentolite Ditch	1.75 3.55 5.5 2.1 --- ---	instream sampler instream sampler retention pond package plant outlet pipe main sump cooling tower
BP Oil-Sandusky 2IN00178	001	RR ditch - Pipe Creek	1.30	sed. oil/water separator
Hanson Aggregates 2IJ00021	001 002	Caswell Ditch Pipe Creek	5.70 12.2	settling settling
LLC Okamoto 2IQ00015	002	storm sewer to Mills Creek		
Bellevue WTP 2IW00011	001 002 003	Snyder's Ditch	4.95	lime sludge lagoon lime sludge lagoon lime sludge lagoon
Bellevue WWTP 2PD00037	001	Snyder's Ditch	3.80	activated sludge, clarifier, trickling filter
Automotive Comp. 2IC00013	001	Schowe Ditch	0.70	
Kyklos Bearings 2IC00011	001	Mills Creek	1.55	storm water/polishing pond
Castalia Trout Farm 2IN00049	001 002	Cold Creek Cold Creek	1.79 2.09	settling settling
Clyde WWTP 2PD00004	001 010	Raccoon Creek Raccoon Creek	11.02 11.30	oxidation, clarifier, polishing, UV combined sewer overflow
Leafy oaks RV Park 2PR00147	001	Westerhouse Ditch	4.70	package plant w/chlorination-dechlorination
Club Rog 2PR00170	001	trib. to Green Creek	4.65	package plant
Green Spring WWTP 2PB00026	001	Flag Run	1.2	aerated lagoons
Apollo MHP 2PY00062	001	Little Muddy Creek	3.90	aeration, clarification, sand filters, chlorination-dechlorination
Carmeuse Lime, Inc. 2IJ00032	001 005	Muddy Creek Rosa Walby Ditch	25.57 0.48	sedimentation sedimentation
Fostoria Ethanol, LLC 2IF00026	001	trib. Muskellunge Ck.	25.0	non-contact cooling water
Adam's Acres Sub. 2PG00082	001	Muskellunge Ck.	8.88	ex-aeration, sand filter, chlorination-dechlorination
Culligan Water Cond. 2IN00084	001	Minnow Creek	2.00	backwash water
Fremont WWTP 2PD00007	001 002	Sandusky River	13.85	primary/sedimentation, activated sludge, sand filter,

Facility Name Permit Number	Outfall	Receiving Stream	River Mile	Description
	003 004 005 006 007 008 009 010 011 012 013 015 016 017	 Sandusky River Sandusky River Sandusky River Sandusky River Sandusky River Sandusky River Sandusky River Sandusky River Sandusky River Sandusky River	 15.80 15.70 15.32 15.05 14.82 16.00 16.00 14.80 14.82 14.48	chlorination/dechlorination bypass secondary bypass combined sewer overflow combined sewer overflow combined sewer overflow combined sewer overflow combined sewer overflow combined sewer overflow combined sewer overflow combined sewer overflow combined sewer overflow combined sewer overflow combined sewer overflow combined sewer overflow combined sewer overflow
Heinz Company 2IN00009	001	Sandusky River	14.16	cooling water
Helena Head Start 2PT00032	001	trib. Muddy Creek		package plant w/chlorination-dechlorination
Lindsey WWTP 2PA00024	001 602	Muddy Creek	15.05	ex-aeration, sand filter, chlorination-dechlorination bypass
Westwood Acres Sub. 2PG00023	001	trib. Muskellunge Ck.	2.95	ex-aeration, sand filter, chlorination-dechlorination bypass

Chemical Water Quality

As mentioned in the Introduction section of this report, the Sandusky Bay tributaries study area was expanded to include several lower Sandusky River and tributaries sites. The expanded area includes the Sandusky River from just upstream of the Ballville Dam to the confluence of Sandusky Bay, Bark Creek, Fishing Creek, and the lower segments of Muskellunge Creek, Muddy Creek and Little Muddy Creek. The Sandusky Bay tributaries study area originally consisted of three 10-digit Hydrologic Unit Codes (HUC 10s) Watershed Assessment Units (WAUs). The sites associated with the expanded area are within two additional HUC10s. Each HUC 10 may be further divided into HUC 12s.

At most sites, five water quality sampling events were conducted June through August, 2009. Results for select water quality constituents that exceed Ohio Water Quality Standards (WQS) or targets are summarized in Tables 4-8. The ecoregional criterion (minimum/maximum, average) or target used to evaluate each constituent is included in the table. Results above these levels are considered degraded and are highlighted in bold. In some cases, the geometric mean of sample results is computed and presented for comparison to the criterion or target. Results of all inorganic and organic water quality samples collected in the survey areas during 2009 are presented in Appendices B and C.

Mills Creek-Frontal Lake Erie (HUC-10 0410001101)

Mills Creek–Frontal Lake Erie WAU consists of three HUC12s, which were sampled and evaluated at 17 locations. The Sawmill Creek WAU (HUC12-041000110101) included one sample location at Sawmill Creek RM 1.0. None of the physical or chemical constituents tested in grab samples exceeded their respective WQS criteria. Nitrate concentrations were slightly elevated in two grab samples; however calculation of the geometric mean indicated a level well below the target value of 1.0 mg/L. Geometric mean calculations for total phosphorus were well below the target value of 0.08 mg/L for headwater streams.

Within the Pipe Creek WAU (HUC12-041000110102), seven water quality sites were evaluated, including sites on Pipe Creek, Plum Brook and Taylor Ditch. Results from the four sites evaluated on Pipe Creek indicated slightly elevated nitrate concentrations, with one individual site (RM 8.15) having a geometric mean calculation exceeding the target value of 1.0 mg/L. Total phosphorus levels were slightly elevated on several occasions, but geometric mean calculations did not exceed the respective target value. The WQS criterion for pH (su) of < 9.0 for the protection of aquatic life was exceeded on one occasion. One sample location was evaluated on Plum Brook with no results exceeding the respective WQS criteria. Nutrient concentrations were elevated in several grab samples, but geometric mean calculations were well below the target values. Two sample locations were evaluated on Taylor Ditch. At RM 0.80 total dissolved solids (TDS) concentrations exceeded the WQS criterion of 1500 mg/L for the protection of aquatic life. One possible source of the elevated TDS is Wagner Quarries DBA (Permit No. 2IJ0000) discharge at approximately RM 1.59.

Within the Mills Creek WAU (HUC12-041000110103), nine sites were evaluated, including locations on Snyder's Ditch, Mills Creek and Caswell Ditch. Severe nutrient enrichment was evident throughout the watershed. Snyder's Ditch is the headwaters of Mills Creek and is a designated PWS for the village of Bellevue. Nitrate concentrations exceeded the drinking water standard Maximum Contaminant Level (MCL) of 10.0 mg/L in one grab sample. At all locations nitrate concentrations and total phosphorus exceeded the respective target values as displayed in Figures 11 and 12. The WQS criteria for pH and TDS were exceeded at several locations. The most prominent source of nutrients leading to impairment throughout Mills Creek is the village of Bellevue WWTP (Permit No. 2PD00037) which discharges to Snyder's Ditch at RM 3.8. In addition, livestock operations and failing HSTS likely contribute to the excessive nutrient enrichment noted in Mills Creek. A single site evaluated on Caswell Ditch exhibited slightly elevated nutrient levels which was likely due to the surrounding crop production with subsurface drainage.

Pickerel Creek-Frontal Sandusky Bay (HUC10-0410001102)

The Pickerel Creek–Frontal Sandusky Bay WAU consists of five HUC12s which were sampled and evaluated at 15 sites. Strong ground water influences in many of the streams within this watershed resulted in TDS concentrations above the WQS criterion of 1500 mg/L. This is likely a natural phenomenon due to high levels of dissolved minerals in the ground water. Sampling locations in Cold Creek, Little Pickerel Creek, Strong Creek, Pickerel Creek, and Buck Creek all had samples exceeding the WQS criterion for TDS. Strontium is also present in high concentrations in the ground water of northwest Ohio, and levels exceeding the Outside Mixing Zone Average (OMZA) criterion of 21,000 µg/L were found in Pickerel Creek.

In addition to naturally occurring exceedences of TDS and strontium, anthropogenic influences resulted in elevated nutrient concentrations at several sampling locations. In Strong Creek, elevated nutrients were detected downstream of the unsewered Village of Vickery and were most likely influenced by the discharge of poorly treated/untreated sewage. Evaluation of sample results from Raccoon Creek indicated elevated nutrient levels throughout all sampling locations with severe nutrient enrichment observed just downstream of the City of Clyde's WWTP (Permit No. 2PD00004) outfall (Figures 13 and 14). Nutrient levels were also slightly elevated in Buck Creek and South Creek. In South Creek, this is likely due to a combination of failing HSTS and agricultural activities. Within Buck Creek, it is likely due to the surrounding agricultural landscape. As discussed within the Macroinvertebrate section of this report, Buck Creek had a historic paucity of macroinvertebrates believed to be related to pesticide usage in upstream orchards and crops. Dieldrin was detected at a concentration of 0.0027 (µg/L) in one grab sample in Buck Creek, which is an extremely persistent organic pesticide used widely in the 1950s to early 1970s as an alternative to DDT.

Green Creek (HUC10-0410001112)

The Green Creek WAU consists of three HUC12s which were evaluated at 11 sampling locations. Elevated nitrate levels were detected at one site on Westerhouse Ditch and also in one grab sample from Emerson Creek, but the sample from Emerson Creek was collected from an isolated pool and was not representative of a free-flowing stream. Beaver Creek had elevated nitrate levels at all sites, including one grab sample with a measured exceedence above the drinking water MCL of 10 mg/L near RM 3.48, the area designated as a PWS for the city of Clyde. The nutrient levels are likely associated with the surrounding crop production with subsurface drainage throughout the watershed. In addition to the occasionally elevated nutrients, elevated TDS and strontium levels were observed throughout the Green Creek WAU due to naturally occurring ground water influences which contain high levels of dissolved minerals.

Muskellunge Creek–Sandusky River (HUC10-0410001113)

The Muskellunge Creek–Sandusky River WAU consists of three HUC12s which were sampled and evaluated at 11 locations. Individual grab samples were elevated for nitrates in samples from Bark Creek, Muskellunge Creek, and free-flowing portions of the Sandusky River. However, only the Sandusky River mouth sites had nitrates exceeding the target threshold. Iron and aluminum were the only parameters besides nutrients with measured exceedences. Aluminum concentrations in the Sandusky River were above the OMZA Human Health WQS criterion of 970 µg/L and iron concentrations were above the WQS criterion of 5000 µg/L for the protection of the Agricultural Water Supply use in several grab samples.

Muddy Creek–Frontal Sandusky Bay (HUC10-0410001114)

For the purpose of this study, two sites were evaluated within the Muddy Creek–Frontal Sandusky Bay WAU. Geometric mean calculations of results from samples collected in Little Muddy Creek and Fishing Creek indicated nutrient levels exceeding the target values. During one site visit to Fishing Creek the dissolved oxygen (DO) level as recorded from a field meter was below the WQS DO minimum criterion of 4.0 mg/L for the protection of aquatic life. Total phosphorus exceeded the respective nutrient target value in samples collected from Muddy Creek near the confluence with Muddy Creek bay. The high levels of nutrients are likely attributable to the upstream crop production with subsurface drainage noted throughout the watershed.

Table 4. Results for select water quality constituents tested in grab samples from the Mills Creek – Frontal Lake Erie WAU. The WQS criterion (min/max, avg.) or target used to evaluate the constituent is included. Concentrations that exceeded these levels are considered degraded and are highlighted in bold.

HUC 10 (04100011-01) Mills Creek – Frontal Lake Erie				
Stream Use Designations	River Mile/ (Drainage)	Use	Constituent	Values
HUC 12 (04100011-01-03) Mills Creek				
Mills Creek WWH, PCR, AWS, IWS (1978 WQS)	10.40 (21.0 mi^2) Wadable	WWH	NO_3-NO_2 (mg/L) Target = 1.0	**18.6, 9.92, 10.4, 10.4, 9.5** **(Geo. Mean = 11.36)**
			Total, P (mg/L) Target = 0.10	**0.741, 0.807, 0.437, 0.303, 0.228** **(Geo. Mean = 0.448)**
			TDS (mg/L) Aquatic Life= 1500	1490, **1620**, 1210, 1260, 820
	6.03 (29.0 mi^2) Wadable	WWH	NO_3-NO_2 (mg/L) Target = 1.0	**6.1, 4.62, 6.9, 6.95, 8.75** **(Geo. Mean = 6.52)**
			Total, P (mg/L) Target = 0.10	**0.549, 0.598, 0.346, 0.168, 0.13** **(Geo. Mean = 0.301)**
			pH (s.u.) Aquatic Life < 9.0	8.11, 8.26**, 9.09,** 8.11
	5.20 (29.0 mi^2) Wadable	WWH	NO_3-NO_2 (mg/L) Target = 1.0	**3.75, 5.28, 6.15, 5.85, 8.35** **(Geo Mean = 5.68)**
			Total, P (mg/L) Target = 0.10	**0.523, 0.65, 0.338, 0.236, 0.152** **(Geo Mean = 0.333)**
			pH (s.u.) Aquatic Life < 9.0	8.29, 8.99**, 9.36,** 8.59
	3.70 (35.0 mi$^{2)}$ Wadable	WWH	NO_3-NO_2 (mg/L) Target = 1.0	**2.6, 3.85, 5.75, 5.29, 8.24** **(Geo. Mean = 4.78)**
			Total, P (mg/L) Target = 0.10	**0.567, 0.568, 0.136, 0.182, 0.133** **(Geo. Mean = 0.254)**
			pH (s.u.) Aquatic Life < 9.0	8.15, 8.79**, 9.19,** 8.70
	1.34 (39.7 mi^2) Wadable	WWH	NO_3-NO_2 (mg/L) Target = 1.0	**3.13, 2.43, 2.13, 1.54, 4.8, 4.26** **(Geo Mean = 2.83)**
			Total, P (mg/L) Target = 0.10	**0.325, 0.292, 0.146, 0.119, 0.135**, 0.07 **(Geo. Mean = 0.158)**
			pH (s.u.) Aquatic Life < 9.0	8.10, 8.24**, 9.31,** 8.51
Caswell Ditch WWH	0.85 (3.90 mi^2) Headwaters	WWH	NO_3-NO_2 (mg/L) Target = 1.0	0.25, 0.80, **1.20, 2.45** (Geo. Mean = 0.87)
			Total, P (mg/L) Target = 0.08	0.061, **0.101**, 0.026, 0.018 (Geo. Mean = 0.041)
			pH (s.u.) Aquatic Life < 9.0	8.70, **9.14**, 7.81
Snyder's Ditch MWH, SCR AWS, IWS (biological assessment) PWS (RM 5.0 & 5.5)	5.00 (1.5 mi^2) Headwaters	MWH PWS	NO_3-NO_2 (mg/L) Target = 1.0	0.25, 0.36, **2.76, 1.06, 14.1** **(Geo. Mean = 1.30)**
			NO_3-NO_2 (mg/L) MCL = 10	0.25, 0.36, 2.76, 1.06**, 14.1**
	3.85 (3.1 mi^2) Headwaters	MWH	NO_3-NO_2 (mg/L) Target = 1.0	**1.77, 1.65, 2.39, 2.87, 8.72** **(Geo. Mean = 2.81)**

Stream Use Designations	River Mile/ (Drainage)	Use	Constituent	Values
Snyder's Ditch (Continued)	2.46 ($4.3\ mi^2$) Headwaters	MWH	NO_3-NO_2 (mg/L) Target = 1.0	**21.6, 16.6, 10.6, 16.1, 8.29 (Geo. Mean = 13.84)**
			Total, P (mg/L) Target = 0.34	**0.742, 0.741, 0.428, 0.409, 0.294 (Geo. Mean = 0.490)**
			TDS (mg/L) Aquatic Life= 1500	**1630, 1680**, 1100, **1620**, 886
HUC 12 (04100011-01-02) - Pipe Creek – Frontal Sandusky Bay				
Pipe Creek WWH, PCR, AWS, IWS (1978 WQS)	10.90 ($9.4\ mi^2$) Headwaters	WWH	NO_3-NO_2 (mg/L) Target = 1.0	0.1, 0.16, **3.55** (Geo. Mean = 0.38)
			Total, P (mg/L) Target = 0.08	**0.144**, 0.02, 0.22 (Geo. Mean = 0.040)
			pH (s.u.) Aquatic Life < 9.0	8.05, 8.45**, 9.81**
	8.15 ($14.7\ mi^2$) Headwaters	WWH	NO_3-NO_2 (mg/L) Target = 1.0	**1.29, 2.0, 1.56, 1.02, 4.54, (Geo. Mean = 1.79)**
			Total, P (mg/L) Target = 0.08	**0.21, 0.137**, 0.057, 0.026, 0.04 (Geo. Mean = 0.0702)
	6.60 ($18.4\ mi^2$) Headwaters	WWH	NO_3-NO_2 (mg/L) Target = 1.0	0.25, 0.30, 0.69, **1.33, 4.41** (Geo. Mean = 0.79)
			Total, P (mg/L) Target = 0.08	**0.132, 0.091**, 0.061, 0.031, 0.034 (Geo. Mean = 0.0599)
	2.30 ($22.8\ mi^2$) Wadable	WWH	NO_3-NO_2 (mg/L) Target = 1.0	0.25, 0.25, 0.57, 0.59, **1.26, 1.70, 7.75** (Geo. Mean = 0.86)
			Total, P (mg/L) Target = 0.10	**1.29**, 0.091, 0.06, 0.068, 0.051, 0.063, **0.114** (Geo. Mean = 0.078)
Taylor Ditch	2.70 ($1.5\ mi^2$) Headwaters	WWH		No Exceedences
	0.80 ($2.9\ mi^2$) Headwaters	WWH	TDS (mg/L) Aquatic Life= 1500	**2010, 2180, 1640,1500**
Plum Brook WWH, PCR, AWS, IWS (1978 WQS)	1.00 ($6.8\ mi^2$) Headwaters	WWH	NO_3-NO_2 (mg/L) Target = 1.0	**3.61**, 0.10, 0.10, 0.38, **1.49** (Geo. Mean = 0.46)
			Total, P (mg/L) Target = 0.08	**0.140, 0.100**, 0.069, 0.066, 0.043 (Geo. Mean = 0.077)
HUC 12 (04100011-01-01) Sawmill Creek				
Sawmill Creek	1.00 ($13.5mi^2$) Headwaters	WWH	NO_3-NO_2 (mg/L) Target = 1.0	0.10, 0.15, 0.35, **1.38, 4.16** (Geo. Mean = 0.50)
			Total, P (mg/L) Target = 0.08	**0.115**, 0.033, 0.041, 0.019, 0.024 (Geo. Mean = 0.037)

Table 5. Results for select water quality constituents tested in grab samples from the Pickerel Creek – Frontal Sandusky Bay WAU. The WQS criterion (min/max, avg.) or target used to evaluate the constituent is included. Concentrations that exceeded these levels are considered degraded and are highlighted in bold.

HUC 10 (04100011-02) Pickerel Creek – Frontal Sandusky Bay				
Stream Use Designations	River Mile/ (Drainage)	Use	Constituent	Values
HUC 12 (04100011-02-01) Frontal South Side of Sandusky Bay				
Cold Creek CWH, PCR, AWS, IWS (1978 WQS)	0.30 (3.0 mi^2) Headwaters	CWH	NO_3-NO_2 (mg/L) Target = 1.0	0.10, 0.10, 0.11, **1.06** (Geo. Mean = 0.18)
			TDS (mg/L) Aquatic Life=1500	**1650, 1680, 1620**, 1450
Little Pickerel Creek CWH, PCR, AWS, IWS (1978 WQS)	1.25 (5.9 mi^2) Headwaters	CWH	NO_3-NO_2 (mg/L) Target = 1.0	0.19, 0.24, 0.42, 0.55, **2.05** (Geo. Mean = 0.46)
			TDS (mg/L) Aquatic Life=1500	**1750, 1770 1760, 1650**, 1430
HUC 12 (04100011-02-02) Strong Creek				
Strong Creek WWH, PCR, AWS, IWS (1978 WQS)	2.90 (4.0 mi^2) Headwaters	WWH	NO_3-NO (mg/L) Target = 1.0	0.10, 0.53, **3.14, 7.96, 9.18** **(Geo. Mean = 1.65)**
			TDS (mg/L) Aquatic Life=1500	1270,**1610**, 870, 638, 656
	2.00 (4.6 mi^2) Headwaters	WWH	NO_3-NO_2 (mg/L) Target = 1.0	0.21, 0.37, **2.39, 7.42, 8.86** **(Geo. Mean = 1.65)**
			Total, P (mg/L) Target = 0.08	**0.753, 0.494, 0.222, 0.112**, 0.078 **(Geo. Mean = 0.235)**
			TDS (mg/L) Aquatic Life=1500	**2540, 2490**, 1030, 702, 598
HUC 12 (04100011-02-03) Pickerel Creek				
Pickerel Creek WWH, PCR, AWS, IWS (biological assessment)	6.26 (9.5 mi^2) Headwaters	WWH	NO_3-NO_2 (mg/L) Target = 1.0	0.13, 0.10, **4.51, 5.11, 8.00** **(Geo. Mean = 1.19)**
			Total, P (mg/L) Target = 0.08	0.047, **0.095, 0.087**, 0.014, 0.033 (Geo Mean = 0.045)
	3.30 (43.7 mi^2) Wadable	WWH	NO_3-NO_2 (mg/L) Target = 1.0	0.43, **1.04, 3.48, 4.04, 3.95, 7.81** **(Geo. Mean = 2.40)**
			Total, P (mg/L) Target = 0.10	0.045, **0.126**, 0.084, 0.088, **0.109** (Geo. Mean = 0.078)
			TDS (mg/L) Aquatic Life=1500	**2230, 2250, 2030, 1840, 1680**, 1050
			Strontium (µg/L) Aquatic Life OMZA = 21,000	**31200, 25600, 21200**, 18000, 14400, 7580

Stream Use Designations	River Mile/ (Drainage)	Use	Constituent	Values
HUC 12 (04100011-02-04) Raccoon Creek				
Raccoon Creek WWH, SCR, AWS, IWS (biological assessment)	13.60 (8.6 mi^2) Headwaters	MWH	NO_3-NO_2 (mg/L) Target = 1.0	0.22, 0.26, **2.62, 1.34, 5.43** **(Geo. Mean = 1.07)**
			Total, P (mg/L) Target = 0.08	**0.105, 0.129, 0.082, 0.081**, 0.045 **(Geo. Mean = 0.083)**
	11.32 (11.3 mi^2) Headwaters	WWH	NO_3-NO_2 (mg/L) Target = 1.0	**1.05, 1.88, 3.29, 1.70, 2.93** **(Geo. Mean = 2.00)**
			Total, P (mg/L) Target = 0.08	**0.154, 0.415, 0.132, 0.091**, 0.062 **(Geo. Mean = 0.137)**
Clyde WWTP Outfall (RM 11.02)	11.01 (11.6 mi^2) Headwaters	WWH	NO_3-NO_2 (mg/L) Target = 1.0	**13.00, 12.10, 11.40, 9.95, 7.95** **(Geo. Mean = 10.72)**
			Total, P (mg/L) Target = 0.08	**0.901, 1.070, 0.415, 0.091**, 0.077 **(Geo. Mean = 0.309)**
	10.76 (13.3 mi^2) Headwaters	WWH	NO_3-NO_2 (mg/L) Target = 1.0	**14.20, 11.90, 9.90, 7.31** **(Geo. Mean = 10.51)**
			Total, P (mg/L) Target = 0.08	**0.931, 0.352, 0.137**, 0.076 **(Geo. Mean = 0.242)**
	10.18 (13.3 mi^2) Headwaters	WWH	NO_3-NO_2 (mg/L) Target = 1.0	**12.0, 14.1, 11.2, 9.21, 9.97, 7.93** **(Geo. Mean = 10.55)**
			Total, P (mg/L) Target = 0.08	**0.893, 0.849, 0.266, 0.126, 0.107, 0.108** **(Geo. Mean = 0.259)**
	5.45 (22.5 mi^2) Wadable	WWH	NO_3-NO_2 (mg/L) Target = 1.0	**5.09, 4.21, 5.07, 5.33, 4.22, 4.59, 5.44** **(Geo. Mean = 4.88)**
			Total, P (mg/L) Target = 0.10	**0.115, 0.323**, 0.089, **0.147**, 0.035, 0.062, 0.078 (Geo. Mean = 0.097)
Buck Creek WWH, PCR, AWS, IWS (1978 WQS)	0.20 (4.5 mi^2) Headwaters	WWH	NO_3-NO_2 (mg/L) Target = 1.0	0.10, **1.94, 2.47, 6.29** **(Geo. Mean = 1.32)**
			TDS (mg/L) Aquatic Life = 1500	**1830**, 912, 804, 574
			Dieldrin (µg/L) Tier II Human Health = 0.0000065	**0.0027,** (0.0022 below MDL)
HUC 12 (04100011-02-05) South Creek				
South Creek WWH, PCR, AWS, IWS (1978 WQS)	7.92 (7.1 mi^2) Headwaters	WWH	NO_3-NO_2 (mg/L) Target = 1.0	0.27, 0.53, **3.09, 3.30, 6.55** **(Geo. Mean = 1.57)**
			Total, P (mg/L) Target = 0.08	**0.123, 0.101, 0.110**, 0.069, 0.053 (**Geo. Mean = 0.087)**
	4.00 (18.1 mi^2) Headwaters	WWH	NO_3-NO_2 (mg/L) Target = 1.0	0.10, **2.44, 3.09, 3.98, 7.37** **(Geo Mean = 1.86)**
			Total, P (mg/L) Target = 0.08	0.076, 0.032, 0.080, **0.100, 0.085** (Geo Mean = 0.045)

Table 6. Results for select water quality constituents tested in grab samples from the Green Creek WAU. The WQS criterion (min/max, avg.) or target used to evaluate the constituent is included. Concentrations that exceeded these levels are considered degraded and are highlighted in bold.

HUC 10 (04100011-12) Green Creek				
Stream Use Designations	River Mile/ (Drainage)	Use	Constituent	Values
HUC 12 (04100011-12-03) Green Creek				
Green Creek CWH, PCR, AWS, IWS (1978 WQS)	18.80 (53.0 mi^2) Wadable	CWH	NO_3-NO (mg/L) Target = 1.0	0.11, 0.10, 0.47, 0.29, **4.45** (Geo. Mean = 0.37)
			TDS (mg/L) Aquatic Life=1500	**2400, 2290, 2200, 2060, 1710**
	12.85 (71.0 mi^2) Wadable	CWH	NO_3-NO (mg/L) Target = 1.0	0.15, 0.23, 0.22, 0.67, 0.94, **4.35** (Geo. Mean = 0.52)
			TDS (mg/L) Aquatic Life=1500	**2380, 2300, 2300, 2130, 1940**, 1460
	9.08 (74.0mi^2) Wadable	CWH	NO_3-NO (mg/L) Target = 1.0	0.10, 0.16, 0.76, **1.21, 1.66, 4.68** (Geo. Mean = 0.70)
			Total, P (mg/L) Target = 0.10	0.024, 0.034, 0.069, **0.104**, 0.054, 0.071 (Geo. Mean = 0.053)
			TDS (mg/L) Aquatic Life=1500	**2330, 2290, 2080, 1870, 1870, 1380**
WWH, PCR, AWS, IWS (1978WQS) Downstream St Rt. 20	5.06 (78.0 mi^2) Wadable	WWH	NO_3-NO (mg/L) Target = 1.0	0.17, 1**.22, 5.96**, 0.30, 0.10, **1.09, 2.13** (Geo. Mean = 0.70)
			TDS (mg/L) Aquatic Life=1500	**2250, 1700**, 992**, 2320, 2290, 1950, 1650**
			Strontium (µg/L) Aquatic Life OMZA = 21,000	**24300**, 13900, 6500, **22700, 22100**, 14400, 10600
HUC 12 (04100011-12-02) Beaver Creek				
Beaver Creek CWH, PCR, AWS, IWS (1978 WQS)	4.00 (20.9 mi^2) Wadable	CWH	NO_3-NO (mg/L) Target = 1.0	0.55, 0.76, **2.37, 2.05, 6.34** **(Geo Mean = 1.67)**
	3.48 (43.4 mi^2) Wadable	CWH PWS	NO_3-NO (mg/L) Target = 1.0	0.10, 0.35, 0.19, **3.33, 2.16, 2.98, 10.0** **(Geo. Mean = 1.05)**
			NO_3-NO_2 (mg/L) MCL = 10	0.10, 0.35, 0.19, 3.33, 2.16, 2.98, **10.0**
Albright Ditch WWH, PCR, AWS, IWS (1978WQS)	3.25 (3.8 mi^2) Headwaters	MWH	NO_3-NO (mg/L) Target = 1.0	0.31, 0.24, **1.50, 1.18, 4.4** (Geo. Mean = 0.90)
			Total, P (mg/L) Target = 0.08	0.073, 0.049, **0.143**, 0.049, 0.045 (Geo Mean = 0.065)

Stream Use Designations	River Mile/ (Drainage)	Use	Constituent	Values
Emerson Creek WWH, PCR, AWS, IWS (1978WQS)	10.10 (6.4 mi^2) Headwaters	WWH	NO_3-NO (mg/L) Target = 1.0	**15.0** (Dry site)
	6.85 (15.2 mi^2) Headwaters	WWH	No Samples/Dry Site	
	1.83 (22.0 mi^2) Wadable	WWH	NO_3-NO (mg/L) Target = 1.0	0.13, 0.10, **1.17**, 0.24, **6.37** (Geo. Mean = 0.47)
			Total, P (mg/L) Target = 0.10	0.077, 0.056, 0.116, 0.07, 0.08 (Geo. Mean = 0.077)
			D.O. (mg/L) Aquatic Life > 4	8.05, 7.94, 9.07, 10.28, **3.37**
HUC 12 (04100011-12-01) Westerhouse Ditch				
Westerhouse Ditch WWH, PCR, AWS, IWS (1978WQS)	3.25 (9.6 mi^2) Headwaters	WWH	NO_3-NO (mg/L) Target = 1.0	**3.49, 4.29, 6.34, 4.78, 7.50** **Geo. Mean = 5.08)**
			Total, P (mg/L) Target = 0.08	**0.29**, 0.074, 0.047, 0.057, **0.104** (Geo. Mean = 0.057))

Table 7. Results for select water quality constituents tested in grab samples from the Muskellunge Creek – Sandusky River WAU. The WQS criterion (min/max, avg.) or target used to evaluate the constituent is included. Concentrations that exceeded these levels are considered degraded and are highlighted in bold.

HUC 10 (04100011-13) Muskellunge Creek – Sandusky River				
Stream Use Designations	River Mile/ (Drainage)	Use	Constituent	Values
HUC 12 (04100011-13-01) Muskellunge Creek				
Muskellunge Creek WWH, PCR, AWS, IWS (1978 WQS)	1.23 (44.0 mi^2) Wadable	WWH	NO_3-NO_2 (mg/L) Target = 1.0	0.13, 0.11, 0.23, **9.66, 3.47** (Geo. Mean = 0.64)
			Total, P (mg/L) Target = 0.10	**0.105**, 0.080, 0.063, **0.171**, 0.048 (Geo. Mean = 0.085)
HUC 12 (04100011-13-02) Indian Creek – Sandusky River				
Sandusky River WWH, PCR, AWS, IWS (1978 WQS) PWS (RM 18.02)	18.05 (1255 mi^2) Large River	WWH PWS	NO_3-NO_2 (mg/L) Target = 2.0	0.10, 0.10, **3.18, 3.41, 8.39** (Geo. Mean = 0.98)
			Aluminum (µg/L) Human Health Drinking OMZA = 970	**1120, 1090**, 272, **1050, 4080**
			Iron (µg/L) Ag. Use = 5000	1930, 1690, 404, 1570, **6010**
	17.70 (1255 mi^2) Large River	WWH	NO_3-NO_2 (mg/L) Target = 2.0	0.10, 0.10, **3.87, 3.57, 8.36** (Geo. Mean = 1.03)
			Iron (µg/L) Ag. Use = 5000	849, 2390, 559, 1150, **6490**
	15.40 (1260 mi^2) Large River	WWH	NO_3-NO_2 (mg/L) Target = 2.0	0.10, 0.13, **3.98, 3.69, 8.93** (Geo. Mean = 1.11)
			Iron (µg/L) Ag. Use = 5000	883, 1140, 576, 1220, **6220**
HUC 12 (04100011-13-03) Mouth Sandusky River				
Sandusky River WWH, PCR, AWS, IWS (1978 WQS)	4.70 (1330 mi^2) Large River	WWH	NO_3-NO_2 (mg/L) Target = 2.0	0.39, **2.14, 6.56, 6.84, 9.75** **(Geo. Mean = 3.25)**
Bark Greek	3.20 (10.0 mi^2) Headwaters	WWH	NO_3-NO_2 (mg/L) Target = 1.0	0.14, 0.32, **1.70, 1.75, 6.20** (Geo. Mean = 0.96)
			Total, P (mg/L) Target = 0.08	0.027, **0.175**, 0.028, **0.096**, 0.020 (Geo. Mean = 0.048)

Table 8. Results for select water quality constituents tested in grab samples from the Muddy Creek – Frontal Sandusky Bay WAU. The WQS criterion (min/max, avg.) or target used to evaluate the constituent is included. Concentrations that exceeded these levels are considered degraded and are highlighted in bold.

HUC 10 (04100011-14) Muddy Creek – Frontal Sandusky Bay				
Stream Use Designations	River Mile/ (Drainage)	Use	Constituent	Values
HUC 12 (04100011-14-03) Little Muddy Creek				
Little Muddy Creek WWH, PCR, AWS, IWS (1978 WQS)	7.55 (12.4 mi^2) Headwaters	WWH	NO_3-NO_2 (mg/L) Target = 1.0	0.71, **5.24, 8.47, 7.30** **(Geo. Mean = 3.89)**
	2.5 (25 mi^2) Wadable	WWH	NO_3-NO_2 (mg/L) Target = 1.0	0.10, 0.10, **3.50, 8.72, 5.36** **(Geo. Mean = 1.10)**
			Total, P (mg/L) Target = 0.10	**0.204, 0.172**, 0.099, 0.082, 0.070 **(Geo. Mean = 0.115)**
Fishing Creek	0.2 (7.0 mi^2) Headwaters	WWH	NO_3-NO_2 (mg/L) Target = 1.0	0.10, 0.10, **1.96, 8.00, 2.52** (Geo. Mean = 0.83)
			Total, P (mg/L) Target = 0.08	**0.229, 0.150, 0.121**, 0.069, **0.084** **(Geo. Mean = 0.119)**
			D.O. (mg/L) Aquatic Life > 4	6.04, 5.95, 7.71, 4.48**, 3.67**
HUC 12 (04100011-14-04) Town of Lindsey – Muddy Creek				
Muddy Creek WWH, PCR, AWS, IWS (Biological Assessment)	1.23 (110 mi^2) Wadable	WWH	NO_3-NO_2 (mg/L) Target = 1.0	0.10, 0.10, 0.16, 0.61, **5.71** (Geo. Mean = 0.35)
			Total, P (mg/L) Target = 0.10	**0.399, 0.273, 0.106, 0.138,** 0.075 **(Geo. Mean = 0.164)**

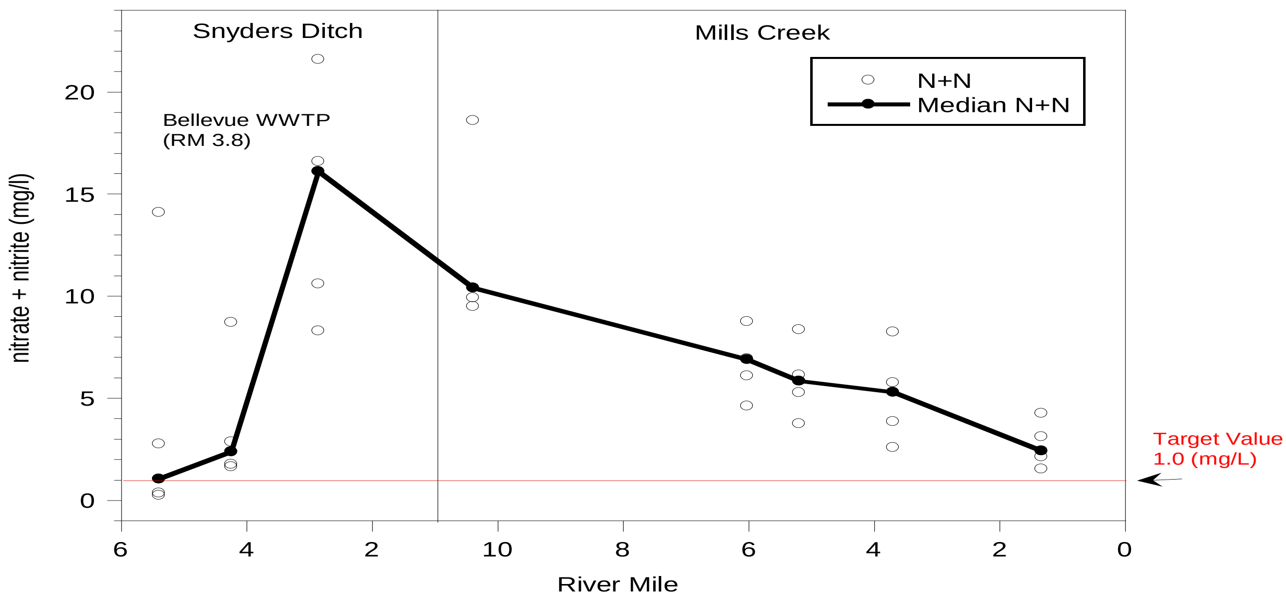


Figure 11. Nitrate+nitrite concentrations from Snyder's Ditch and Mills Creek, 2009.

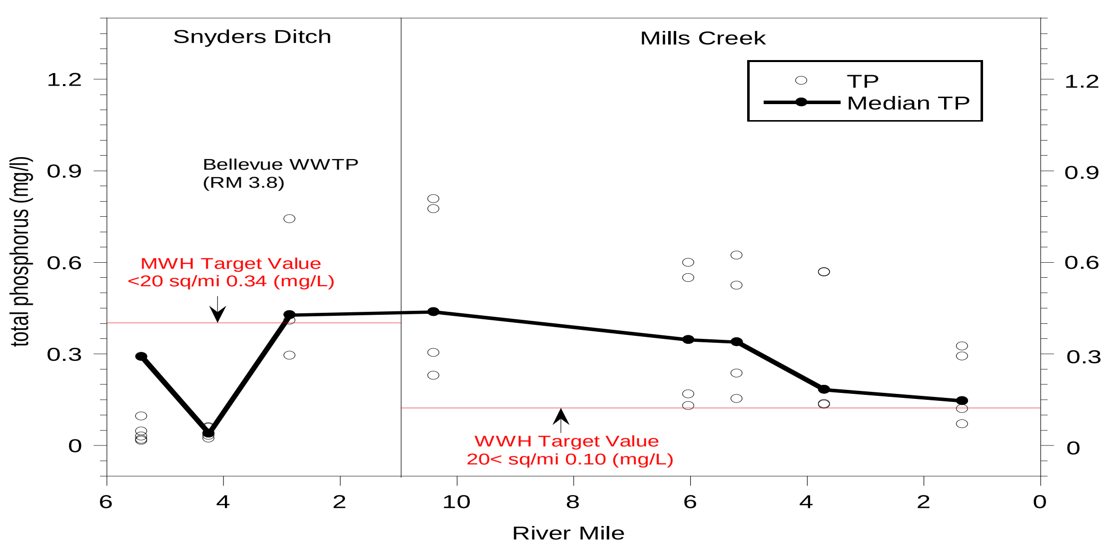


Figure 12. Total phosphorus concentrations from Snyder's Ditch and Mills Creek, 2009.

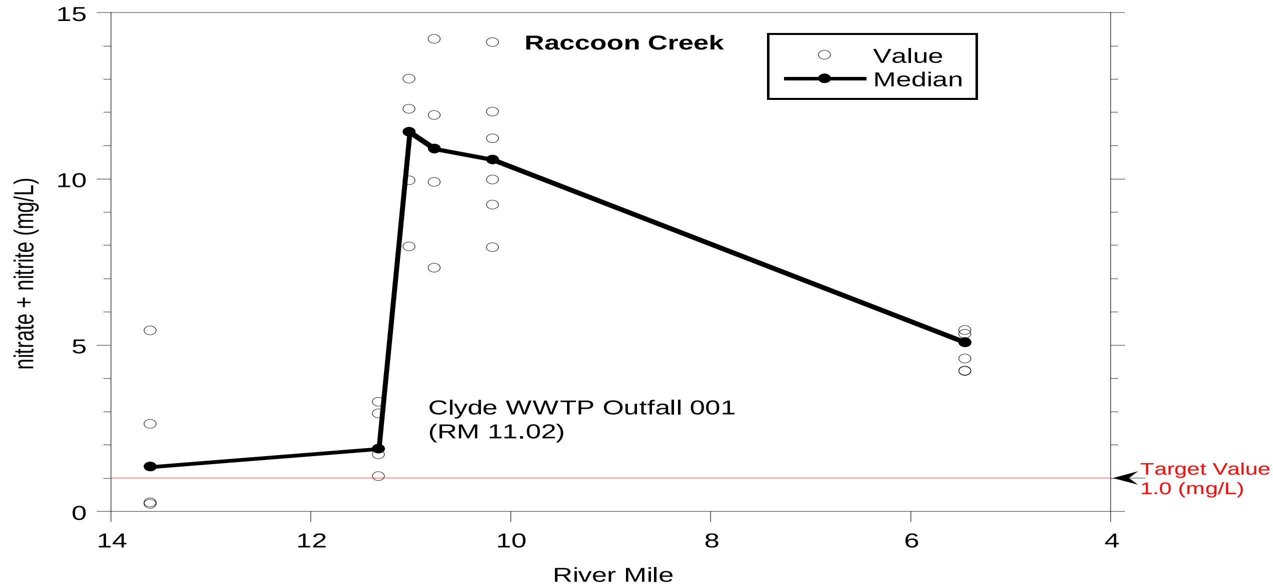


Figure 13. Nitrate+nitrite concentrations from Raccoon Creek, 2009.

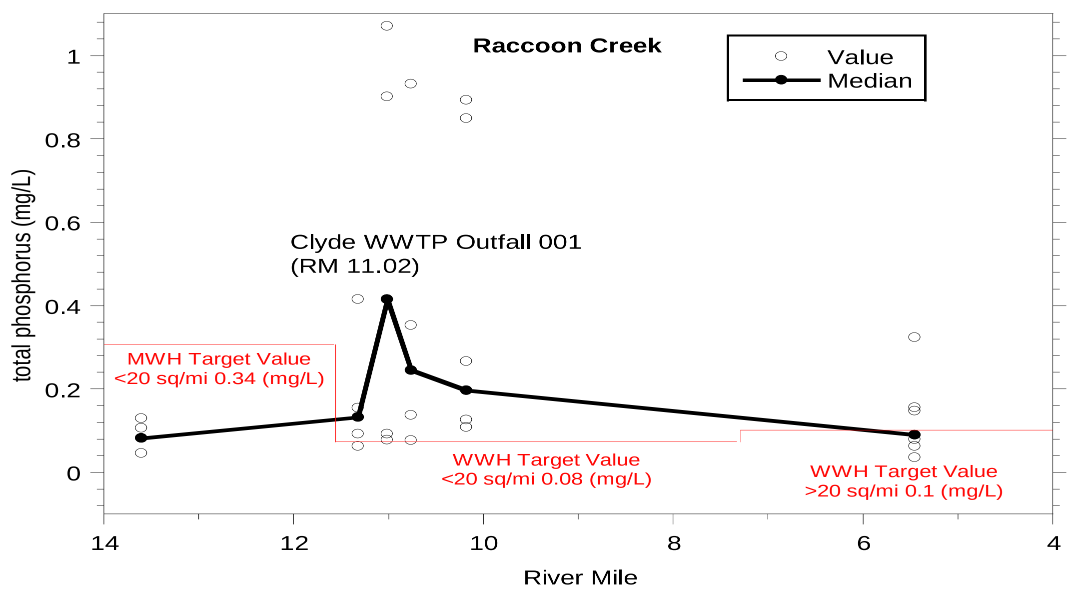


Figure 14. Total phosphorus concentrations from Raccoon Creek, 2009.

Recreational Use

There was widespread impairment of the recreation use in the Sandusky Bay tributaries study area (Table 9). All twelve sites exceeded the assigned or recommended recreation use criterion.

Recreation use attainment status was determined by comparing *E. coli* sample results to the recreational use WQS criteria. Individual site geometric mean calculations which exceed the standard applied to the stream class designation are considered to be in non-attainment with the WQS. The following methodology was applied: at least one site was sampled within a HUC 12, all sentinel sites were sampled, and all sites on class A streams were sampled. Five sampling events were conducted at each site during the recreation use season, which extends from May 1st through October 31st. Additional sampling was conducted at sentinel sites throughout the year. All 12 sites are considered to be in non-attainment of the *E. coli* WQS criteria. A summary of the *E. coli* sample results is presented in Table 9.

Of particular note are the extremely high *E. coli* counts found downstream of the following sources:

Unknown – Mills Creek RM 1.34
Unknown sources – Pipe Creek RM 2.3
Vickery (unsewered) – Strong Creek RM 2.0
Livestock – South Creek RM 4.0

Some of the potential sources of bacterial contamination throughout the entire study area are indicated in Table 9, but the sources listed have not necessarily been confirmed as a source of impairment nor are other possible sources excluded.

Table 9. Recreation use attainment table for 12 locations in the Sandusky Bay tributaries study area, May 1 through October 31, 2009. Attainment decisions were made based on cells outlined in bold. Note:All *E. coli* values are expressed as colony forming units (cfu) per 100 ml of water. Gray shaded values exceed the criteria for the associated use (Secondary Contact Recreation or the assigned class of the Primary Contact Recreation use):

Class A (lakes and popular paddling streams) - Geometric Mean <126 Single Sample Maximum Value ≤298
Class B (most streams; those that are not Class A or C) - Geometric Mean <161 Single Sample Maximum Value ≤523
Class C (streams that support infrequent recreation (e.g. wading)) - Geometric Mean <206 Single Sample Maximum Value ≤940
Secondary Contact Recreation (SCR). Geometric Mean ≤ 1030. Single Sample Maximum Value ≤ 1030.

Station ID	Location	River Mile	PCR Class	Number of Samples	*E. coli* Geometric Mean	*E. coli* Maximum Value	Attainment Status	Source(s) of Bacteria
HUC 10 - 0410001101 Mills Creek – Frontal Lake Erie								
U05P05	Mills Creek @ Perkins Ave.	1.34	B*	8	646	2000	NON	Unknown
U05K15	Pipe Creek @ Columbus Ave.	2.30	B	8	546	2000	NON	Unknown
K01K21	Sawmill Creek @ Boos Rd.	1.0	B	8	204	310	NON	Unknown
HUC 10 - 0410001102 Pickerel Creek – Frontal Sandusky Bay								
300670	Cold Creek @ Bardshar Road	0.30	B	5	173	910	NON	Unknown
201385	Little Pickerel Creek @ Yetter Rd.	1.25	B	8	352	710	NON	Unknown
U05K11	Pickerel Creek @ Twp. Rd. 247	3.30	B	8	471	1600	NON	Unknown
U05K11	Strong Creek @ Twp. Rd. 268	2.0	B	8	1434	4200	NON	Vickery (unsewered)
U05W17	Raccoon Creek @Twp. Rd. 244	5.45	B*	8	467	1200	NON	Unknown
U05K05	South Creek @ Twp. Rd. 247	4.0	B	8	968	>2400	NON	Livestock
HUC 10 - 0410001112 - Green Creek								
U04K01	Green Creek @ Twp. Rd. 239	5.06	B	8	392	920	NON	Unknown
U04G25	Beaver Creek @ Clyde WTP intake	3.48	B	8	186	340	NON	Unknown
U04K02	Westerhouse Ditch @ Snavely Rd.	3.25	B	5	333	1100	NON	Unknown

*- The existing recreation use is SCR, but this stream is being assessed with the recommended use, which is PCR-B.

Sediment Quality

Sediment sample results were evaluated using guidelines established in *Development and Evaluation of Consensus-Based Sediment Quality Guidelines for Freshwater Ecosystems* (MacDonald *et al*. 2000). The consensus-based sediment guidelines define two levels of ecotoxic effects. A *Threshold Effect Concentration* (TEC) is a level of sediment chemical quality below which harmful effects are unlikely to be observed. A *Probable Effect Concentration* (PEC) indicates a level above which harmful effects are likely to be observed. In addition, the Ohio Sediment Reference Values (SRV) were used which represents ecoregion background conditions based on data collected at Ohio reference sites (Ohio EPA 2008).

Sediments selected for sampling consisted mainly of fine silts and clays, which are generally associated with persistent environmental contaminants. Chemical quality of sediment is a concern because many pollutants bind strongly to soil particles, are persistent in the environment and accumulate in the food chain.

Sediment grab samples were analyzed for inorganic metals, semi-volatile organics, polychlorinated biphenyls (PCBs), and pesticides. Sediments with chemical concentrations reported above the PEC and/or the SRV may result in negative environmental impacts and warrant further evaluation. Only the results which exceeded guidance values are reported in Table 10. For a complete summary of all sediment chemistry results, refer to Appendices D and E.

In addition to the routine sediment analysis described above, gross Alpha radiation and gross Beta radiation analysis was conducted on all sediment samples. These analyses were conducted to coordinate with the radiation assessment being conducted as part of the childhood cancer investigation. Ohio EPA collected the sediment samples and sent them to ODH for analysis. All samples were found to be below the lower limit of detection for both gross Alpha and gross Beta radiation (Appendix F).

Sediment quality was evaluated at eight sampling locations within the study area. Several locations identified in the study plan were not sampled due to a lack of suitable sediments. Overall, sediment quality within the study area was found to be slightly impaired.

Sediment collected from the Sandusky River near the Ohio Turnpike crossing contained mercury concentrations above the SRV and TEC values, but well below the PEC level. PCB was detected in sediment collected from Raccoon Creek near the confluence with Sandusky Bay, with concentrations of total PCBs above the TEC but below the PEC. However, PCBs may be of concern due to the potential for bioaccumulation up the food-chain. The source of PCBs is unknown.

Sediment sampling in Buck Creek detected DDT, DDE, DDD and dieldrin. These compounds are pesticides which are no longer in use in the U.S. but are persistent in the environment. DDE, which is a breakdown product of DDT, was elevated above the PEC and may be of concern to aquatic life. A possible source of the pesticides may be historical use at nurseries and orchards located upstream of the sample location. As discussed in the Macroinvertebrate section of this report, historical sampling in Buck Creek indicated the possible presence of toxins to aquatic life, as there were very few macroinvertebrates present. It was thought at that time that upstream pesticide use may be negatively influencing the aquatic community. The presence of legacy pesticides and their by-products in the sediments of Buck Creek lend credence to this conclusion. Dieldrin was also detected above the TEC in sediments collected from Mills Creek at Portland Road. Samples collected from Mills Creek at Monroe Street contained total PCBs and the pesticide chlordane at levels elevated above the TEC but below the PEC. The source is unknown. Sediments collected from Pipe Creek at U.S. Route 6 contained lead, DDT and DDE at concentrations above the TEC but well below the PEC.

Table 10. Sediment results from the Sandusky Bay tributary study area which exceeded guidance values, 2009.

Parameter	Result	SRV	TEC	PEC
HUC 12 (04100011-13-03) Mouth Sandusky River				
Sandusky River Upstream Ohio Turnpike (RM 9.0)				
Mercury (mg/kg)	0.274	0.12	0.18	1.06
HUC 12 (04100011-14-04) Town of Lindsey – Muddy Creek				
Muddy Creek @ State Route 53 (RM 1.23)				
Strontium(mg/kg)	289	250	----	----
HUC 12 (04100011-02-04) Raccoon Creek				
Raccoon Creek @ Brugger Road (RM 2.18)				
Total PCBs (µg/kg)	281.5	----	59.8	676
PCB -1254	249	----	----	----
PCB -1260	32.5	----	----	----
Buck Creek @ Township Road 223 (RM 0.20)				
DDD (µg/kg)	22.7	----	4.88	28.0
DDE (µg/kg)	52.5	----	3.16	31.3
DDT (µg/kg)	34.5	----	4.16	62.9
Dieldrin (µg/kg)	7.2	----	1.90	61.8
HUC 12 (04100011-01-03) Mills Creek – Frontal Lake Erie				
Mills Creek @ Portland Road (RM 10.40)				
Dieldrin (µg/kg)	4.9	----	1.90	61.8
Mills Creek @ Monroe Street (RM 0.03)				
Chlordane (µg/kg)	8.6	----	3.24	17.6
Total PCBs (µg/kg)	314.3	----	59.8	676
PCB -1242	76.9	----	----	----
PCB -1254	205	----	----	----
PCB -1260	32.4	----	----	----
HUC 12 (04100011-01-02) Pipe Creek – Frontal Sandusky Bay				
Pipe Creek @ US 6 (RM 1.0)				
Lead (mg/kg)	40.4	47	35.8	128
DDE (µg/kg)	7.9	----	3.16	31.3
DDT (µg/kg)	10.8	----	4.16	62.9

Physical Habitat

Figure 15. The poor habitat quality of Pipe Creek RM 2.32 due to siltation, poor channel development and lack of adequate instream cover from channelization activities.

Figure 16. Good habitat quality is present at sites such as Green Creek RM 18.8. Diverse substrates and abundant instream cover with good channel development provide habitat for aquatic organisms and the dense riparian corridor assists with nutrient assimilation within the stream.

Stream habitat was evaluated at the 43 fish sampling locations (Table 11 and Appendix G). Excellent stream habitat was noted at only one location, Sandusky River (RM 12.85). Good stream habitat was recorded at 15 sites (35%), fair habitat was noted at 17 locations (40%), poor habitat was documented at 8 locations (19%), and very poor habitat was documented at 2 locations (4%) (Table 11). The average QHEI score for the watershed was 52.3, solidly within the fair range. QHEI scores lower than 60 indicate habitat conditions which may not be favorable to support WWH communities. The average QHEI score reflects the low habitat quality throughout the study area which is a direct result of excessive siltation from both crop production with poor erosion controls and channel modifications.

The Sandusky River mainstem had good to excellent habitat quality at five locations, with only fair habitat quality within the impounded portion upstream of Ballville Dam (RM 18.05). Muskellunge Creek and Bark Creek were the only Sandusky River tributaries in the study area. The two sites on Muskellunge Creek (RMs 5.4 and 1.23) exhibited fair to good habitat quality, respectively. Bark Creek RM 3.2 had poor habitat quality with heavy silt and extensively embedded substrates as a result of surrounding agricultural activities (Table 11 and Appendix G).

Raccoon Creek RM 5.45 was the only site within the Pickerel Creek–Frontal Sandusky Bay (HUC 10 – 0410001102) portion of the study area to have good overall habitat quality. Eight of the remaining ten sites presented fair habitat quality, with moderately heavy silt and embedded substrates/riffles as common causes of the less than ideal habitat conditions. The heavy silt loads were often associated with subsurface drainage for crop production, though channelization also contributed to the overall fair habitat quality. Pickerel Creek RM 3.35 had heavy silt and embedded substrates from channel erosion and incision as a result of upstream hydromodifications and bank destabilization. This was also likely the result of subsurface drainage for crop production. Raccoon Creek RM 11.32 and South Creek RM 4.04 both exhibited poor habitat quality as a result of extensively embedded substrates from heavy silt loads. A combination of channelization activities and livestock access to the stream were responsible for the heavy silt loads at South Creek RM 4.04, while channelization of the stream and urban run-off contributed to the heavy silt noted at Raccoon Creek RM 11.32 (Table 17 and Appendix G).

Habitat quality of ten sites was evaluated within the Mills Creek–Frontal Lake Erie (HUC 10 – 0410001101) portion of the study area. One site, Mills Creek RM 5.2, was the only site which demonstrated good habitat quality. However, the site was adjacent to a meat processing facility which had a small drainage ditch leading from the property to the stream approximately 50 to 100 meters downstream of Bogart Road. Sampling extended from about 175 meters downstream of the ditch to about 25 meters upstream of the ditch. A noxious, eye-watering odor was evident throughout the sampling reach, but was strongest as the water flowed through riffles and over logs. An inspection of the pretreatment lagoons for the facility on December 1, 2009, did not indicate any issues (Appendix H). An investigation as to the source of flow in the ditch should be conducted, along with sediment sampling of the ditch and stream below the confluence to determine the origin of the sediment odor.

The remaining sites within Mills Creek – Frontal Lake Erie had fair to very poor habitat. Extensively embedded substrates contributed to the fair habitat quality present at two sites, Mills Creek RMs 6.03 and 1.35, while poor channel development and unstable riffles contributed to the fair habitat quality of Sawmill Creek RM 1.10 and Pipe Creek RM 8.18. Heavy silt loads and extensively embedded substrates contributed to the poor habitat quality at three sites, while poor channel development and sparse instream cover resulted in poor habitat conditions for Pipe Creek RM 2.32 (Figure 15). Very poor habitat conditions were present at Mills Creek RM 10.4 due to heavy silt and embedded substrates from crop production with subsurface drainage (Table 11 and Appendix G).

Good overall habitat quality was present at eight of the ten sampling locations within the Green Creek (HUC 10 – 0410001112) portion of the study area. While silt loads were still heavy at some sites, diverse instream cover and fair to good channel development resulted in good overall habitat quality at these sites (Figure 16). Fair habitat quality was noted at Westerhouse Ditch RM 3.25 and poor habitat quality was observed at Emerson Creek (Royer Ditch) RM 6.85. The lower habitat quality at these two sites was the result of heavy siltation and extensively embedded substrates (Table 11 and Appendix G).

Two of the three sites within the Muddy Creek–Frontal Lake Erie (HUC 10 - 041000111404) portion of the study area exhibited fair habitat quality. Muddy Creek

RM 1.23 and Little Muddy Creek RM 2.5 both exhibited fair habitat quality, though the former was a result of channelization activities, including extensive levees and armored banks, while the latter was from upstream subsurface drainage practices for crop production resulting in heavy silt loads and extensively embedded substrates. Fishing Creek RM 0.2 had very poor habitat quality as a result of upstream subsurface drainage practices for crop production This contributed to heavy silt loads and extensively embedded substrates with no riffle present and poor channel development (Table 11 and Appendix G).

Table 11. Stream physical habitat (QHEI) summarized results for the Sandusky Bay tributaries study area, 2009.

Stream and Location	RM[a] (STORET)	Drain. (mi^2)	QHEI	Comments
Excellent				
SANDUSKY RIVER AT FREMONT UPSTREAM ROGER YOUNG PARK	16.8	1256	93	
Good				
GREEN CREEK SE OF FREMONT @ DEWEY RD.	12.85 (U04S10)	71	73	
MUSKELLUNGE CREEK NEAR FREMONT @ FANGBONER RD.	1.23 (U04P08)	44	69	
BEAVER CREEK DST. LEAFY OAKS MHP	4.00 (U04K03)	20.9	68	
GREEN CREEK @ CO. RD. 229	9.08 (U04G20)	74	67.5	
SANDUSKY RIVER AT FREMONT @ STATE ST.	15.4 (U04W11)	1260	67	
SANDUSKY RIVER OPPOSITE FREMONT YACHT CLUB	12.8	1264	67	
GREEN CREEK @ CO. RD. 34	18.80 (U04G24)	53	67	
EMERSON CREEK @ TWP. RD. 179	1.83 (U04G26)	22	67	
RACCOON CREEK DST. OHIO TURNPIKE @ TWP. RD. 244	5.45 (U05W17)	23.6	66	
SANDUSKY RIVER UPSTREAM BAY CONFLUENCE	1.3	1335	64.5	
GREEN CREEK NE OF FREMONT @ TWP. RD. 239	5.06 (U04K01)	78.3	64	
BEAVER CREEK @ ST. RT. 101	3.48 (U04G25)	43.4	62.5	
MILLS CREEK NEAR CASTALIA @ BOGART RD.	5.20 (U05P07)	29	61.5	Extensively embedded substrates
SANDUSKY RIVER UPSTREAM WIGHTMANS GROVE	5.5	1330	60	Heavy silt with extensively embedded substrates
WESTERHOUSE DITCH NE OF LOWELL @ ST. RT. 19	0.63 (U04K04)	16.2	57	Heavy silt with extensively embedded substrates
Fair				
MUSKELLUNGE CREEK NEAR FREMONT @ SPIELDENNER RD.	5.40 (201332)	37	58.5	Moderately heavy silt with low flow
WESTERHOUSE DITCH @ SNAVELY RD.	3.25 (U04K05)	9.6	52.5	Moderately heavy silt with extensively embedded riffles
SANDUSKY RIVER UST. BALLVILLE DAM	18.05	1255	52	Dam impoundment
RACCOON CREEK N OF CLYDE @ TWP. RD. 223	10.18 (U05W10)	13.8	51.5	Moderately heavy silt with extensively embedded substrates

Stream and Location	RM[a] (STORET)	Drain. (mi^2)	QHEI	Comments
MUDDY CREEK @ EAST SIDE OF ST. RT. 53	1.23 (U04Q13)	110	50.5	Channelization (including extensive levees and armored banks)
LITTLE PICKEREL CREEK @ YETTER RD.	2.00 (201385)	5.5	50.5	Heavy silt with extensively embedded substrates
SAWMILL CREEK W OF HURON @ BOOS RD.	1.10 (K01K21)	13.5	50.5	Unstable riffle and poor channel development
RACCOON CREEK UPST. CLYDE @ LIMERICK RD.	13.26 (U05S01)	9.9	49.5	Moderately heavy silt with extensively embedded substrates
MILLS CREEK SE OF CASTALIA @ ST. RT. 99	6.03 (U05S06)	29	49	Extensively embedded substrates
SOUTH CREEK @ CO. RD. 229	7.92 (U05G01)	7.1	48.5	Poor channel development from channelization activities
PICKEREL CREEK @ REINICKE RD. (TWP. RD. 233)	6.26 (U05K10)	9.5	48	Poor channel development with unstable riffles and moderately heavy silt
COLD CREEK @ BARDSHAR RD.	0.36 (300670)	2.9	47	Heavy silt with extensively embedded substrates
LITTLE MUDDY CREEK @ KLINE RD.	2.5 (300676)	25	47.5	Heavy silt with extensively embedded substrates
MILLS CREEK AT SANDUSKY @ PERKINS AVE.	1.35 (U05P05)	41	46.5	Extensively embedded substrates
PIPE CREEK N OF BLOOMINGVILLE @ PATTEN TRACT RD.	8.18 (U05K17)	14.7	46.5	Poor channel development with moderately heavy silt and unstable riffles
BUCK CREEK N OF CLYDE @ TWP. RD. 223	0.2 (U05S03)	4.5	45.5	Moderately heavy silt with extensively embedded riffles
PICKEREL CREEK @ TWP. RD. 247	3.35 (U05S04)	43.7	45	Channel erosion/incision from upstream hydromodifications; bank destabilization
Poor				
MILLS CREEK S OF SANDUSKY @ STRUB RD.	3.70 (U05S18)	35	42.5	Extensively embedded substrates
RACCOON CREEK AT CLYDE @ U.S. RT. 20	11.32 (U05P04)	12.7	42	Heavy silt with extensively embedded substrates
PIPE CREEK AT SANDUSKY @ COLUMBUS AVE.	2.32 (U05K15)	22.8	41.5	Poor channel development and sparse instream cover
CASWELL DITCH (TRIB TO MILLS CREEK 3.95) @ BOGART RD.	0.85 (U05W37)	3.9	34.5	Moderately heavy silt with extensively embedded riffles and lack of trees in riparian corridor
SOUTH CREEK NEAR RILEY CENTER @ WHITMORE RD. (TWP. RD. 247)	4.04 (U05K05)	18.1	33.5	Heavy silt with extensively embedded substrates, no riffle and poor channel development
BARK CREEK AT KELLEY RD. (CR 245)	3.20 (300671)	10.0	32.0	Heavy silt with extensively embedded substrates, no riffle and poor channel development
EMERSON CREEK (ROYER DITCH) NEAR FIRESIDE @ RON MEYERS RD.	6.85 (U04K07)	15.2	30.5	Heavy silt with extensively embedded substrates
PIPE CREEK S OF SANDUSKY @ SCHENK RD.	6.7 (U05K16)	18.4	30	Poor channel development with moderately heavy silt, extensively embedded substrates, and no riffle
Very Poor				
MILLS CREEK W OF PARKERTOWN @ PORTLAND RD.	10.40 (U05S07)	21	28.5	Extensively embedded substrates
FISHING CREEK @ WEICKERT RD.	0.20 (300678)	7	21.5	Heavy silt with extensively embedded substrates and no riffle

General narrative ranges assigned to QHEI scores.				
Narrative Rating		QHEI Range		
		Headwaters (≤20 sq mi)	Larger Streams	Lacustuary
Excellent		≥70	≥75	≥80
Good		55 to 69	60 to 74	60 to 80
Fair		43 to 54	45 to 59	45 to 59
Poor		30 to 42	30 to 44	30 to 44
Very Poor		<30	<30	<30

Fish Community

A total of 32,449 fish representing 74 species was collected from the study area between June and September 2009. Five pollution-sensitive species were collected, including river redhorse, which are considered a special interest species in Ohio. In addition, two state threatened species, brook trout and greater redhorse were also collected. Relative numbers and species collected per location are presented in Appendix I, and IBI and MIwb scores are presented in Appendix J. Sampling locations were evaluated using either Warmwater Habitat or Coldwater Habitat biocriteria according to the assigned or recommended aquatic life use designation. A summary of the fish data is presented in Table 12.

Sandusky River mainstem sites sampled during 2009 achieved the applicable WWH fish biocriteria at the two free-flowing sites. The Ballville Dam-impounded site at RM 18.05 also attained the WWH fish biocriteria, but may narratively be described as only a fair community. Dams create monotypic pool habitat which cannot support the diverse fish assemblage common in free-flowing streams, and therefore, the fair fish community performance within the Ballville Dam pool is not unexpected. However, dam removal would likely result in an improved fish community similar to the good fish community downstream at RM 16.8. The lacustuary sites on the Sandusky River, RMs 12.8, 5.5 and 1.3, did not the lacustuary benchmarks. Poor diversity at these sites was noted with IBI scores ranging from 26 to 32. Poor lacustuary MIwb scores, 8.7 and 7.5, respectively, for RMs 5.5 and 1.3, indicated imbalance in the fish communities at these sites (Table 12 and Appendices I and J).

The fish communities of two tributaries to the Sandusky River, Bark Creek and Muskellunge Creek, were included within the study area. The poor fish community of Bark Creek reflected the poor habitat conditions provided by the channelized stream conditions. The fish community of Muskellunge Creek met WWH expectations at both sites and was considered marginally good (Table 12 and Appendices I and J).

Six (55%) of the eleven fish sites within the Pickerel Creek–Frontal Sandusky Bay (HUC 10 – 0410001102) portion of the study area held fair fish communities. One of the sites, Cold Creek RM 0.36, would likely not have any fish community present if the ODNR fish hatchery and various trout clubs were not present. As mentioned in the Study Area Description section of this report, the spring which forms Cold Creek has little oxygen when it emerges. The ODNR hatchery aerates the water to increase oxygen levels sufficient to support the rearing of various species of trout (Dave Insley, Personal Communication). This aeration allows Cold Creek to support aquatic communities, including stocked trout from several clubs located downstream from the hatchery. Brown trout (37% by number), rainbow trout (12% by number) and brook trout (1% by number) comprised 50% of the fish community sampled during 2009. This was a direct result of stocking by trout clubs and the presence of the ODNR fish hatchery (Table 12 and Appendices I and J).

The remaining five sites in this HUC 10 supported poor fish communities, with an average IBI of 25. The poor fish community scores associated with three of the sites, South Creek RMs 7.92 and 4.04 and Raccoon Creek RM 5.45, reflected nutrient enriched conditions from unsewered areas, livestock, and the Clyde WWTP, respectively. The fish community of Little Pickerel Creek received an IBI of 26 and was dominated by white sucker (46% by number) and mottled sculpin (22% by number). The abundance of mottled sculpin, in addition to brown trout (16.7% by number) and rainbow trout (2% by number), are indicative of the strong ground water contribution to the stream flow. However, the trout are likely escapees from the upstream trout hatchery known as Little Pickerel Creek Farm (See Appendix K). Pickerel Creek is another stream with a significant ground water contribution resulting in a fish community representative of a small headwater stream though the drainage area at RM 3.35 was 43.7mi^2. Therefore, the headwater biocriterion were used to evaluate the fish community and the site received an IBI of 27. Pioneering species (creek chub, fathead minnow, bluntnose minnow, green sunfish, and johnny darter) comprised 58% of the fish community at the Pickerel Creek site, reflecting the unstable nature of the stream habitat affected by channel erosion and incision (Table 12 and Appendices I and J).

Only one fish site within the Mills Creek–Frontal Lake Erie (HUC 10 – 0410001101) portion of the study area supported an overall good fish community. Sawmill Creek RM 1.10 received an IBI of 44, which was the highest IBI score of streams less than 20mi^2. Insectivorous species, including striped shiner, green sunfish, logperch darter, johnny darter, and rainbow darter, comprised 48% of the fish community, reflecting the availability of interstitial spaces among the substrates to support aquatic life. In contrast, embedded substrates and heavy silt limited the available habitat for aquatic communities among the remaining streams in this portion of the study area. The remaining nine fish sampling locations were representative of poor fish communities with an average IBI of 22.6, directly related to the fair to very poor habitat conditions present at most sampling locations. In addition, insectivores comprised less than14% of the fish community at each of these sites, reflecting a degraded macroinvertebrate community, as discussed in the Macroinvertebrate section of this report.

The fish community of Green Creek (HUC 10 – 0410001112) was evaluated at ten locations during 2009. Several streams within this portion of the study area receive significant amounts of ground water which result in the fish communities deviating from expectation of increased diversity and density with increased drainage area. Swaidner and Berra (1979) conducted an ecological analysis of the fish distribution of Green Creek and found that the fish community is more representative of a much smaller stream than what the drainage area would indicate. They attributed the fish community structure to Beaver Creek spring which contributes vast amounts of cold, CaCO3 rich waters at the terminus of Beaver Creek/origin of Green Creek. CaCO3 may precipitate out of solution under specific temperature and pH regimes. When deposition occurs, it creates marl or travertine, which is a very harsh substrate with similar properties to clay. Both are detrimental to reproduction and distribution of aquatic invertebrates and fishes.

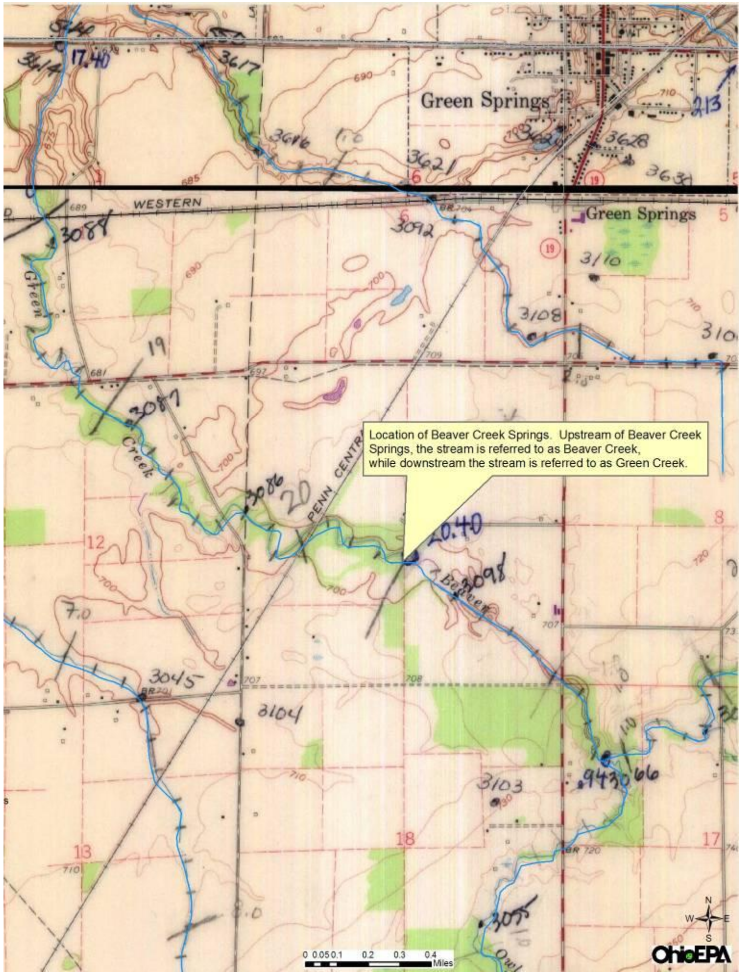


Figure 16. Location of Beaver Creek Springs. Upstream of this location, the stream is Beaver Creek, while downstream it is called Green Creek.

An examination of the fish communities collected at each Green Creek site in 2009 were compared to the similar locations collected by Swaidner and Berra (1979), though the most downstream site from 2009 (RM 3.9) corresponded with their Station 7, and no comparable site was available for their Station 8. Species diversity was found to be similar, with a slight increase in 2009 in the number of species at RM 3.9 that was attributed to Lake Erie influence, though biomass at this location was still low. Overall, fish biomass and diversity was low and similar to expectations of smaller streams. Therefore, headwater IBI metrics were applied to all of the Green Creek sites. The origin of Green Creek is at the confluence of Beaver Creek Springs and Beaver Creek, so with only headwater fish communities present in Green Creek, there was little likelihood that Beaver Creek or its tributary Emerson Creek (tributary to Beaver Creek at RM 3.60) would have established fish communities representative of larger drainage areas (Figure 16). An examination of the species and densities represented indicated that the fish communities of Beaver Creek and Emerson Creek are representative of headwater communities, and therefore the headwater IBI metrics were applied to them as well. Use of the headwater IBI metrics at these locations provides a method to adequately assess the fish communities present in areas of strong ground water contributions that deviate from the expectation of increased biodiversity and biomass with greater drainage area.

To that end, the fish community of Green Creek was considered marginally good to good at RMs 18.8 and 9.08, respectively. However, the fish communities were considered poor to fair at RMs 5.06 and 12.85, respectively. Insectivorous fish species at these two latter sites comprised only 18% of the fish community, as compared to 58% of the fish community at RM 18.9 and 34% of the fish community at RM 9.0. The low percentage of insectivores reflected the disruption in the macroinvertebrate community from sedimentation and siltation as a result of agricultural subsurface drainage and channel instability. The fish community of Beaver Creek was considered fair at both RMs 4.00 and 3.48, with pollution tolerant fish comprising 71% and 61.5%, respectively. The fish communities of Emerson Creek RMs 1.83 and 6.85 were considered poor, with tolerant fish comprising 79% and 99%, respectively. The high percentages of tolerant fish reflected the excessive siltation from the surrounding agricultural landscape surrounding Emerson Creek. In contrast, the fish community of Westerhouse Ditch had a fair fish community with an IBI of 30 at RM 3.30 and an IBI of 34 at RM 0.70.

The only fair fish community within Muddy Creek–Frontal Sandusky Bay (HUC 10 – 041000111404) was found at Fishing Creek RM 0.2, which scored an IBI of 32. The two remaining streams sampled received poor fish community scores with an IBI of 21 for Muddy Creek RM 1.23 and an IBI of 23 for Little Muddy Creek RM 2.5. The fish community at Muddy Creek RM 1.23 reflected the extensive channelization (levees and armored banks) present throughout the reach, while the upstream agricultural landscape of Little Muddy Creek RM 2.5 resulted in excessive siltation and excess nutrients affecting the aquatic communities.

The intensive agricultural landscape throughout the Sandusky Bay tributaries study area combined with occasional point sources such as failing HSTS, CSOs and WWTPs contributed to the overall impairments noted within the fish communities. Improvements with sewage treatments, both for HSTS and municipal WWTPs, would assist in improving the fish community integrity throughout the areas affected. In addition, encouragement of BMPs and the decrease of channelization activities with increased riparian corridor restoration would likely improve nearly all streams within the study area.

Trends

Since 1983, fish community sampling has occurred at various locations within the study area. Similar to many other areas sampled across the state of Ohio, water quality has generally improved over time. However, there are several areas where point sources are still a concern and nonpoint issues need to be addressed in order for full attainment of aquatic life uses to occur.

The Sandusky River mainstem had been previously sampled in 1988 before being most recently sampled in 2009 (Figure 17). One site in 2009 was within the Ballville Dam pool, and while the IBI met WWH expectations, the MIwb was below WWH expectations. Historically, the upstream extent of the lacustuary portion of the Sandusky River extended to RM 15.8, but it varies depending on Lake Erie water levels. In 2009, the lacustuary zone did not extend as far upstream as in 1988 and, hence, the fish community at RM 15.4 was representative of a free-flowing stream and free-flowing IBI and MIwb metrics were used to assess the site. Interestingly, there was only slight improvement noted here between 1988 and 2009. Throughout the rest of the lacustuary portion of the Sandusky River, IBI scores in 2009 paralleled results from 1988 from below RM 15.0 to RM 10.0, showing a dip in the IBI score downstream from the Fremont WWTP (RM 12.8). From RM 10.0 to RM 3.0, the IBI scored consistently below lacustuary WWH benchmarks, similar to 1988 results, though the MIwb exceeded lacustuary WWH benchmarks. The most downstream site on the Sandusky River, which showed improvement in both lacustuary IBI and MIwb scores since 1988, was still below lacustuary WWH benchmarks. Improvements addressing nutrient enrichment from upstream WWTPs and crop production with subsurface drainage are needed across the Sandusky River basin in order for the fish community to meet lacustuary WWH expectations in the future.

The fish community of Raccoon Creek had previously been sampled in 1983, 1986, and 1995 before being sampled in 2009 (Figure 18). Results in the headwaters near RM 13.26 have been fairly consistent in meeting WWH expectations over time. The marked improvement in fish community scores between 1986 and 1995 near RM 10.18 is a result of the construction of the Clyde WWTP in 1986, which discharges to Raccoon Creek at RM 11.02. The facility underwent upgrades in 2006, which may have contributed to the improved IBI scores noted near RMs 10.18 and 5.45 in 2009; however, nutrient enrichment continues to negatively influence the aquatic community of Raccoon Creek in the lower 11 miles. Throughout time, MIwb scores in the lower reach have not met WWH expectations and the fish community in 2009 was no exception. As the MIwb is sensitive to the uneven distribution of individuals and biomass within a community, the continual inability of the stream to support a more balanced community is reflective of the excessive nutrients from both the Clyde WWTP and the surrounding agricultural landscape. The one active CSO present in Clyde should be addressed, as should the nutrients from the Clyde WWTP and the surrounding crop production with subsurface drainage.

The fish community of Buck Creek showed little change over time, receiving an IBI of 28 in 1983 and an IBI of 30 in 2009. However, as detailed in the Macroinvertebrate section of this report, concern was raised about pesticide use in orchards and agricultural fields upstream of the site at RM 0.3 due to the unusually low density and diversity of macroinvertebrates at the site in 1983. Sediment sampling in 2009, detailed in the Sediment Quality section of this report, revealed levels of DDE, DDT and dieldrin above guidance values. These results indicate that historical pesticide application may have contributed to the poor to fair aquatic communities observed in Buck Creek over time.

In 1985, the lower 5.1 miles of Mills Creek was sampled, while sampling in 2009 extended upstream to RM 10.4 (Figure 19). In 1985, the Bellevue WWTP (via Snyder Ditch, tributary to Mills Creek at RM 11.6), and J.H. Routh Packing (RM 5.1) were determined to be degrading aquatic communities downstream of their respective discharges (Ohio EPA, 1986). As discussed in the NPDES section of this report, Bellevue WWTP continues to discharge excessive nutrients to the stream, resulting in organic and nutrient enrichment. In 1986, J.H. Routh Packing received a Permit-to-Install (PTI) to construct a force main to the Sandusky WWTP, which went on-line in 1987. Therefore, discharges to Mills Creek should have ceased when the system was put in place. However, as discussed in the Habitat and Macroinvertebrate section of this report, noxious odors erupted from the sediments downstream of a ditch leading from the facility and joining the stream approximately 75m downstream of Bogart Road.

Water chemistry sampling for this site was conducted at the Bogart Road bridge, and was therefore upstream of the ditch. Sediment sampling in the ditch and Mills Creek downstream from the confluence with the ditch is recommended to determine if the sediments are contaminated and locate the source of the noxious odors. Further downstream near RM 3.7, the fish community improved to an IBI of 25 and MIwb of 6.9, before decreasing to near 1985 scores, with an IBI of 19 and MIwb of 4.9 in 2009 near RM 1.35. The fish community of Mills Creek has generally improved over time, though agricultural activities, the Bellevue WWTP and urban run-off with active CSOs continue to cause organic and nutrient enrichment that negatively influences the aquatic communities.

The lacustuary portion of Little Muddy Creek was sampled previously in 1988 and indicated a very poor fish community near RM 1.2 with an IBI of 12 and MIwb of 5.6, and a poor fish community further downstream at RM 0.5 with an IBI of 22 and MIwb of 7.4. The very poor fish community at the upper site was associated with Countyline Landfill. In 2009, sampling was conducted upstream of this area near RM 1.7 where the poor fish community received an IBI of 23 and MIwb of 6.9. While the Countyline Landfill may have contributed to problems in the past, the intense agricultural land use throughout the upper watershed has led to increased siltation and nutrient enrichment evident in the lacustuary portion of Little Muddy Creek.

The fish communities of the Sandusky Bay tributaries have shown gradual improvement over time, but are still negatively influenced by the crop production with subsurface drainage prevalent throughout the study area. Many historical point sources, the Clyde WWTP, the Bellevue WWTP, and CSOs, continue to impact aquatic life in associated streams. Outreach to the agricultural community regarding nutrient management and erosion control BMPs, in concert with improved point source control, would benefit the fish community of the Sandusky Bay tributaries.

Table 12. Fish community summaries based on pulsed D.C. electrofishing sampling conducted by Ohio EPA in the Sandusky Bay tributaries from June 2009 through September 2009. Relative numbers and weight are per 1.0 km for boat sites and 0.3 km for wading and headwater sites. The Index of Biotic Integrity (IBI) and Modified Index of well being (MIwb) are scores based on the performance of the biotic community. The Qualitative Habitat Evaluation Index (QHEI) is a measure of the ability of the physical habitat to support a biotic community. Blue fill indicates sites assessed with Lacustuary metrics and breakpoints; biocriteria are not applicable so attainment status is based on a narrative determination of the designated use using IBI and MIwb scores adapted to lacustuary and other attributes of the fish community samples. All sites are within the Huron Erie Lake Plain ecoregion. NA = not applicable.

Stream Name	RM[a] (STORET)	Drain. (mi^2)	Fish Species Total	Relative Number	Relative Weight	IBI	MIwb[b]	QHEI	Narrative Evaluation
Sandusky River (05-001-000) ***Tributary to Lake Erie***									
SANDUSKY RIVER UST. BALLVILLE DAM	18.05 [B]	1255	16	270	72.7	35	7.2*	52	Fair
SANDUSKY RIVER AT FREMONT UPSTREAM ROGER YOUNG PARK	16.8 [B]	1256	34	688	637.3	41	9.9	93	Good
SANDUSKY RIVER AT FREMONT @ STATE ST.	15.4 [B] (U04W11)	1260	34	735	187.7	38	9.7	67	Marginally Good
SANDUSKY RIVER OPPOSITE FREMONT YACHT CLUB	12.8 [B]	1264	25	511	332.7	<u>26</u>*	9.2	67	Poor
SANDUSKY RIVER UPSTREAM WIGHTMANS GROVE	5.5 [B]	1330	29	631	131.5	32*	8.7*	60	Fair
SANDUSKY RIVER UPSTREAM BAY CONFLUENCE	1.3 [B]	1335	30	483	171.5	31*	7.5*	64.5	Fair
HUC 12 – 041000111303 (Mouth Sandusky River)									
Bark Creek (05-002-000) ***Tributary to Sandusky River at RM 5.88***					**WWH Existing**				
BARK CREEK AT KELLEY RD. (CR 245)	3.20[H] (300671)	10.0	11	345	N/A	<u>20</u>*	N/A	32.0	Poor
HUC 12 – 041000111301 (Muskellunge Creek)									
Muskellunge Creek (05-003-000) ***Tributary to Sandusky River at RM 9.37***					**WWH Existing**				
MUSKELLUNGE CREEK NEAR FREMONT @ SPIELDENNER RD.	5.40[W] (201332)	37	14	653	2.6	37	6.9[NS]	58.5	Marginally Good
MUSKELLUNGE CREEK NEAR FREMONT @ FANGBONER RD.	1.23 [B] (U04P08)	44	31	599	90.9	37	9.1	69	Marginally Good
HUC 12 – 041000110205 (South Creek)									
South Creek (05-044-000) ***Tributary to Lake Erie***					**WWH Existing**				
SOUTH CREEK @ CO. RD. 229	7.92[H] (U05G01)	7.1	6	850	N/A	<u>20</u>*	N/A	48.5	Poor
SOUTH CREEK NEAR RILEY CENTER @ WHITMORE RD. (TWP. RD. 247)	4.04 [H] (U05K05)	18.1	17	364	N/A	24[NS]	N/A	33.5	Poor
HUC 12 – 041000110204 (Raccoon Creek)									

Stream Name	RM[a] (STORET)	Drain. (mi²)	Fish Species Total	Relative Number	Relative Weight	IBI	MIwb[b]	QHEI	Narrative Evaluation
Raccoon Creek (05-045-000) *Tributary to Lake Erie*					**WWH Existing**				
RACCOON CREEK UPST. CLYDE @ LIMERICK RD.	13.26[H] (U05S01)	9.9	11	1520	10.2	28	N/A	49.5	Fair
RACCOON CREEK AT CLYDE @ U.S. RT. 20	11.32[H] (U05P04)	12.7	11	1230	N/A	32	N/A	42	Fair
RACCOON CREEK N OF CLYDE @ TWP. RD. 223	10.18[H] (U05W10)	13.8	13	1875	N/A	34	N/A	51.5	Fair
RACCOON CREEK DST. OHIO TURNPIKE @ TWP. RD. 244	5.45[W] (U05W17)	23.6	20	687	11.2	29[NS]	5.5*	66	Fair
Buck Creek (05-045-003) *Tributary to Raccoon Creek at RM 10.06*					**WWH Recommended**				
BUCK CREEK N OF CLYDE @ TWP. RD. 223	0.2[H] (U05S03)	4.5	7	1442	N/A	30	N/A	45.5	Fair
HUC 12 – 041000110203 (Pickerel Creek)									
Pickerel Creek (05-046-000) *Tributary to Lake Erie*					**WWH Existing**				
PICKEREL CREEK @ REINICKE RD. (TWP. RD. 233)	6.26[H] (U05K10)	9.5	9	1180	N/A	32	N/A	48	Fair
PICKEREL CREEK @ TWP. RD. 247	3.35[H]* (U05S04)	43.7	16	814	N/A	27[NS]	N/A	45	Poor
HUC 12 – 041000110201 (Frontal South Side of Sandusky Bay)									
Little Pickerel Creek (05-049-000) *Tributary to Lake Erie*					**CWH Existing**				
LITTLE PICKEREL CREEK @ YETTER RD.	2.00[H] (201385)	5.5	9	312	N/A	26[NS]	N/A	50.5	Poor
Cold Creek (05-050-000) *Tributary to Lake Erie*					**CWH Existing**				
COLD CREEK @ BARDSHAR RD.	0.36[H] (300670)	2.9	5	203	N/A	34	N/A	47	Fair
HUC 12 - 041000110103 Mills Creek									
Mills Creek (05-051-000) *Tributary to Lake Erie*					**WWH Existing**				
MILLS CREEK W OF PARKERTOWN @ PORTLAND RD.	10.40[W] (U05S07)	21	9	410	9.3	26[NS]	5.3*	28.5	Poor
MILLS CREEK SE OF CASTALIA @ ST. RT. 99	6.03[W] (U05S06)	29	7	884	2.8	21*	4.9*	49	Poor
MILLS CREEK NEAR CASTALIA @ BOGART RD.	5.20[W] (U05P07)	29	12	689	14.8	23*	5.7*	61.5	Poor
MILLS CREEK S OF SANDUSKY @ STRUB RD.	3.70[W] (U05S18)	35	17	1682	15.4	25[NS]	6.9[NS]	42.5	Poor
MILLS CREEK AT SANDUSKY @ PERKINS AVE.	1.35[W] (U05P05)	41	15	326	3.2	19*	4.9*	46.5	Poor
Caswell Ditch (05-051-004) *Tributary to Mills Creek at RM 3.95*					**WWH Existing**				

Stream Name	RM[a] (STORET)	Drain. (mi^2)	Fish Species Total	Relative Number	Relative Weight	IBI	MIwb[b]	QHEI	Narrative Evaluation
CASWELL DITCH (TRIB TO MILLS CREEK 3.95) @ BOGART RD.	0.85 H (U05W37)	3.9	7	1340	N/A	22*	N/A	34.5	Poor
HUC 12-041000110102 (Pipe Creek – Frontal Sandusky Bay)									
Pipe Creek (05-052-000) *Tributary to Lake Erie*					**WWH Existing**				
PIPE CREEK N OF BLOOMINGVILLE @ PATTEN TRACT RD.	8.18 H (U05K17)	14.7	7	1618	N/A	20*	N/A	46.5	Poor
PIPE CREEK S OF SANDUSKY @ SCHENK RD.	6.7 H (U05K16)	18.4	11	1256	N/A	24 NS	N/A	30	Poor
PIPE CREEK AT SANDUSKY @ COLUMBUS AVE.	2.32 W (U05K15)	22.8	9	199	1.3	23*	4.6*	41.5	Poor
Sawmill Creek (12-004-000) *Tributary to Lake Erie*					**WWH Recommended**				
SAWMILL CREEK W OF HURON @ BOOS RD.	1.10 H (K01K21)	13.5	13	1344	N/A	44	N/A	50.5	Good
HUC 12 041000111203 (Green Creek)									
Green Creek (05-100-000) *Tributary to Lake Erie*					**CWH Existing**				
GREEN CREEK @ CO. RD. 34	18.80 H* (U04G24)	53	15	372	6.9	42	N/A	67	Good
GREEN CREEK SE OF FREMONT @ DEWEY RD.	12.85 H* (U04S10)	71	16	181	22.2	27 NS	N/A	73	Poor
Green Creek (05-100-000) *Tributary to Lake Erie*					**WWH Existing**				
GREEN CREEK @ CO. RD. 229	9.08 H* (U04G20)	74	21	334	11.3	36	N/A	67.5	Marginally Good
GREEN CREEK NE OF FREMONT @ TWP. RD. 239	5.06 H* (U04K01)	78.3	26	251	7.5	33	N/A	64	Fair
HUC 12 – 041000111202 (Beaver Creek)									
Beaver Creek (05-103-000) *Tributary to Green Creek at RM 20.4*					**CWH Existing**				
BEAVER CREEK DST. LEAFY OAKS MHP	4.00 H* (U04K03)	20.9	10	1160	13.7	29	N/A	68	Fair
BEAVER CREEK @ ST. RT. 101	3.48 H* (U04G25)	43.4	13	1238	11.4	31	N/A	62.5	Fair
Emerson Creek (05-108-000) *Tributary to Beaver Creek at RM 3.60*					**WWH Existing**				
EMERSON CREEK @ TWP. RD. 179	1.83 H* (U04G26)	22	10	1272	9.1	25*	N/A	67	Poor
Emerson Creek a.k.a. Royer Ditch (05-109-000)					**WWH Existing**				
EMERSON CREEK (ROYER DITCH) NEAR FIRESIDE @ RON MEYERS RD.	6.85 H (U04K07)	15.2	6	178	N/A	18*	N/A	30.5	Poor
Westerhouse Ditch (05-105-000) *Tributary to Beaver Creek at RM 4.73*					**WWH Existing**				

Stream Name	RM[a] (STORET)	Drain. (mi^2)	Fish Species Total	Relative Number	Relative Weight	IBI	MIwb[b]	QHEI	Narrative Evaluation
WESTERHOUSE DITCH @ SNAVELY RD.	3.25 H (U04K05)	9.6	10	4488	24.7	30	N/A	52.5	Fair
WESTERHOUSE DITCH NE OF LOWELL @ ST. RT. 19	0.63 H (U04K04)	16.2	11	2662	23.5	34	N/A	57	Fair
Muddy Creek (05-219-000) *Tributary to Lake Erie*					**WWH Existing**				
MUDDY CREEK @ EAST SIDE OF ST. RT. 53	1.23B (U04Q13)	110	21	404	296.6	<u>21</u>*	6.7*	50.5	Poor
HUC 12 – 041000111403 (Little Muddy Creek)									
Little Muddy Creek (05-220-001) *Tributary to Muddy Creek at RM 1.31*					**WWH Existing**				
LITTLE MUDDY CREEK @ KLINE RD.	2.5 B (300676)	25	22	926	36.1	<u>20</u>*	6.9NS	47.5	Poor
Fishing Creek (05-220-001) *Tributary to Little Muddy Creek at RM 2.36*					**WWH Recommended**				
FISHING CREEK @ WEICKERT RD.	0.20 H (300678)	7	14	336	N/A	32	N/A	21.5	Fair

a - River Mile (RM) represents the Point of Record (POR) for the station, not the actual sampling RM.

b - MIwb is not applicable to headwater streams with drainage areas $\leq$ 20 mi^2.

ns - Nonsignificant departure from biocriteria ($\leq$4 IBI units, or $\leq$0.5 MIwb units).

* - Indicates significant departure from applicable biocriteria (>4 IBI units, or >0.5 MIwb units). Underlined scores are in the Poor or Very Poor range.

B - Boat site.

H - Headwater site.

W - Wading site.

H* - Sites with strong ground water resulting in fish communities representative of headwater systems, though drainage area is >20mi^2. Headwater biocriterion were used to evaluate the fish community.

Index – Site Type	Biological Criteria			Lacustuary Benchmarks[1]				
	Huron Erie Lake Plain							
	EWH	WWH	MWH (Channelized)	Exceptional	Good	Fair	Poor	Very Poor
IBI – Headwaters	50	28	20	N/A	N/A	N/A	N/A	N/A
IBI – Wading	50	32	22	N/A	N/A	N/A	N/A	N/A
IBI – Boat	48	34	20	50	42	31	17	<17
MIwb – Wading	9.4	7.3	5.6	N/A	N/A	N/A	N/A	N/A
MIwb – Boat	9.6	8.6	5.7	10	8.6	5.6	2.8	<2.8

1- Proposed Lacustuary scoring breakpoints. These have not yet been adopted into rule.

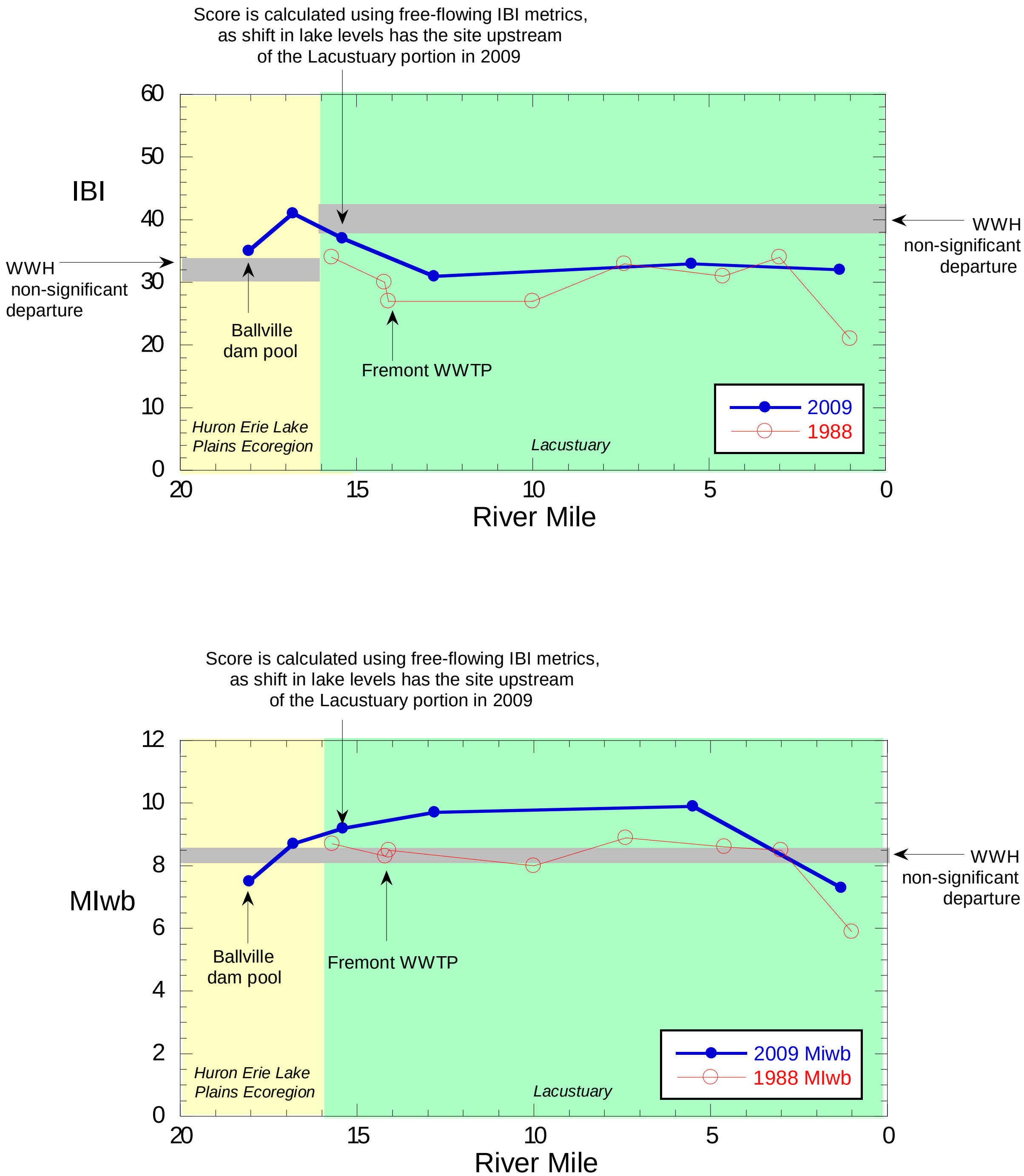
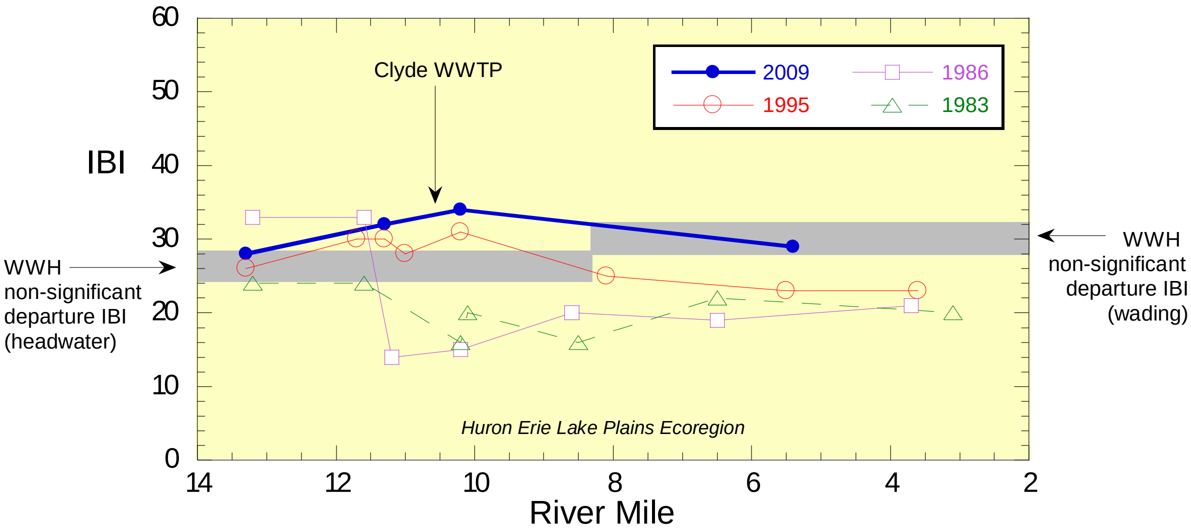


Figure 17. Sandusky River fish community IBI and MIwb scores from 1988 and 2009.



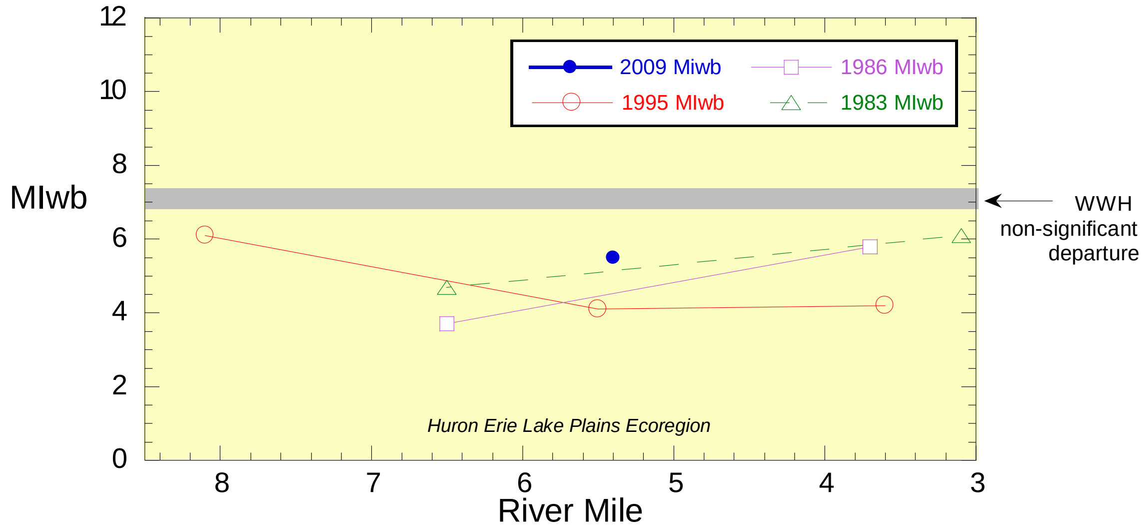
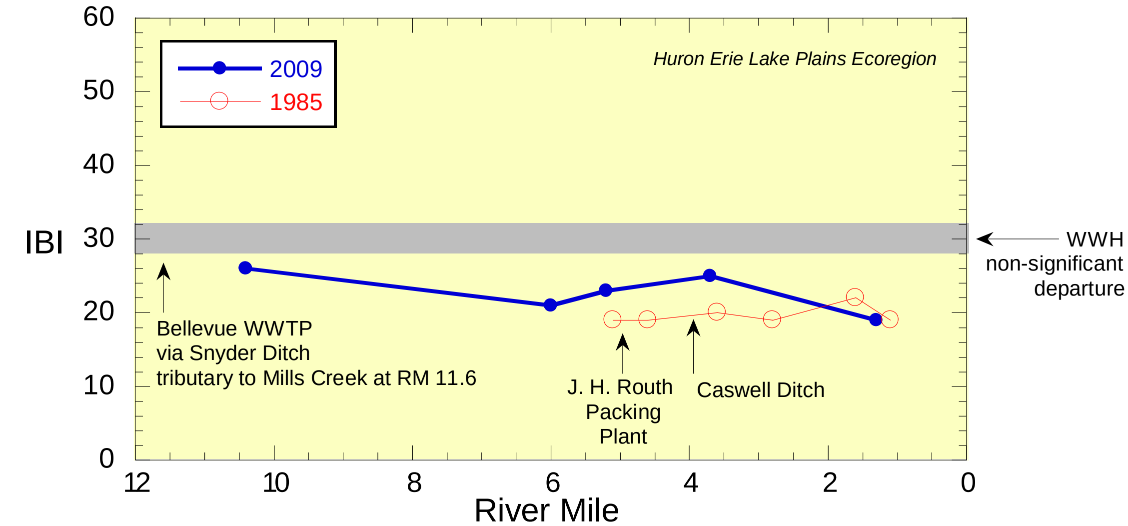


Figure 18. Raccoon Creek fish community IBI and MIwb scores from 1983, 1986, 1995, and 2009. MIwb is not applicable to sites smaller than 20 mi^2.



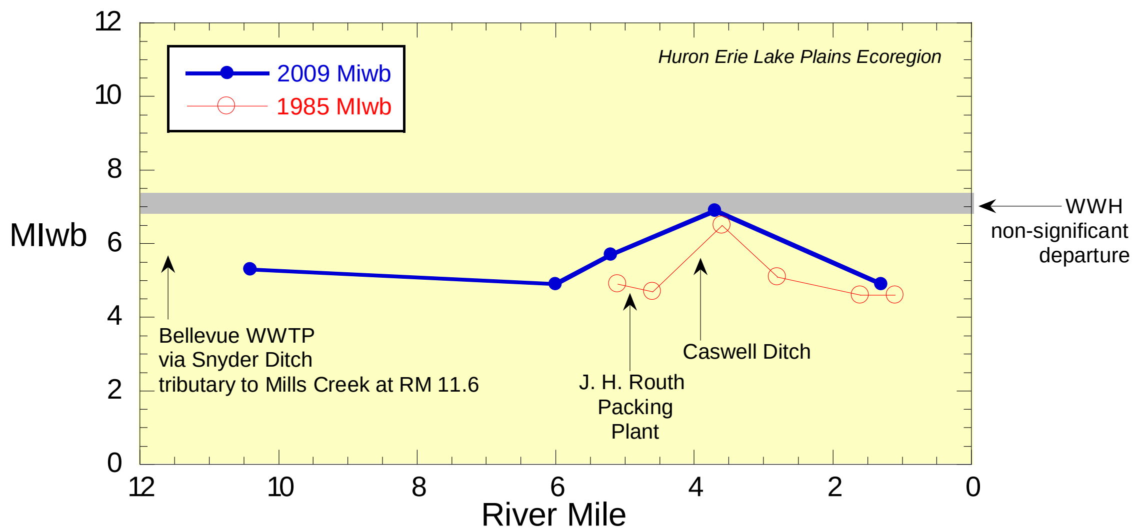


Figure19. Mills Creek fish community IBI and MIwb scores from 1985 and 2009. MIwb is not applicable for sites with <20mi^2 drainage area.

Macroinvertebrate Communities

Mills Creek-Frontal Lake Erie WAU: HUC 0410001110

Eleven sites on four streams were sampled for macroinvertebrates in the Mills Creek-Frontal Lake Erie WAU. Of these, five sites supported communities that met applicable WWH criteria with scores or evaluations that were either marginally good or good, while the remaining six hosted impaired communities (Table 13). All impaired communities were collected in Mills Creek and Pipe Creek. Both creeks bracket the city of Sandusky, with Mills Creek draining into Lake Erie to the west of Sandusky and Pipe Creek draining to the east. While both streams have similar demographics concerning land use (predominantly agriculture, with urbanization increasing in a downstream direction), the issues that impacted these streams were different.

Three of the four sites sampled on Pipe Creek revealed benthic communities that were impaired. In the headwaters at RM 10.9, the stream was channelized with no riparian cover. Grass clippings coated the stream's surface, and a charcoal pile that was deposited streamside was observed to be leaching into the stream. As a result of these impacts, a fair benthic community that included only three pollution-sensitive taxa was collected at this location. Similar conditions existed at RM 6.6, also resulting in a fair community. WWH criteria were met in between these two sites at RM 8.15. The effects of prior channelization allowed for some silt to accumulate in this reach (as evidenced by the predominance of burrowing fingernail clams), but an intact riparian corridor and numerous functional riffles allowed for a diverse community that included 14 EPT[1] and 11 pollution-sensitive taxa. Superior habitat conditions were present at the lowermost site at RM 2.5, yet only a fair benthic community was collected. Due to the surrounding urban land use, as RM 2.5 is within the city of Sandusky, impacts from urban runoff are suspected to be the cause of benthic underperformance at this location.

Like Pipe Creek, Mills Creek also included three sites that were not meeting WWH criteria for macroinvertebrates. However, the mode of impairment for Mills Creek was different from that of Pipe Creek. In the upper segment of Mills Creek, agricultural runoff and discharge from the Bellevue WWTP impacted the benthic communities of both RM 10.4 and RM 6.03. Both sites included numerous pollution-tolerant taxa that increase under organically enriched conditions – particularly aquatic worms and leeches. In the lower reach of Mills Creek that flows through the city of Sandusky, urban runoff and active CSOs marginalized the community at RM 1.34, which received a fair range ICI of 18. Forty-two percent of the organisms collected on the artificial substrates were the tolerant midge *Cricotopus bicinctus*, indicating an impact from either nutrient or organic enrichment, or a combination of both.

The middle two sites on Mills Creek at RMs 5.2 and 3.7 were both meeting WWH expectations, but conditions at RM 5.2 warrant further discussion. The tanytarsini midge *Rheotanytarsus* was very numerous and overwhelmingly predominant on the natural substrates at this location. It also comprised nearly sixty percent of all organisms

1 EPT stands for Ephemeroptera, Plecoptera, and Tricoptera – the orders of invertebrates commonly known as mayflies, stoneflies, and caddisflies, respectively. Their collective presence and abundance in the benthos is generally considered an indicator of high biotic integrity.

captured on the artificial substrates, while total tanytarsini midges represented nearly three-fourths of the community. Such monotony within the benthic community is an indication of instability due to nutrient over-enrichment. The subsequent reduction in insect diversity can in turn disrupt the trophic structure of the fish community by replacing insectivorous species in favor of omnivores (Ohio EPA 1987). A cow pasture with unrestricted stream access exists just upstream from the sampling reach, and a pork processing plant lies adjacent to the site. In addition to the Bellevue WWTP, both of these may serve as sources of excess nutrients. In order to assure that the middle segment of Mills Creek continues to meet water quality goals, it is recommended that livestock be excluded from the stream and that any discharges or runoff associated with the pork processing plant be addressed.

Pickerel Creek-Frontal Sandusky Bay WAU: HUC 0410001102

Eleven sites on six streams were sampled for macroinvertebrates in the Pickerel Creek-Frontal Sandusky Bay WAU (Table 13). Of these, only three sites received scores or evaluations that met the applicable biocriteria. The remaining eight sites received evaluations that were in the fair or poor range and were considered impaired. Streams that were of similar constitution are grouped and discussed in the paragraphs that follow.

Cold Creek, Little Pickerel Creek, and Pickerel Creek

Cold Creek, Little Pickerel Creek, and Pickerel Creek inhabit the eastern portion of the watershed and are spring-fed streams. As such, ambient water temperatures tended to be low (usually < 20°C) and dissolved minerals were elevated. Cold Creek was a deep, hardpan bottom stream that featured very strong current throughout its length due to its origin from an artesian spring locally known as the Blue Hole of Castalia. While the water from the Blue Hole is naturally devoid of oxygen, a hatchery operated by ODNR in Castalia aerates the stream in order to raise dissolved oxygen levels, thereby making Cold Creek suitable for raising trout. The depth of this stream was variable throughout its length, but for the most part was not wadeable. The sampled reach at RM 0.2 was chest deep (~3 to 4 feet), and was considered the most shallow segment of the stream. Like Cold Creek, Little Pickerel Creek was also a hardpan substrate stream, though it was shallower than Cold Creek and contained very little detectable current. Pickerel Creek appeared to be more subject to the influence of hydromodification, as the lower segment was channelized and featured heavily eroded banks with no riparian corridor and sand/silt bottom substrate. The upper reach of Pickerel Creek, however, was more intact, with riffle-run-pool complexes, a full riparian canopy, and coarse bottom substrates.

Benthic quality in these streams was a reflection of the above habitat attributes. Only the benthic community of Pickerel Creek RM 6.26 was meeting applicable biocriteria at the four sites in these three streams with an evaluation of marginally good. There, 53 total taxa were collected, with the balance of the other three sites averaging only 31 taxa. As previously mentioned, Pickerel Creek RM 6.26 was the only site that featured the combination of riffle-run-pool complexes, full riparian canopy, and coarse substrates. As a result of these high quality habitat attributes, a high quality benthic community was collected. Poor substrate quality and a lack of true functional riffles resulted in depressed communities at Cold Creek RM 0.2, Little Pickerel Creek RM 2.1, and Pickerel Creek RM 3.3. Channelization and erosion were additional impacts to Pickerel Creek RM 3.3.

Raccoon Creek, Buck Creek and South Creek

Raccoon Creek, Buck Creek and South Creek occupy the western portion of the Pickerel Creek-Frontal Sandusky Bay WAU. While habitat was adequate to support warmwater communities at all four sites sampled on Raccoon Creek, only the upper site at RM 13.3 and the lower site at RM 5.45 met WWH criteria (Figure 22). The two middle sites received qualitative evaluations of poor. The first site, at RM 11.32, was located within the city of Clyde. Benthic fauna were low in both density and diversity and no pollution-sensitive taxa were found. A crayfish with a deformed rostrum was also collected; however, the deformity could be an artifact of an injury rather than a response to a toxin. Organic enrichment via active CSOs and urban runoff were likely responsible for the poor community at this location. Diversity was also low and pollution-sensitive taxa were absent at RM 10.18; however, organism density on the natural substrates was considerably higher than that at RM 11.32. The increase in organism density is a signature response due to nutrient enrichment from the Clyde WWTP, which discharges to Raccoon Creek at RM 11.02.

Buck Creek, a tributary to Raccoon Creek at RM 10.06, was sampled in order to appraise its recovery from past toxicity issues. Sampling conducted at RM 0.2 in 1983 indicated an acute toxic event, possibly from a pesticide spill (Ohio EPA 1984). Only a few individuals representing five total taxa were collected during that sampling event. Any toxic effect of pesticides in this stream has somewhat dissipated over time, as 23 total taxa were collected on a return visit in 1986, and 30 total taxa were collected in 2009. However, a crayfish was collected with extra spines on its rostrum, a deformity which may be tied to an environmental disturbance rather than injury (Roger Thoma, personal communication, February 26, 2010). Because crayfish eggs spend considerable time in contact with the sediment, contaminants contained within may predispose the developing crustacean to genetic deformity. Pesticides were detected in a sediment sample of Buck Creek; however, a connection to the crayfish deformity is difficult to establish, as only one specimen was collected. Therefore, additional sediment sampling and a more thorough survey of the crayfish community of both Buck Creek and Raccoon Creek may be necessary to characterize and classify the incidence of these deformities. The low fair community that was collected in Buck Creek in 2009 still failed to meet WWH criteria due to excessive siltation and pesticide residues.

The benthic communities of South Creek were marginalized by the effects of siltation due to current or past channelization activities. Heavy silt loads resulted in low sensitive and total taxa numbers at both sites sampled. Septic leachate was also observed to be entering the stream via a culvert at RM 7.92, which further depressed the benthos.

Green Creek WAU: HUC 0410001112

The Green Creek watershed was among the most unique of those sampled in the Sandusky Bay tributaries survey. The stream originates with the confluence of Westerhouse Ditch and Emerson Creek in the headwaters to form Beaver Creek (Figure 20). The entrance of Beaver Creek Springs on Beaver Creek at its terminus marks the beginning of Green Creek. Eleven sites were sampled among the streams that comprise the Green Creek watershed (Table 13). Westerhouse Ditch and Beaver Creek both exhibited overall high resource quality, with all four sites sampled on those streams receiving good to very good scores or evaluations. The Royer Ditch portion of Emerson Creek fared less well, primarily due to heavy siltation and a lack of stream flow that resulted in poor communities predominated by pond snails. Siltation in the form of embedded substrates was evident at Emerson Creek RM 1.83, which reduced both density and diversity and resulted in a fair benthic community.

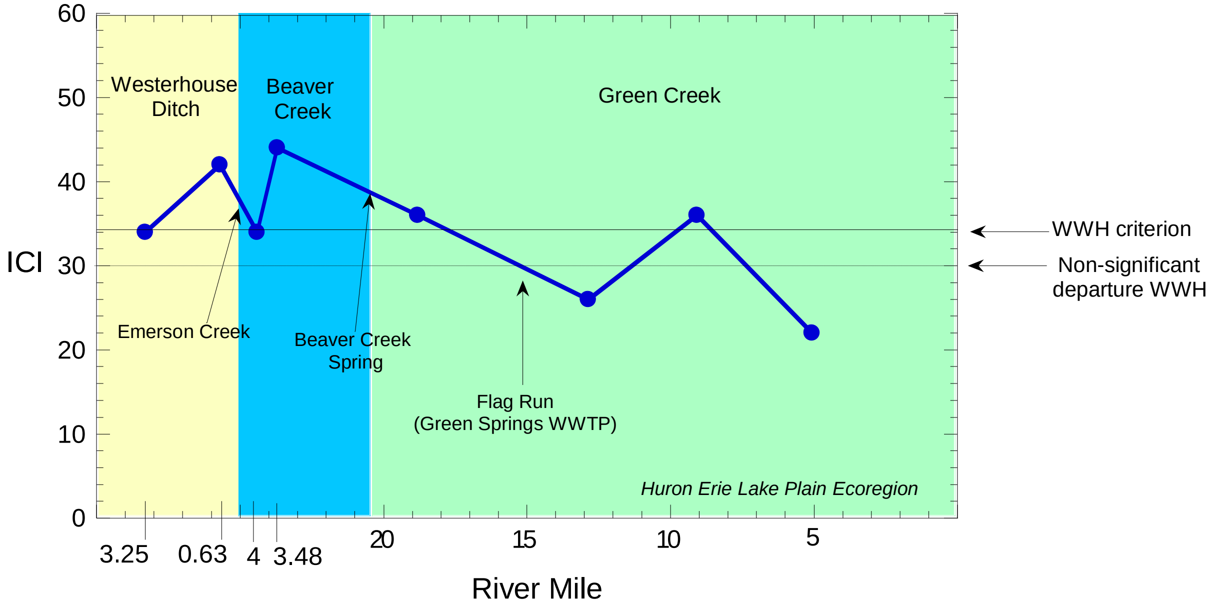


Figure 20. Longitudinal plot of 2009 ICI scores for sampling locations on Westerhouse Ditch, Beaver Creek, and Green Creek. Where only qualitative data are available, ICIs are represented as the lowest ICI associated with a given narrative for the HELP ecoregion.

Green Creek is influenced by Beaver Creek Springs, which contributes large volumes of cold, $CaCO_3$-infused water to the stream. As a result of the spring's influence, Green Creek had some of the highest TDS values in the study area. Marl-encrusted substrates were also common in Green Creek due to the high carbonate content of the spring water. In spite of these natural limitations, two of the four sites sampled – RM 18.8 and RM 9.08 - met WWH criteria. Those two sites had just as high concentrations of TDS as the non-attaining sites and also had more $CaCO_3$ –related impacts to the substrate. The riffle substrates of RM 18.8 were cemented together by marl, while the substrate of RM 9.08 was composed entirely of hardpan. The difference between attainment and non-attainment appeared to be related to the stream's ability to move silt. The flow regime present at both RMs 18.8 and 9.08 consisted of well-defined riffle-run-pool complexes. The two non-attaining sites at RMs 12.85 and 5.06 did not have these habitat attributes; rather, their flow regime consisted of pools and/or glides that did not feature true riffles. As a result, RMs 12.85 and 5.06 acted as sinks for sediment, as the sluggish stream flows did not flush out silt as effectively as sites that had the stronger, regular riffle intervals. As a result, tolerant taxa comprised a larger proportion of the benthic community collected from the artificial substrates at RMs 12.85 and 5.06 than at RMs 18.8 and 9.08 (Table 13). Significant erosion noted throughout the Green Creek watershed was a likely source of the sediment loads observed at RMs 12.85 and 5.06. This erosion is likely a result of agricultural field tiling and channelization in the headwater streams that comprise Green Creek.

Muskellunge Creek –Sandusky River WAU: HUC 0410001113
Seven sites on three streams were sampled in the Muskellunge Creek–Sandusky Bay WAU (Table 13). Of these, three sites met WWH criteria with good range ICIs or evaluations. These sites were free-flowing with coarse riffle substrates. EPT and sensitive taxa for the attaining sites averaged 11 and 16, respectively, while the non-attaining sites averaged only three EPT and four sensitive taxa. Channelization and organic enrichment from urban runoff resulted in a fair community on Bark Creek. On the Sandusky River, the Ballville Dam impounded the sampling reach at RM 18.05, while siltation and lacustuary conditions influenced the Sandusky River at RM 4.70 and Muskellunge Creek at RM 1.23. The heavy muck substrates present at all three of these sites depressed the benthic communities and resulted in poor to very poor index scores.

Muddy Creek–Frontal Sandusky Bay WAU: HUC 0410001114
Three sites on three streams were sampled in the Muddy Creek–Frontal Sandusky Bay WAU (Table 13). All three sites received poor scores or evaluations. Mean EPT and sensitive taxa were the lowest of any assessment unit sampled in the entire survey, averaging two and one, respectively. The substrates of Muddy Creek, Little Muddy Creek, and Fishing Creek were comprised entirely of heavy, anoxic muck resulting from silt deposition into the Lake Erie-influenced portions of these streams.

Table 13. Summary of macroinvertebrate data collected from artificial substrates (quantitative data) and natural substrates (qualitative data) in the Sandusky Bay tributaries basin, July-September, 2009.

Location	River Mile	Drain. (mi^2)	Total Taxa	Qual EPT	Total Sens	Total Tol.	Total CW	Substrate Density[a]	ICI[b] or Qual Narrative	Observations[c]
HUC 10 0410001110 Mills Creek - Frontal Lake Erie										
Mills Creek @ Portland Road	10.4	21.0	25	3	1	13	0	Low	Low Fair	Beetles, water boatmen and leeches were predominant taxa. Mostly sand/clay substrate stream with no riffle habitat.
Mills Creek @ SR 99	6.03	29.0	59	6	9	13	2	Moderate	28	High numbers of midges and blackflies in riffle.
Mills Creek @ Bogart Road	5.20	29.0	49	6	10	9	1	Very High	38	Very high numbers of *Rheotanytarsus sp.* and other midges in riffle.
Mills Creek @ Strub Road	3.70	35.0	55	6	12	12	0	High	30	High numbers of *Rheotanytarsus sp.* and other midges in riffle.
Mills Creek @ Perkins Avenue	1.34	39.7	49	6	6	12	0	Low	18	Hydropsychid caddisflies, midges and flatworms predominant. CSOs appear to be active.
Caswell Ditch @ Bogart Road	0.85	3.9	58	9	13	12	0	Moderate	30	Hydropsychid caddisflies, leeches, midges, burrowing mayflies, fingernail clams, and *Stenacron sp.* mayflies common.
Pipe Creek @ Harris Road	10.90	9.4	27	8	3	8	0	Moderate	Fair	Sow bugs and midges predominant. Thick mats of algae, along with grass clippings and charcoal abundant in stream.
Pipe Creek @ Patten Tract Rd.	8.15	14.7	48	14	11	7	1	Low	Good	Heavy silt deposits favored fingernail clam abundance.
Pipe Creek @ Schenk Road	6.60	18.4	32	9	5	6	0	Low	Fair	Poor habitat with clayey silt substrate and one weak riffle.
Pipe Creek @ Columbus Ave.	2.30	22.8	43	4	6	8	0	Low	22	Habitat was sufficient to support a good community, but expected taxa were rare or not found.
Sawmill Creek @ Boos Road	1.00	13.5	35	8	9	3	1	Very low	Marginally Good	Site nearly interstitial. Hydropsychid caddisflies, flatworms, and flathead mayflies predominant.

Location	River Mile	Drain. (mi^2)	Total Taxa	Qual EPT	Total Sens	Total Tol.	Total CW	Substrate Density[a]	ICI[b] or Qual Narrative	Observations[c]
HUC 10 0410001102 Pickerel Creek – Frontal Sandusky Bay										
Cold Creek @ Bardshar Road	0.30	3.0	31	7	7	6	1	High	Fair	Very cold, very deep hardpan-bottom stream. Abundant stringy algae with blackflies and scuds predominant.
Little Pickerel Creek @ Yetter Rd.	2.1	5.9	25	2	3	3	3	Low	Low Fair	Poor substrate quality (hardpan). Only debris snags available as riffle habitat. Midges and blackflies predominant.
Pickerel Creek @ TR 233	6.26	9.5	53	8	11	8	1	Low	Marginally Good	Overall density of organisms was low, but *Physella sp.* (pouch snails) was very high. Good quality substrate.
Pickerel Creek @ TR 247	3.30	43.7	38	3	3	8	0	Low	Low Fair	Hydropsychid caddisflies, midges, water boatmen, and mosquito larvae predominant.
Raccoon Creek ust. Limerick Rd.	13.30	8.6	42	9	10	6	1	Low	Marginally Good	High densities of scuds in margin. Hydropsychid caddisflies and midges predominant elsewhere.
Raccoon Creek @ US 20	11.32	11.3	23	3	0	6	0	Very low	Poor	Midges, capshell snails, and flatworms predominant. Abundant algae on substrates. Crayfish with deformed rostrum.
Raccoon Creek @ TR 223	10.18	12.2	30	4	0	7	0	Moderate	Poor	*Physella sp.* flatworms and midges predominant.
Raccoon Creek @ TR 244	5.45	22.5	50	6	10	9	0	Moderate	34	Residual enrichment effect from upstream sources via abundance of indicator taxa such as blackflies, flatworms, bryozoa, and hydropsychid caddisflies.
Buck Creek @ TR 223	0.20	4.5	30	2	7	2	1	Very low	Low Fair	Channel maintenance activities occurred upstream prior to sampling event. Fingernail clams most common taxa in all habitats. Crayfish with deformed rostrum.
South Creek @ CR 229	7.92	7.1	28	2	3	8	0	Moderate	Low Fair	Fingernail clams, *Physella sp.*, and red midges predominant. Septic leachate from culvert.
South Creek @ TR 247	4.00	18.1	26	4	1	10	0	Very low	Low Fair	Glide/pool habitat. Red midges and squaregill mayflies predominant.

Location	River Mile	Drain. (mi^2)	Total Taxa	Qual EPT	Total Sens	Total Tol.	Total CW	Substrate Density[a]	ICI[b] or Qual Narrative	Observations[c]
HUC 10 0410001112 Green Creek										
Westerhouse Ditch @ Snavely Road	3.25	9.6	54	15	13	6	0	Moderate	Good	Hydropsychid caddisflies, midges, and flathead mayflies predominant.
Westerhouse Ditch @ SR 19	0.62	16.2	48	18	18	1	1	Moderate	Very Good	Hydropsychid caddisflies, minnow mayflies, and squaregill mayflies predominant.
Beaver Creek adj. SR 19	4.00	20.9	45	14	19	2	1	Moderate	Good	Severely eroded banks. Near interstitial flow. Philopotamid caddisflies, waterpenny beetles, and flathead mayflies predominant.
Beaver Creek @ SR 101	3.48	43.4	70	13	27	8	0	Moderate	44	Philopotamid and hydropsychid caddisflies , flathead mayflies, and red midges predominant.
Green Creek @ CR 34	18.80	53.0	59	8	20	7	4	Moderate	36	Embedded, algae-laden substrates. Microcaddisflies, snipe fly larvae, and midges predominant.
Green Creek @ Dewey Road	12.85	71.0	52	7	19	5	2	Very low	26	Fixed retreat caddisflies (*Nyctiophylax sp.* and *Lype diversa*) and flathead mayfly *Stenacron sp.* abundant. Wetland stream conditions.
Green Creek @ CR 229	9.08	74.0	49	10	15	6	2	Very low	36	Stream entirely hardpan substrate. Taxa similar to upstream at RM 12.85, but with greater abundance of hydropsychid caddisflies.
Green Creek @ TR 239	5.06	78.3	44	8	11	4	1	Low	22	Snipe fly larvae very abundant.
Emerson Creek (Royer Ditch) @ CR 46	10.10	6.4	30	3	2	14	0	Moderate	Low Fair	Site moved to Alternate Sampling Point (ALP) at RM 9.9 due to dry conditions at 10.1. Site interstitial with water boatmen and *Physella sp.* predominant.
Emerson Creek (Royer Ditch) @ Roy Meyers Road	6.85	15.2	23	2	0	12	0	High	Poor	Site moved to ALP RM 5.8 due to dry conditions at 6.85. Pond snails and *Physella sp.* very predominant.
Emerson Creek @ TR 179	1.83	22.0	27	5	3	6	0	Very low	Fair	Very embedded substrates. Hydropsychid caddisflies, flathead mayflies and midges predominant.
HUC 10 0410001113 Muskellunge Creek – Sandusky River										
Sandusky River ust. Ballville Dam	18.05	1255.0	37	2	4	14	0	Moderate	6	Water boatmen and red midges predominant on margin substrates. Instream substrates mostly muck and fine peat. Dam effect.

Location	River Mile	Drain. (mi^2)	Total Taxa	Qual EPT	Total Sens	Total Tol.	Total CW	Substrate Density[a]	ICI[b] or Qual Narrative	Observations[c]
Sandusky River @ Fremont @ Tiffin Rd.	17.70	1255.0	48	11	21	5	0	High	34	Minnow mayflies, hydropsychid caddisflies, and *Rheotanytarsus sp*. midges predominant. Slight enrichment effect coupled with monotonous habitat.
Sandusky River @ Fremont @ State St.	15.4	1260.0	27	11	13	1	0	High	Good	Midges and hydropsychid caddisflies predominant. Flows were above normal, making sampling difficult.
Sandusky River ust. Wightman's Grove (Fisher Road)	4.70	1330.0	20	2	2	5	0	Low	*14*	Squaregill mayflies and scuds predominant. Muck substrates. Lacustuary/Lake Erie influence.
Bark Creek @ Kelley Rd. (CR 245)	3.20	10.0	33	6	3	10	0	Moderate	Fair	Channelized ditch with numerous blackfly larvae, indicating potential enrichment from runoff events.
Muskellunge Creek @ Spieldenner Road	5.40	37.0	50	12	14	3	0	Moderate	Good	Very high number of flathead mayfly *Stenacron sp.*, along with significant numbers of Elimia sp. snails, crayfish and waterpennies. Community somewhat limited by low flow.
Muskellunge Creek @ Fangboner Road	1.23	44.0	35	2	8	8	0	Low	*20*	Lacustuary/Lake Erie influence.
HUC 10 0410001114 Muddy Creek – Frontal Sandusky Bay										
Muddy Creek @ SR 53	1.23	110.0	28	0	0	9	0	Low	*12*	Lacustuary/Lake Erie influence.
Little Muddy Creek @ Kline Road	2.50	25.0	36	3	2	9	0	Low	*20*	Lacustuary/Lake Erie influence.
Fishing Creek @ Weickert Rd.	0.20	7.0	20	2	0	10	0	Moderate	Poor	Midges and water boatmen predominant.

a – Observed relative density of benthos on natural substrates. Please refer to Appendix L for relative densities on artificial substrates (where available).
b – Invertebrate Community Index. ICI not available for sampling locations with drainage area <20mi^2 (excluding reference sites). A narrative assessment of the qualitative sample is provided for sites where an ICI is not available. Scores in italics were generated using the Lacustuary ICI (LICI) benchmarks.
c – Predominant taxa are those observed on natural substrates. Please refer to Appendix M for predominant taxa on the artificial substrates.
RM: River Mile.
Drain.: Drainage Area
Sens.: Sensitive (pollution-sensitive)
Tol.: Tolerant
WWH Criteria – Huron-Erie Lake Plain: ICI = 34; Narrative = Good
Lacustuary Benchmarks: Final goal LICI = 42; Narrative = Good

Trends

Seven streams have been sampled in the Sandusky Bay tributaries study area prior to the 2009 survey. In the Mills Creek-Frontal Lake Erie WAU, Mills Creek was sampled in 1985 and Caswell Ditch in 1995. Figure 21 shows the longitudinal trend of the 1985 Mills Creek ICIs versus those of 2009. One noticeable difference between sampling years was that sampling was confined to the lower half of the stream in 1985 (RMs 5.2 to the mouth), while the 2009 sampling was conducted further into the headwaters (RM 10.4 to RM 1.35). When comparing two sites from 1985 that were repeated in 2009 (RMs 5.2 and 3.7) it appears that great improvement has taken place. However, a close examination of the ICI metrics from 1985 revealed a noticeable reduction in net-spinning caddisflies and tanytarsini midges when compared to 2009. This may indicate that there may not have been consistent velocities at the artificial substrate placement point. When one compares qualitative EPT and sensitive taxa numbers, both sites appear to have performed similarly, though taxa richness was slightly higher in 2009 (Appendix M). Overall, benthic community quality declined in both sampling years once within the city of Sandusky and continued to decline downstream into the Lake Erie backwaters.

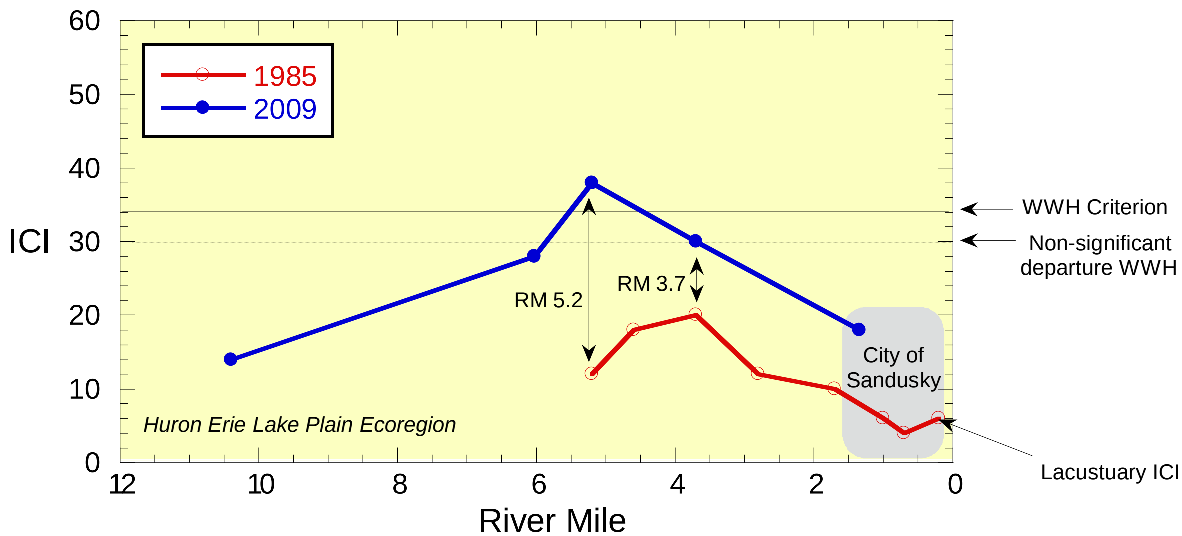


Figure 21. Longitudinal plot of Mills Creek ICI scores comparing survey years 1985 and 2009. ICI is estimated at RM 10.4.

Caswell Ditch was last sampled in 1995 at RM 0.5 and scored an exceptional ICI of 48 in spite of poor habitat quality. Similar habitat was encountered at RM 0.85 in 2009; however, due to near interstitial flows, a marginally good ICI of only 30 was achieved.

In the Pickerel Creek-Frontal Sandusky Bay WAU, only Raccoon Creek, Buck Creek, and Pickerel Creek have been previously sampled. The trend associated with Buck Creek was addressed in the previous Macroinvertebrate Results section above. Pickerel Creek was sampled at RM 3.3 in 1983. A low fair range ICI of 14 was garnered at that site, with only four EPT and three sensitive taxa collected. The community collected at that location in 2009 showed no appreciable difference from that collected in 1983.

Of any stream in the entire Sandusky Bay tributaries survey, Raccoon Creek has been the most extensively sampled, with sampling events occurring in 1983, 1986, 1995, and 2009 . Figure 22 compares the macroinvertebrate communities from 1995 and 2009, as the 1995 data is similar to the previous two sampling events of the 1980s. As evident from the figure, benthic communities have remained within non-significant departure of WWH criteria upstream from Clyde, and then declined markedly into the poor range once within the influence of the city of Clyde, CSOs and the Clyde WWTP. The 1995 data show the beginning of a gradual recovery downstream from these pollutant sources; this recovery appeared to be complete in 2009. Field notes from the 1995 macroinvertebrate sampling crew indicated gross pollution from the Clyde WWTP that had a persistent negative influence on the benthos for nearly 7.5 miles. In 2009, negative impacts from the WWTP had dissipated at least by RM 5.45, where the ICI rebounded into the good range and consequently met WWH criteria.

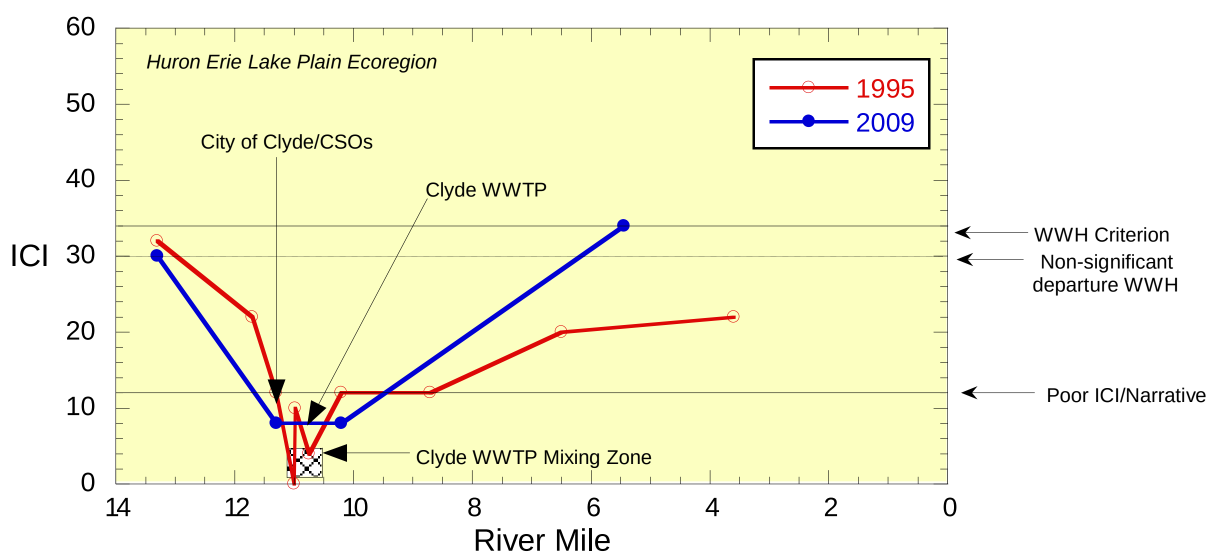


Figure 22. Longitudinal plot of Raccoon Creek ICI scores and narratives for survey years 1995 and 2009. Where only qualitative data are available, ICIs are represented as the lowest ICI associated with a given narrative for the HELP ecoregion (i.e. narrative of good = ICI of 34, etc.).

Four sampling stations were repeated on the Sandusky River in 2009 that were previously sampled in 1988 and 1999. Within the Ballville Dam pool at RM 19.0 in 1999 and at RM 18.05 in 2009, an ICI of 6 was garnered both years, reflecting the persistent impounded conditions caused by the dam. Downstream from the dam at RM 17.7, the ICI improved dramatically, increasing by 24 points from a 10 in 1988 to a 34 in 2009. Field notes from 1988 noted heavy growths of filamentous algae on the natural substrates and black muck in the backwaters that was attributed to a large die-off of algae. The predominance of flatworms, aquatic worms, and tolerant midges corroborate that organic enrichment was indeed depressing the community at this location in 1988, a year of drought conditions and extreme low flows.

The lacustuarine portion of the lower Sandusky River begins at RM 15.8, so all sites from RM 15.8 to the confluence with Lake Erie were evaluated using the Lacustuary ICI (LICI) benchmarks (Ohio EPA 1994). The community at RM 15.8 in 1988 failed to achieve expectations with a poor LICI of 14. In 2009, sampling was conducted just a little further downstream at RM 15.4. Although the sampling reach was limited, a modest riffle/run habitat was available, which provided enough diversity to allow for a narrative assessment of good. Deeper into the lacustuary at RM 4.7, excessive sedimentation in both 1988 and 2009 resulted in LICIs of 6 and 14, respectively. Both scores were in the very poor to poor range and reflected the mudflat-type habitat at this location resulting from excessive sediment deposition from upstream sources.

Muddy Creek and Little Muddy Creek were also previously sampled in their lacustuary portions in 1988 (Appendix table M). LICI scores improved only minimally from 1988 to 2009, increasing from very poor to poor. Taxa richness was slightly higher in both streams in 2009, and the pollution-tolerant midge genus *Glyptotendipes* was slightly less predominant. However, like the Sandusky River lacustuary, Muddy Creek and Little Muddy Creek both featured mudflat-type habitat with heavy silt and muck substrates, indicating that sedimentation and excessive downstream deposition in both those watersheds is still problematic.

Public Water Supplies

The Public Water Supply (PWS) beneficial use in the Ohio WQS (OAC 3745-1-33) currently applies within 500 yards of drinking water intakes and for 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. The 2010 Integrated Water Quality Report describes this methodology and is available on Ohio EPA's website: http://www.epa.ohio.gov/dsw/tmdl/OhioIntegratedReport.aspx.

Impaired source waters may contribute to increased human health risk or treatment costs. 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 are three public water systems (Bellevue, Clyde, and Fremont) directly served by surface water sources within the study area. Bellevue has an intake on Snyder's Ditch, Clyde has an intake on

Beaver Creek at RM 2.88, and Fremont's intake is located on the mainstem of the Sandusky River at the Ballville Dam (RM 18.02). Table 14 provides a summary of exceedances for the PWS use while Appendices B, C, and N contain all of the water quality analytical results.

Village of Bellevue

The village of Bellevue operates a community public water system that serves a population of approximately 8,193 people through 3,200 service connections. The water treatment system obtains its water from Frink Run and Snyder's Ditch (aka Berry Creek). Frink Run is pumped into the large upground Reservoir #5. Water from this reservoir is gravity fed or pumped up to the main reservoir complex via a series of pipes and ditches that ultimately become Snyder's Ditch. The primary source of water in Snyder's Ditch is Reservoir #5, although there are open portions of the waterway that allow some surface runoff. This report focuses on an evaluation of Snyder's Ditch since Frink Run is located in the adjacent Huron River watershed and will be assessed during the next survey in that basin. The system's treatment capacity is approximately 3 million gallons per day, but current average production is 1.32 million gallons per day. The City of Bellevue's treatment processes include lime softening, coagulation, sedimentation, stabilization, fluoridation, sand filtration, and disinfection.

Ohio EPA collected a total of eight water quality samples at Snyder's Ditch intake (near reservoirs at the railroad tracks) during 2008 and 2009. To assess the PWS beneficial use, samples were analyzed for nitrate and pesticides. Nitrate ranged from 0.25 mg/L to 14.1 mg/L and averaged 4.28 mg/L. Additional samples are needed to complete a full assessment of the PWS use but since one sample exceeded the WQS criterion for nitrate (10.0 mg/L), the waters will at a minimum be placed on the watch list for elevated nitrate. Pesticides concentrations were very low or below detection limits (BDL) in all eight samples. Atrazine ranged from Below Detection Limit (BDL) to 0.79 ug/L and all results were well below the water quality criteria.

City of Clyde

The city of Clyde operates a community public water system that serves a population of approximately 7,330 people, including water sold to the village of Green Springs. The city of Clyde draws water from a surface water intake on Beaver Creek and pumps into the Beaver Creek upground reservoir. Water is then gravity-fed from the Beaver Creek Reservoir to the Raccoon Creek Reservoir and then to the water treatment plant. The system's treatment capacity is approximately 2.4 million gallons per day, but current average production is 1.2 million gallons per day. The city of Clyde's water treatment system consists of coagulation, lime softening, sedimentation, filtration, adsorption, stabilization, fluoridation and disinfection.

Ohio EPA collected three water quality samples in 2008 and 2009 directly at the Beaver Creek intake and nine samples in 2009 from Beaver Creek at State Route 101 (RM 3.48). The sampling site is a little more than 3,000 feet upstream of the Clyde intake and there are no significant tributaries or dischargers between this location and the intake. Therefore, water quality data collected at both locations were used to assess the PWS beneficial use.

To assess the PWS use samples were analyzed for nitrate and pesticides. Nitrate ranged from BDL to 13.7 mg/L and averaged 3.53 mg/L. Two samples (6/13/08 and 6/3/09) exceeded the WQS criterion for nitrate (10.0 mg/L) and Beaver Creek will likely be identified as impaired for the PWS use during the next reporting cycle in 2012. Pesticides were sampled a total of eight times during 2008 and 2009 and concentrations were low or below detection limits. Atrazine ranged from 0.29 ug/L to 8.43 ug/L and although one individual sample was above the WQS criterion, the overall average was 2.1 ug/L and below the WQS criterion of 3.0 ug/L (assessed as an annual average).

Since the Raccoon Creek Reservoir feeds directly into the water treatment plant and the current treatment processes do not remove nitrate, the finished water quality data are considered representative of the nitrate levels in the reservoir. Raccoon Creek Reservoir was assessed in the 2010 Integrated Water Quality in full attainment of the nitrate indicator since the maximum nitrate level detected in the finished water for the period 2004 through 2008 was 1.32 mg/L, well below the water quality criteria (10.0 mg/L).

As part of the childhood cancer investigation, additional pesticide samples were collected in June 2009 from the raw water intakes at each reservoir and the finished water by Ohio EPA and analyzed by Ohio Department of Agriculture. Results are currently available online at Ohio EPA's website (http://www.epa.ohio.gov/pic/clyde.aspx) by clicking the "Summary of 2009 Pesticide Sampling Results" link. In the city of Clyde treated drinking water sample, atrazine was detected at 0.25 ug/L and deethylatarzine (breakdown product of atrazine) and simazine were below the level of quantification (LOQ). In the city of Clyde water supply reservoirs, all three chemicals were detected at 0.25 ug/L. Drinking water sampling results for the cancer cluster investigation from finished water are included in an Ohio EPA Division of Drinking and Ground Water report available at http://www.epa.ohio.gov/portals/47/citizen/clyde/Final_Clyde_WQ_Report_041609.pdf (Ohio EPA 2009).

City of Fremont

The city of Fremont operates a community public water system that serves a population of approximately 19,500 people through 7,400 service connections. The water treatment system obtains its water from a surface water intake on the Sandusky River at the Ballville Dam. The system's treatment capacity is approximately 10.5 million gallons per day, but current average production is approximately four million gallons per day. Fremont's water treatment system consists of coagulation, lime softening, sedimentation, filtration, adsorption, stabilization, fluoridation, and disinfection.

The city of Fremont exceeded the nitrate WQS criterion in finished water and was in violation of the Safe Drinking Water Act five times during the past five years. Most recently, Fremont posted water quality advisories due to elevated nitrate in January and February of 2010. Due to high nitrate levels in the Sandusky River, Fremont began construction of a large upground reservoir to allow for selective pumping of the river water during periods of poor water quality. Once the upground reservoir is completed, a new surface water intake will be constructed on the Sandusky River mainstem upstream of the current location at the Ballville Dam. The new intake location will be moved approximately one mile upstream of the Ballville Dam to a site near the Portage Trail Canoe Livery.

Ohio EPA collected two samples in 2008 and seven more in 2009 to assess nitrate levels at the Fremont intake. Nitrate levels ranged from BDL to 11.4 mg/L for this sample set. Ohio EPA also reviewed nitrate levels in the finished water since the city of Fremont does not remove nitrate during the treatment process. During the period 2004 through 2008, nitrate levels were greater than 10 mg/L in 17 of 128 samples with a maximum of 20.70 mg/L in finished water. Nitrate levels in the finished water triggered the impairment listings in the 2008 and 2010 Integrated Water Quality Monitoring and Assessment Reports.

In 2008 and 2009, a total of four samples were collected at the intake and analyzed for pesticides. Atrazine ranged from 0.88 to 16.5 ug/L with two samples exceeding the WQS criterion of 3.0 ug/L. However, additional samples are needed in order to complete the assessment for pesticides since pesticide criteria are evaluated as an annual average. At a minimum, the Sandusky River at the Fremont intake will be identified on the watch list for pesticides since at least one sample was greater than 4 times the WQS criterion for atrazine.

Fremont’s raw and finished water were also included in the additional June 2009 pesticide sampling described above. The highest concentration of pesticides was found in Fremont’s Sandusky River raw water intake, with 2,4-D (4.1 ppb), acetochlor (0.72 ppb), atrazine (6.27ppb), deethylatarzine (0.48 ppb), and simazine (0.24 ppb). Fremont’s treated drinking water sample had significantly lower concentrations of pesticides with atrazine at 0.25 ppb and acetochlor and deethylatarzine at concentrations below LOQ.

Table 14. Summary of available water quality data for parameters of interest at sampling sites near/at PWS intakes.

Location(s)	**PWS Parameters of Interest**			
	Nitrate-Nitrite WQC = 10 mg/L[1]		**Atrazine WQC = 3.0 ug/L[2]**	
	Average/ (sample count)	**Maximum (# samples >WQC)**	**Average / (sample count)**	**Maximum**
Snyders Ditch near Reservoirs @ RR	4.3 mg/L n=8	14.1 mg/L (1)	0.37 ug/L n=8	0.79 ug/L
Beaver Creek @ PWS intake and SR 101 (data combined from both sites)	3.5 mg/L n=12	13.7 mg/L (2)	2.1 ug/L N=8	8.43 ug/L
Sandusky River Just Upst. Ballville Dam	5.0 mg/L n=9	11.4 mg/L (1)	**7.07 ug/L[3]** N=4	16.5 ug/L

1 Nitrate Water Quality Criterion (WQC) evaluated as maximum value not to be exceeded, impaired waters defined as having two or more excursions about the criterion.

2 Atrazine WQC evaluated as annual average.

3 Insufficient data available to assess the annual average for the PWS beneficial use. Only four spring samples available; additional data required to more accurately characterize the annual average.

Lake Sampling

Monitoring and assessing lakes, including natural lakes and manmade impounded or upground reservoirs, is an important compliment to the study of stream ecosystems. Lakes act as watershed sinks for the upstream loading of sediment, nutrients and pesticides. Thus, their assessment may be the best indicator of the combined effects that both point and nonpoint pollution sources have on surface water quality.

Lake Description

Beaver Creek Reservoir is a 110 acre lake located in Section 9 of Adams Township, Seneca County. In conjunction with Raccoon Creek Reservoir, it provides drinking water to the city of Clyde. At normal stage of 762 feet above sea level the lake has a maximum depth of 36 feet and holds 692 million gallons of water. Source water for the lake is obtained from Beaver Creek via a pumping station located at river mile 2.88. There are two 5,000 gpm and one 2,000 gpm raw pumps in service. A 24-inch line feeds water by gravity to Raccoon Creek Reservoir. Raccoon Creek Reservoir is a 34-acre lake located within the Clyde municipal limits adjacent to the water treatment plant. At normal stage, it has a maximum depth of 20 feet and holds 200 million gallons of water. Under normal circumstances, water from Raccoon Creek Reservoir is then fed into the water treatment plant.

Beaver Creek Reservoir was built in 1971 of upground construction and consists of a 32-foot earthen levee approximately 12 feet wide at the top with 2:1 side slopes. The inside of the levee is covered with limestone riprap to protect from wind and wave erosion. The lake is open to public fishing, but swimming is not allowed. A concrete boat ramp is provided and only electric motors are allowed. Fish management activities include routine stocking, population monitoring, and angler harvest studies. Raccoon Creek Reservoir was built in 1950 and is also of upground construction. It is open to shore fishing only. The adjacent Raccoon Creek pump station was eliminated in 2001. Both lakes have been treated in the past on an as needed basis with copper sulfate to control nuisance algae. No treatments were necessary in 2007 or 2008.

Water Quality

Guidance used to assess lake water quality had not been finalized by completion of this report. The Lake Habitat aquatic life use designation and associated numerical criteria and assessment methods were piloted and available for public comments in the Ohio 2010 Integrated Water Quality Monitoring and Assessment Report (Ohio EPA, 2010). Final administrative rules establishing Lake Habitat aquatic life use and associated numerical criteria in the Ohio WQS were anticipated for 2011. A standard lake assessment spans two years and includes 5 sets of samples collected each year during the May 1 through October 31 recreation season. The use is evaluated based on both a set of tiered and base aquatic life criteria.

Sampling in Beaver Creek Reservoir following the lake assessment protocol began in 2009 and will be completed in autumn 2010. The results of the sampling will be incorporated into the 2012 Integrated Water Quality Monitoring and Assessment Report. Results based on the use of the reservoir as a Public Water Supply are provided in the Public Water Supply section of this report.

Fish Consumption Advisory

In order to issue fish consumption advisories, or make impairment determinations for the Integrated Water Quality Monitoring and Assessment Report, certain data requirements need to be met. Because many of the Sandusky tributaries have small drainage areas and do not support many sport-sized fish, most do not have adequate data to determine either advisories or impairments. However, the highlighted values in Table 15 do indicate individual samples that exceed the one meal per month advisory thresholds.

Two watersheds have enough data to make impairment decisions based on the 2010 Integrated Report Human Health Use methodology. The Beaver Creek WAU (HUC 12 – 041000111202), which includes Beaver Creek Reservoir, would be considered category 1, or unimpaired, using the methodology. The Muddy Creek – Frontal Sandusky Bay WAU (HUC 12 – 041000111404), which includes Muddy Creek, would be considered impaired due to PCBs, with the average level of PCBs in the WAU at 41 µg/kg in fish tissue, slightly exceeding the impairment threshold of 23 µg/kg in fish tissue.

The only stream with enough data to issue advisories is the Sandusky River. Species that meet the data requirements of a minimum of three samples are common carp and smallmouth buffalo. In both cases, a one-meal-per-month advisory would be issued due to PCBs. Not enough higher trophic level species were collected to determine impairment status for the lower Sandusky mainstem.

Table 15 is not a comprehensive list of all analytical data for the samples. Some other contaminants, such as arsenic and dieldrin, were detected at levels that would be in the unrestricted consumption advisory range, and therefore were not given in the table. Appendix O contains the comprehensive list of all analytical data for the samples.

Table 15. Fish tissue specimens sampled from the Sandusky Bay tributaries study area during the 2009 field season (June-Oct.), with concentrations of selected contaminants of concern.

Site Name	RM	Species	Sample Type	No. of fish	Mean Length (mm)	Mean Weight (g)	Lead (mg/kg)	Mercury (mg/kg)	Total PCBs (µg/kg)	Total DDTs (µg/kg)	Hexachlorobenzene (µg/kg)
Raccoon Creek Reservoir – Entire Perimeter	NA	Brown Bullhead	SFF	1	300	310	ND	0.097	ND	ND	ND
		Channel Catfish	SFF	1	319	210	ND	ND	ND	ND	ND
		Largemouth Bass	SFF	1	277	261	ND	0.057	ND	ND	ND
Beaver Creek Reservoir – Southern Perimeter	NA	Bluegill Sunfish	SFFC	2	172	101	ND	0.078	ND	ND	ND
		Channel Catfish	SFF	1	450	800	ND	0.097	ND	ND	ND
		Largemouth Bass	SFFC	3	381	750	ND	0.256	ND	ND	ND
		Largemouth Bass	SFFC	5	311	410	ND	0.143	ND	ND	ND
		Saugeye	SFF	1	517	1450	ND	0.395	ND	ND	ND
Raccoon Creek	10.18	Common Carp	SFFC	2	529	1900	ND	0.125	126	17	ND
		Creek Chub	WB	5	171	52	ND	0.019	332	58	ND
	5.45	Creek Chub	WBC	5	204	100	0.04	0.051	295	56	ND
	3.2	Common Carp	SFFC	1	453	1200	0.046	0.03	244	39	ND
		Yellow Bullhead	WB	3	200	117	ND	0.15	101	16	ND
Green Creek	18.8	Creek Chub	WBC	8	170	56	ND	0.036	ND	ND	ND
Mills Creek – Adjacent Pork Packaging Plant	5.2	Common Carp	SFFC	3	466	1036	ND	0.042	ND	ND	ND
		Creek Chub	WBC	2	233	148	0.049	0.083	ND	ND	ND
		White Sucker	WBC	2	239	317	0.075	0.055	ND	ND	ND
		White Sucker	SFFC	2	378	579	ND	0.104	ND	ND	ND
Beaver Creek – downstream RV Park	4	Creek Chub	WBC	8	186	68	ND	0.043	ND	ND	ND
		White Sucker	SFFC	4	289	212	ND	0.06	ND	ND	ND
Beaver Creek	3.48	Creek Chub	WBC	5	214	100	ND	0.09	ND	ND	ND
Pickerel Creek	3.3	White Sucker	SOFC	5	285	205	ND	0.077	ND	14	ND

Site Name	RM	Species	Sample Type	No. of fish	Mean Length (mm)	Mean Weight (g)	Lead (mg/kg)	Mercury (mg/kg)	Total PCBs (µg/kg)	Total DDTs (µg/kg)	Hexachlorobenzene (µg/kg)
Muskellunge Creek – upstream Fangboner Road	1.2	Common Carp	SFFC	4	483	1562	ND	0.11	249	22	ND
		Largemouth Bass	SFF	1	293	345	ND	0.139	ND	ND	ND
		Rock Bass	SFFC	3	178	113	ND	0.217	ND	ND	ND
		Yellow Perch	SFF	1	233	150	ND	0.11	ND	ND	ND
Muddy Creek – upstream Church Street	5.0	Common Carp	SFFC	4	516	1537	ND	0.112	130	12	ND
		Freshwater Drum	SFFC	2	354	492	ND	0.257	ND	ND	ND
		Largemouth Bass	SFF	1	419	960	ND	0.234	ND	ND	ND
Muddy Creek – upstream SR 53	2.0	Common Carp	SFFC	4	507	1762	ND	0.096	57	ND	ND
		Freshwater Drum	SFFC	2	343	495	ND	0.042	ND	ND	ND
		Largemouth Bass	SFF	1	270	270	ND	0.099	ND	ND	ND
Sandusky River – adjacent Portage Trails	19	Common Carp	SFFC	3	564	2300	ND	0.224	ND	ND	ND
		Largemouth Bass	SFFC	2	242	230	ND	0.245	ND	ND	ND
		Yellow Bullhead	SFFC	2	228	154	ND	0.203	ND	ND	ND
Sandusky River – RR bridge adjacent island	14.8	Common Carp	SFFC	3	483	1733	NA	NA	NA	NA	ND
		Smallmouth Buffalo	SFFC	2	502	1950	0.083	0.076	337	21.8	ND
Sandusky River – downstream US 20 and WWTP	13.3	Bigmouth Buffalo	SFFC	2	622	4425	ND	0.037	ND	ND	ND
		Common Carp	SFFC	3	502	2000	ND	0.119	844	64.9	ND
		Smallmouth Buffalo	SFFC	3	474	1667	ND	0.165	511	25.8	ND
		Yellow Bullhead	SFFC	2	211	134	ND	0.117	54.6	ND	ND

Site Name	RM	Species	Sample Type	No. of fish	Mean Length (mm)	Mean Weight (g)	Lead (mg/kg)	Mercury (mg/kg)	Total PCBs (µg/kg)	Total DDTs (µg/kg)	Hexachlorobenzene (µg/kg)
Sandusky River – downstream Wightman's Grove	3.8	Bluegill Sunfish	SFFC	5	147	89	ND	0.039	ND	ND	ND
		Common Carp	SFFC	2	532	2225	0.059	0.088	545	32	ND
		Largemouth Bass	SFF	2	275	317	ND	0.075	631	58	ND
		Smallmouth Buffalo	SFF	1	470	1350	0.135	0.058	ND	ND	ND

Sample types are as follows: SOF/SOFC, skin on fillet/skin on fillet composite; SFF/SFFC, skin off fillet/skin off fillet composite; WB/WBC, whole body/whole body composite. ND indicates the compound was not detected. Highlighted data indicate individual samples where the contaminant levels exceed the one-meal-per-month advisory threshold.

SUMMARY WATERSHED ASSESSMENT UNITS

The Sandusky Bay tributaries study area is comprised of five 10-digit Hydrologic Unit Code (HUC10) watersheds. These may be further divided into fourteen 12-digit Hydrologic Unit Code (HUC12) watersheds. Data from individual sampling locations in a HUC 12 Watershed Assessment Unit (WAU) are accumulated and analyzed; summary information for each WAU is presented in this section (Table 16). Data used in this analysis were collected in 2009. High magnitude causes and sources contributing to the biological impairment (partial and non-attainment percents) are noted. This information was used in aggregate statewide statistics for Ohio's universe of assessed streams and rivers, and will be reported in Ohio's 2012 Integrated Water Quality Monitoring and Assessment Report. Information about the report and past reports is available at: http://www.epa.ohio.gov/dsw/tmdl/OhioIntegratedReport.aspx.

The Mills Creek–Frontal Lake Erie (HUC 10–0410001101) WAU consists of three HUC 12s which included a total of 11 sites (Table 16 and Figure 23). Only two sites were in full attainment of the WWH aquatic life use designation, Sawmill Creek RM 1.10 and Mills Creek RM 3.70. Sedimentation and siltation from channelization contributed to partial and non-attainment throughout Pipe Creek, with altered flow regimes from urban runoff also contributing to non-attainment at Pipe Creek RM 2.32. The Bellevue WWTP negatively influenced the water quality of Mills Creek resulting in organic and nutrient enrichment. Livestock access to Mills Creek, potentially failing HSTS, and CSOs also contributed to the organic and nutrient enrichment noted at several sites on Mills Creek. Crop production with subsurface drainage resulted in heavy siltation and embedded substrates, limiting the amount of interstitial spaces available for aquatic organisms in Mills Creek and Caswell Ditch.

The Pickerel Creek–Frontal Sandusky Bay (HUC 10 – 0410001102) WAU consists of four HUC 12s which included 11 sampling locations (Table 16 and Figure 24). Only two sites were in full attainment of the WWH aquatic life use designation, Pickerel Creek RM 6.26 and Raccoon Creek RM 13.26. As discussed in the Fish Results section above, Cold Creek was only able to support a fish community due to artificial aeration of the stream. While the stream did not meet aquatic life use expectations, it was a result of the natural characteristics of the stream. Excessive siltation and embedded substrates from crop production with subsurface drainage contributed to partial and non-attainment at five sites. The subsurface drainage also likely contributed to the streambank destabilization, channel erosion and incision noted at Pickerel Creek RM 3.35. Organic and nutrient enrichment were noted along Raccoon Creek as a result of a CSO near RM 11.32, and also from the Clyde WWTP, which negatively affected water through the remaining sites on Raccoon Creek. Crop production with subsurface drainage continued to impact the aquatic life communities of Buck Creek, resulting in excessive siltation and embedded substrates. Historical pesticide toxicity was evident with the continued presence of legacy pesticides present in the sediments. In addition to the negative habitat effects noted by the surrounding crop production with subsurface drainage along South Creek, nutrient enrichment and organic enrichment from possibly failing HSTS was noted near RM 7.92, while livestock operations contributed to nutrient enrichment further downstream at RM 4.04.

The Green Creek (HUC10 – 0410001112) WAU consists of three HUC 12s with a total of eleven sampling locations (Table 16 and Figure 25). Six of the eleven sites were in full attainment of their respective aquatic life use designation. The two non-attaining sites on Emerson Creek were the result of excessive sedimentation from crop production with subsurface drainage near RM 1.83 and excessive sedimentation and direct habitat alterations from channelization near RM 6.85. The excessive sedimentation resulting in partial attainment at Green Creek RMs

12.85 and 5.06 was caused by the channel erosion and incision likely attributable to the surrounding and upstream crop production with subsurface drainage.

The Muskellunge Creek–Sandusky River (HUC 10 – 0410001113) WAU consists of two HUC 12s with a total of three sites in addition to the six Sandusky River mainstem sites (Table 16 and Figure 26). The Sandusky River RM 18.05 site was in the Ballville dam pool and was in non-attainment due to the siltation and impounded conditions created by the dam. The next two downstream Sandusky River sites, RMs 16.8 and 15.4, were in full attainment of the WWH aquatic life use designation. Non attainment of the lacustuary benchmark was noted at RM 12.8, with siltation and nutrient enrichment from the upstream crop production with subsurface drainage and Fremont WWTP negatively affecting water quality. Siltation and embedded substrates from the upstream crop production with subsurface drainage continued to negatively affect water quality in a downstream direction, as the two most downstream sites, RMs 5.5 and 1.3, did not meet the lacustuary benchmarks. Muskellunge Creek RM 5.4 was in full attainment of the WWH aquatic life use designation, while the downstream site near RM 1.23 was in non-attainment due to nutrient enrichment and siltation from crop production with subsurface drainage. A combination of siltation, embedded substrates, and direct habitat alterations from crop production with subsurface drainage and channelization contributed to the non attainment noted at Bark Creek RM 3.2, along with organic and nutrient enrichment from sewage discharges in unsewered areas.

The Muddy Creek–Frontal Sandusky Bay (HUC 10 – 0410001114) WAU consists of two HUC 12s and a total of three sites (Table 16 and Figure 27). Crop production with subsurface drainage contributed to the excessive siltation and sedimentation along with nutrient enrichment noted in Little Muddy Creek and Fishing Creek. Nutrient enrichment and direct habitat alterations from channelization were noted in Muddy Creek. All three of these sites were in non-attainment for the WWH aquatic life use designation.

Table 16. Sampling locations and associated attainment status with causes and sources of impairment organized by HUC 12 Watershed Assessment Units for the Sandusky Bay tributaries. The Site column refers to the labels on the locations depicted in Figures 23-27 of the sampling locations.

Site	Station Code	Station	River Mile	Drainage (sq.mi.)	ALU1	Attain Status	Cause	Sources
HUC 10 - 0410001101 (Mills Creek-Frontal Lake Erie)								
HUC 12 - 041000110101 (Sawmill Creek)								
1	K01K21	SAWMILL CREEK W OF HURON @ BOOS RD.	1.10	13.5	WWH	Full	-	-
HUC 12 - 041000110102 (Pipe Creek-Frontal Sandusky Bay)								
2	U05K18	PIPE CREEK JUST UPST. TURNPIKE @ HARRIS RD.	10.81	9.4	WWH	N/A	-	-
3	U05K17	PIPE CREEK N OF BLOOMINGVILLE @ PATTEN TRACT RD.	8.18	14.7	WWH	Partial	Sedimentation/Siltation	Channelization
4	U05K16	PIPE CREEK S OF SANDUSKY @ SCHENK RD.	6.66	18.4	WWH	Partial	Sedimentation/Siltation	Channelization
5	U05K15	PIPE CREEK AT SANDUSKY @ COLUMBUS AVE.	2.32	22.8	WWH	Non	Other flow regime alterations, Sedimentation/Siltation	Urban Runoff/Storm Sewers, Channelization
HUC 12 - 041000110103 (Mills Creek)								
6	U05S07	MILLS CREEK W OF PARKERTOWN @ PORTLAND RD.	10.40	21.0	WWH	Non	Organic Enrichment (Sewage) Biological Indicators, Sedimentation/Siltation, Nutrient/Eutrophication Biological Indicators, Particle distribution (Embeddedness), Phosphorus (Total)	Municipal Point Source Discharges, Crop Production with Subsurface Drainage
7	U05S06	MILLS CREEK SE OF CASTALIA @ ST. RT. 99	6.03	29.0	WWH	Non	Organic Enrichment (Sewage) Biological Indicators, Phosphorus (Total), Nutrient/Eutrophication Biological Indicators, Sedimentation/Siltation	Municipal Point Source Discharges, Livestock (Grazing or Feeding Operations), Crop Production with Subsurface Drainage

Site	Station Code	Station	River Mile	Drainage (sq.mi.)	ALU1	Attain Status	Cause	Sources
8	U05P07	MILLS CREEK NEAR CASTALIA @ BOGART RD.	5.20	29.0	WWH	Non	Phosphorus (Total), Particle distribution (Embeddedness), Sedimentation/Siltation, Organic Enrichment (Sewage) Biological Indicators, Nutrient/Eutrophication Biological Indicators	Livestock (Grazing or Feeding Operations), Municipal Point Source Discharges, On-site Treatment Systems (Septic Systems and Similar Decentralized Systems)
9	U05S18	MILLS CREEK S OF SANDUSKY @ STRUB RD.	3.70	35.0	WWH	Full	-	-
10	U05P05	MILLS CREEK AT SANDUSKY @ PERKINS AVE.	1.35	41.0	WWH	Non	Nutrient/Eutrophication Biological Indicators, Organic Enrichment (Sewage) Biological Indicators, Sedimentation/Siltation, Phosphorus (Total)	Municipal Point Source Discharges, Combined Sewer Overflows, Urban Runoff/Storm Sewers
11	U05W37	CASWELL DITCH (TRIB TO MILLS CREEK 3.95) @ BOGART RD.	0.85	3.9	WWH	Partial	Sedimentation/Siltation	Loss of Riparian Habitat, Crop Production with Subsurface Drainage
HUC 10 - 0410001102 (Pickerel Creek-Frontal Sandusky Bay)								
HUC 12 - 041000110201 (Frontal South Side of Sandusky Bay)								
1	201385	LITTLE PICKEREL CREEK @ YETTER RD.	2.00	5.5	CWH	Partial	Sedimentation/Siltation, Particle distribution (Embeddedness)	Crop Production with Subsurface Drainage
2	300670	COLD CREEK @ BARDSHAR RD.	0.36	2.9	CWH	Partial	Natural Conditions (Flow or Habitat)	Natural Sources
HUC 12 - 041000110203 (Pickerel Creek)								
3	U05K10	PICKEREL CREEK @ REINICKE RD. (TWP. RD. 233)	6.26	9.5	WWH	Full	-	-
4	U05S04	PICKEREL CREEK @ TWP. RD. 247	3.35	43.7	WWH	Partial	Sedimentation/Siltation, Particle distribution (Embeddedness)	Streambank Modifications/destabilization, Channel Erosion/Incision from Upstream Hydromodifications, Crop Production with Subsurface Drainage
HUC 12 - 041000110204 (Raccoon Creek)								
5	U05S01	RACCOON CREEK UPST. CLYDE @ LIMERICK RD.	13.26	9.9	WWH	Full	-	-

Site	Station Code	Station	River Mile	Drainage (sq.mi.)	ALU1	Attain Status	Cause	Sources
6	U05P04	RACCOON CREEK AT CLYDE @ U.S. RT. 20	11.32	12.7	WWH	Non	Phosphorus (Total), Organic Enrichment (Sewage) Biological Indicators, Direct Habitat Alterations, Nutrient/Eutrophication Biological Indicators, Sedimentation/Siltation	Urban Runoff/Storm Sewers, Channelization, Combined Sewer Overflows
7	U05W10	RACCOON CREEK N OF CLYDE @ TWP. RD. 223	10.18	13.8	WWH	Non	Phosphorus (Total), Nutrient/Eutrophication Biological Indicators, Particle distribution (Embeddedness), Sedimentation/Siltation	Municipal Point Source Discharges
8	U05W17	RACCOON CREEK DST. OHIO TURNPIKE @ TWP. RD. 244	5.45	23.6	WWH	Partial	Organic Enrichment (Sewage) Biological Indicators, Nutrient/Eutrophication Biological Indicators, Phosphorus (Total)	Municipal Point Source Discharges, Crop Production with Subsurface Drainage
9	U05S03	BUCK CREEK N OF CLYDE @ TWP. RD. 223	0.20	4.5	WWH	Partial	Pesticides, Sedimentation/Siltation, Particle distribution (Embeddedness), Nutrient/Eutrophication Biological Indicators	Specialty Crop Production, Highways, Roads, Bridges, Infrastructure (New Construction), Crop Production with Subsurface Drainage
HUC 12 - 041000110205 (South Creek)								
10	U05G01	SOUTH CREEK @ CO. RD. 229	7.92	7.1	WWH	Non	Nutrient/Eutrophication Biological Indicators, Organic Enrichment (Sewage) Biological Indicators, Phosphorus (Total)	On-site Treatment Systems (Septic Systems and Similar Decentralized Systems), Crop Production with Subsurface Drainage
11	U05K05	SOUTH CREEK NEAR RILEY CENTER @ WHITMORE RD. (TWP. RD. 247)	4.04	18.1	WWH	Partial	Nutrient/Eutrophication Biological Indicators, Particle distribution (Embeddedness), Sedimentation/Siltation, Phosphorus (Total)	Channelization, Livestock (Grazing or Feeding Operations)
HUC 10 - 0410001112 (Green Creek)								
HUC 12 - 041000111201 (Westerhouse Ditch)								
1	U04K05	WESTERHOUSE DITCH @ SNAVELY RD.	3.25	9.6	WWH	Full	-	-
2	U04K04	WESTERHOUSE DITCH NE OF LOWELL @ ST. RT. 19	0.63	16.2	WWH	Full	-	-
HUC 12 - 041000111202 (Beaver Creek)								

Site	Station Code	Station	River Mile	Drainage (sq.mi.)	ALU1	Attain Status	Cause	Sources
3	U04K03	BEAVER CREEK DST. LEAFY OAKS MHP	4.00	20.9	CWH	Full	-	-
4	U04G25	BEAVER CREEK @ ST. RT. 101	3.48	43.4	CWH	Full	-	-
5	U04G26	EMERSON CREEK @ TWP. RD. 179	1.83	22.0	WWH	Non	Sedimentation/Siltation	Crop Production with Subsurface Drainage
6	U04K08	EMERSON CREEK (ROYER DITCH) @ CO. RD. 46	10.12	6.4	WWH	N/A	-	-
7	U04K07	EMERSON CREEK (ROYER DITCH) NEAR FIRESIDE @ RON MEYERS RD.	6.85	15.2	WWH	Non	Sedimentation/Siltation, Direct Habitat Alterations	Channelization
HUC 12 - 041000111203 (Green Creek)								
8	U04G24	GREEN CREEK @ CO. RD. 34	18.80	53.0	CWH	Full	-	-
9	U04S10	GREEN CREEK SE OF FREMONT @ DEWEY RD.	12.85	71.0	CWH	Partial	Sedimentation/Siltation	Channel Erosion/Incision from Upstream Hydromodifications, Crop Production with Subsurface Drainage
10	U04G20	GREEN CREEK @ CO. RD. 229	9.08	74.0	WWH	Full	-	-
11	U04K01	GREEN CREEK NE OF FREMONT @ TWP. RD. 239	5.06	78.3	WWH	Partial	Sedimentation/Siltation	Crop Production with Subsurface Drainage, Channel Erosion/Incision from Upstream Hydromodifications
HUC 10 - 0410001113 (Muskellunge Creek-Sandusky River)								
1	U04T02	SADUSKY RIVER UST. BALLVILLE DAM	18.05	1255	WWH	NON	Sedimentation/Siltation, Direct habitat Alteration	Dam or impounded
2	U04S23	SANDUSKY RIVER AT FREMONT UPSTREAM ROGER YOUNG PARK	16.8	1256	WWH	FULL		
3	U04W11	SANDUSKY RIVER AT FREMONT AT STATE STREET	15.4	1260	WWH	FULL		
4	500890	SANDUSKY RIVER OPPOSITE FREMONT YACHT CLUB	12.8	1264	WWH	PARTIAL	Sedimentation/Siltation, Nutrient/Eutrophication Biological Indicators,	Municipal Point Source Discharges, Crop Production with Subsurface Drainage

Site	Station Code	Station	River Mile	Drainage (sq.mi.)	ALU1	Attain Status	Cause	Sources
5	U04S17	SANDUSKY RIVER UPSTREAM WIGHTMANS GROVE	5.5	1330	WWH	NON	Sedimentation/Siltation, Nutrient/Eutrophication Biological Indicators , Particle distribution (Embeddedness)	Crop Production with Subsurface Drainage
6	201314	SANDUSKY RIVER UPSTREAM BAY CONFLUENCE	1.3	1335	WWH	NON	Sedimentation/Siltation, Particle distribution (Embeddedness)	Crop Production with Subsurface Drainage
HUC 12 - 041000111301 (Muskellunge Creek)								
7	201332	MUSKELLUNGE CREEK NEAR FREMONT @ SPIELDENNER RD.	5.40	37.0	WWH	Full	-	-
8	U04P08	MUSKELLUNGE CREEK NEAR FREMONT @ FANGBONER RD.	1.23	44.0	WWH	Non	Nutrient/Eutrophication Biological Indicators, Sedimentation/Siltation, Phosphorus (Total)	Crop Production with Subsurface Drainage
HUC 12 - 041000111303 (Mouth Sandusky River)								
9	300671	BARK CREEK AT KELLEY RD. (CO. RD. 245)	3.20	10.0	WWH	Non	Sedimentation/Siltation, Particle distribution (Embeddedness), Direct Habitat Alterations, Phosphorus (Total), Organic Enrichment (Sewage) Biological Indicators	Sewage Discharges in Unsewered Areas, Crop Production with Subsurface Drainage, Channelization
HUC 10 - 0410001114 (Muddy Creek-Frontal Sandusky Bay)								
HUC 12 - 041000111403 (Little Muddy Creek)								
1	300676	LITTLE MUDDY CREEK AT KLINE RD	2.50	25.0	WWH	Non	Sedimentation/Siltation, Phosphorus (Total), Nutrient/Eutrophication Biological Indicators	Crop Production with Subsurface Drainage
2	300678	FISHING CREEK @ WEICKERT RD.	0.20	7.0	WWH	Non	Sedimentation/Siltation, Phosphorus (Total), Nutrient/Eutrophication Biological Indicators	Crop Production with Subsurface Drainage
HUC 12 - 041000111404 (Town of Lindsey-Muddy Creek)								
3	U04Q13	MUDDY CREEK @ EAST SIDE OF ST. RT. 53	1.23	110.0	WWH	Non	Direct Habitat Alterations, Other flow regime alterations, Phosphorus (Total)	Channelization

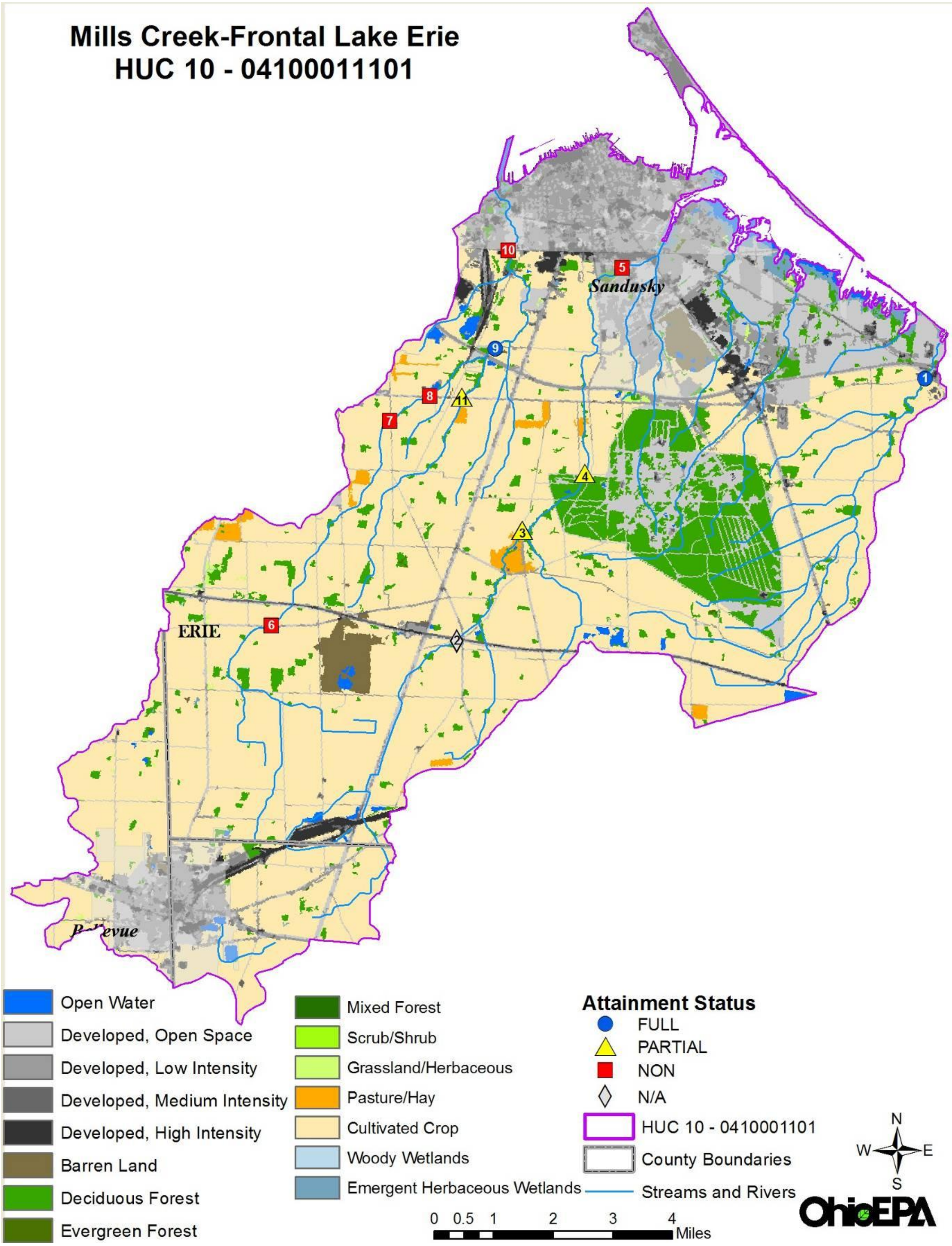


Figure 23. Land use and attainment status of sampling locations within Mills Creek – Frontal Lake Erie (HUC 10 - 0410001101).

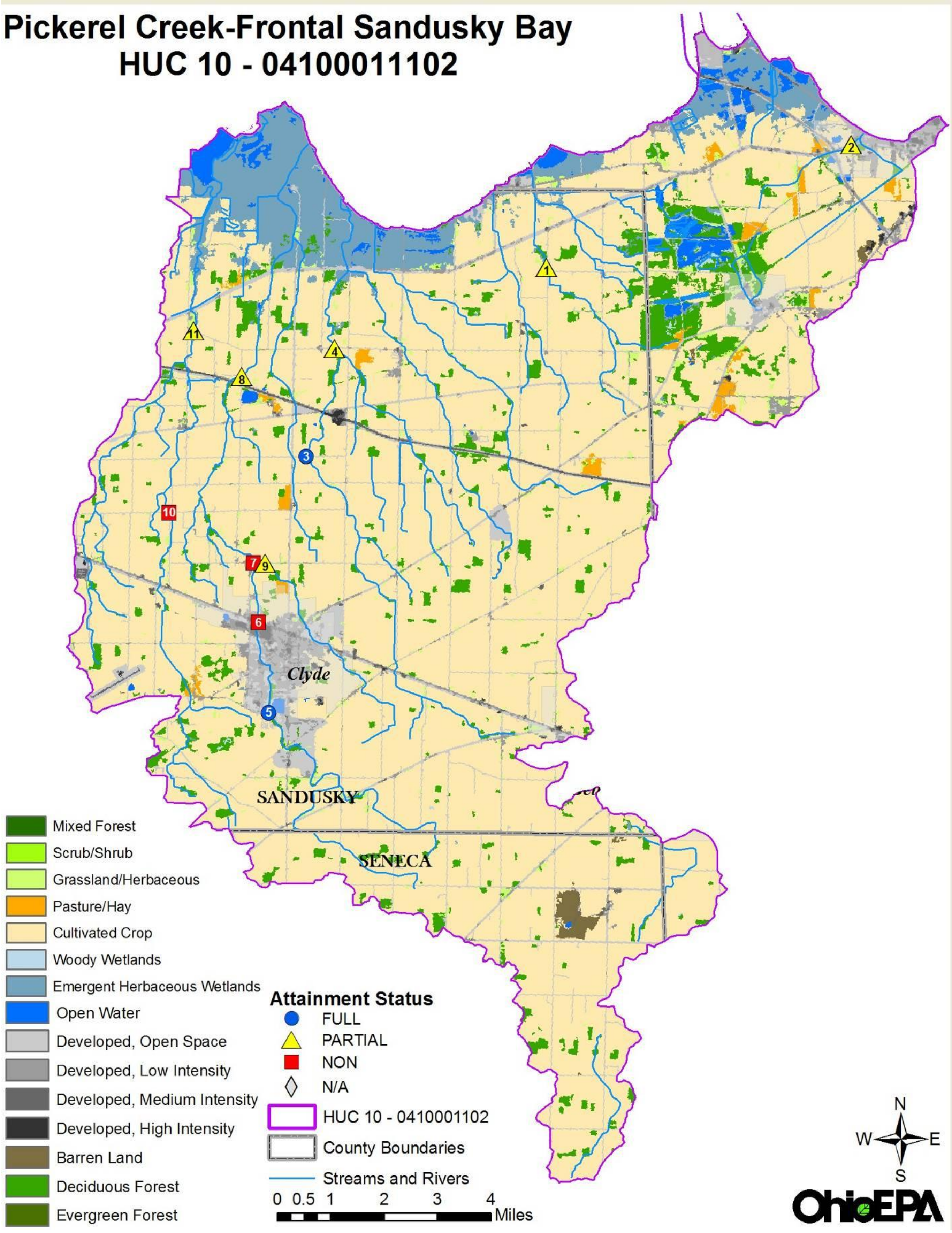


Figure 24. Land use and attainment status of sampling locations within Pickerel Creek – Frontal Sandusky Bay (HUC 10 - 0410001102).

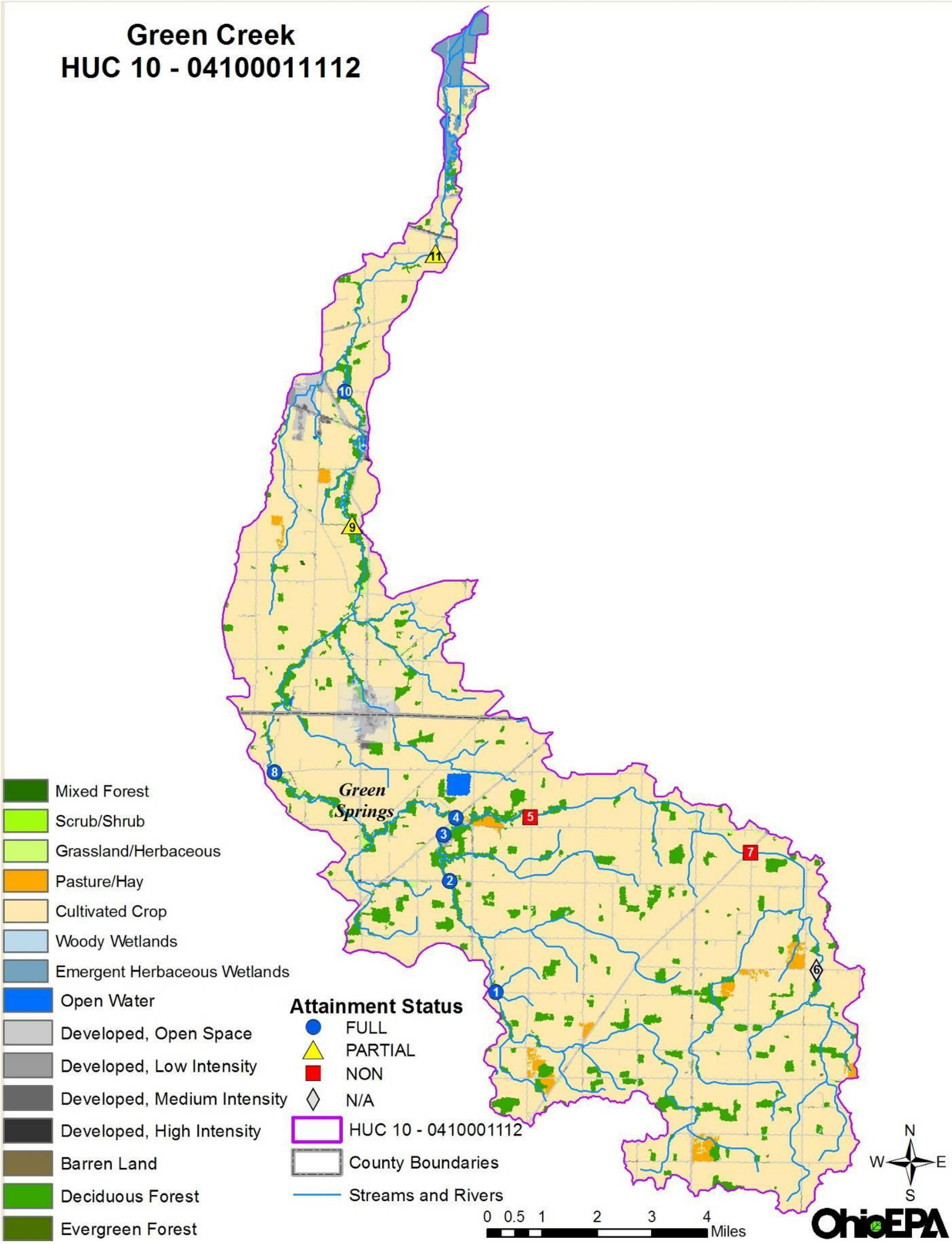


Figure 25. Land use and attainment status of sampling locations within Green Creek (HUC 10 - 0410001112).

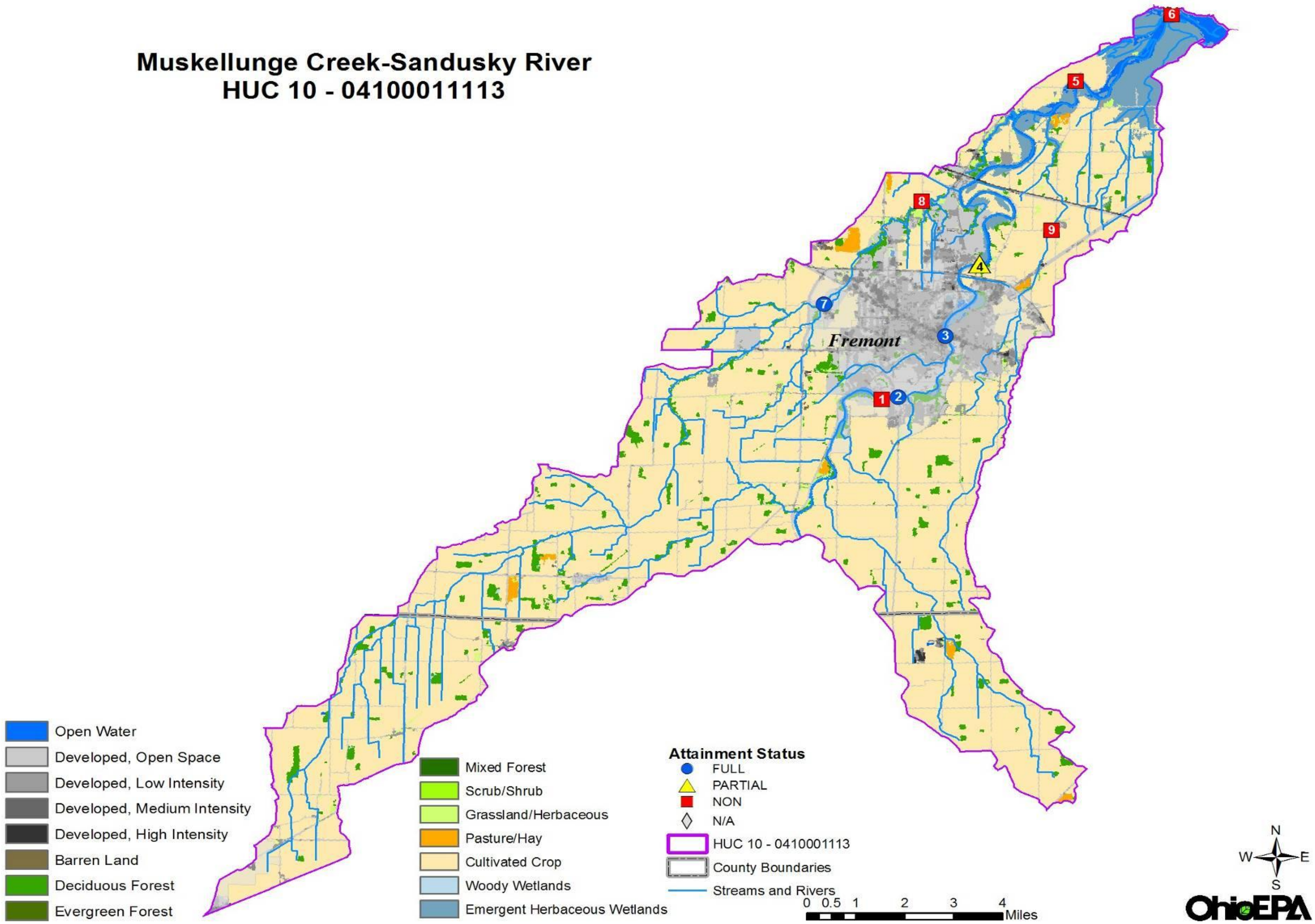


Figure 26. Land use and attainment status of sampling locations within Muskellunge Creek – Sandusky River (HUC 10 - 0410001113).

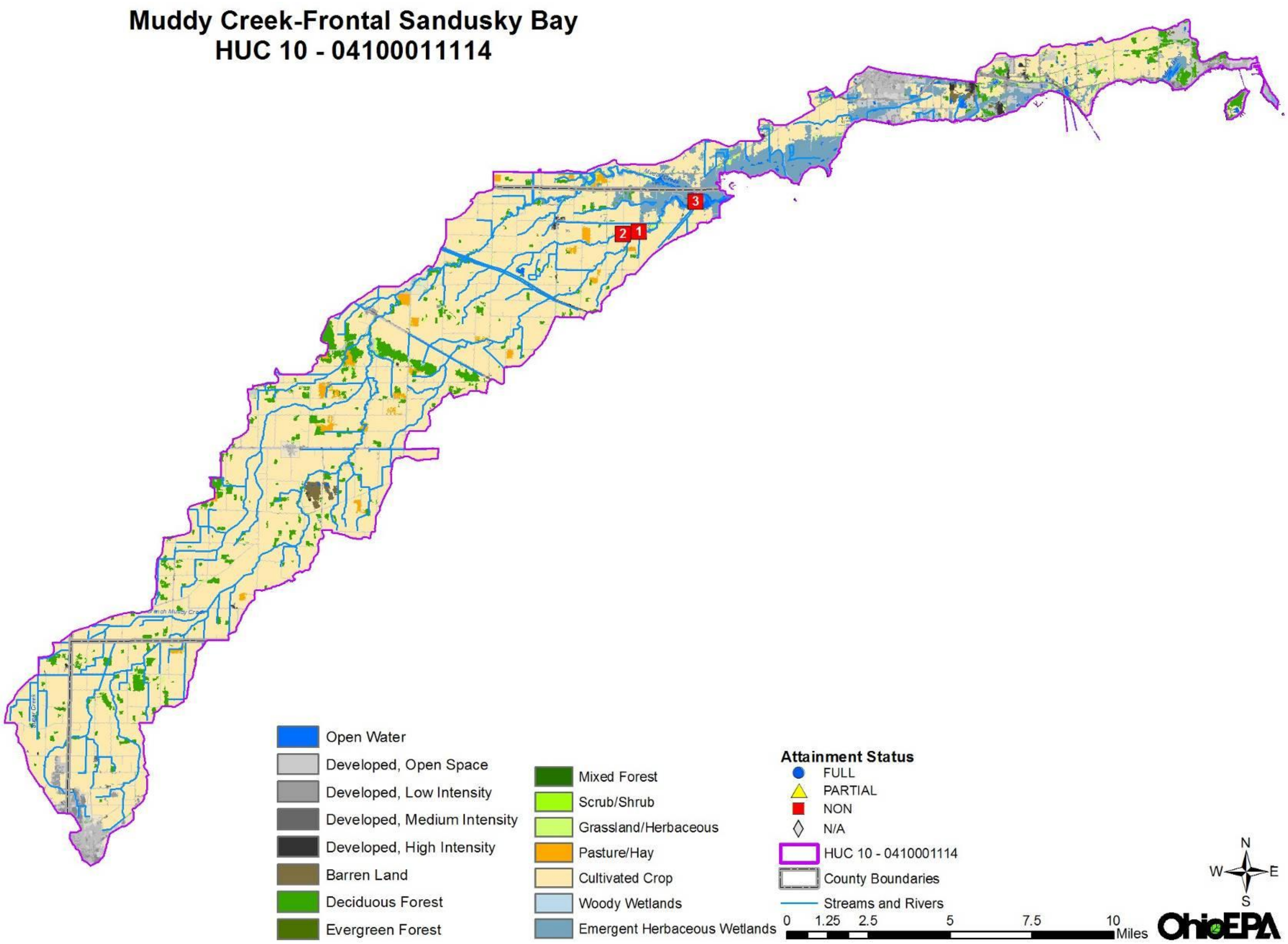


Figure 27. Land use and attainment status of sampling locations within Muddy Creek – Frontal Sandusky Bay (HUC 10 - 0410001114).

BENEFICIAL USE RECOMMENDATIONS

The majority of the streams listed in the Ohio WQS for the study area are assigned the WWH aquatic life use designation (Tables 17 and 18). These streams were originally designated for aquatic life uses in the 1978 Ohio WQS. The techniques used then did not include standardized approaches to the collection of instream biological data or numerical biological criteria. This study used biological data to evaluate and establish aquatic life uses for a number of streams in the study area.

Twenty-one streams were evaluated for aquatic life and recreational use potential during 2009 (Tables 2, 17 and 18). Significant findings include the following:

- Two undesignated streams were evaluated for the first time and received the WWH aquatic life use designation. The fish communities of Fishing Creek and Buck Creek were within WWH expectations.

- The existing SCR use for Raccoon Creek, Mills Creek, and Caswell Ditch should be changed to PCR. When these streams received the SCR designation, it was based on the understanding that PCR only applied to streams of sufficient depth and breadth to allow for full body immersion and swimming by adults. Today, PCR is looked upon from a more general perspective, in that, if access is available and people live within the vicinity, children are likely to play and come into contact with the waters of the stream. Field observations combined with review of aerial photos for each stream indicate potential for easy access to the streams through residential yards.

- Biological sampling confirmed the appropriateness of the WWH aquatic life use designation for twelve streams in the study area. These streams included Sandusky River (Fremont STP at RM 13.85 to Muskellunge Creek at RM 9.37), Little Muddy Creek, Green Creek (State Route 20 to confluence with Lake Erie), Westerhouse Ditch, Emerson Creek, Emerson Creek (a.k.a. Royer Ditch), Bark Creek, Muskellunge Creek, South Creek, Mills Creek, Pipe Creek, and Sawmill Creek (Huron River basin).

- Biological sampling confirmed the CWH aquatic life use designation for Cold Creek. The ODNR fish hatchery and several trout clubs present on Cold Creek indicate that the "CWH, inland trout streams" is the most appropriate aquatic life use designation from the Blue Hole to the confluence with Lake Erie.

- The CWH aquatic life use designation for Green Creek (confluence with Beaver Creek to State Route 20) was deemed appropriate based upon a combination of biological sampling results and an understanding of the unique characteristics of the stream. Four CWH macroinvertebrate taxa were collected near RM 18.8, and 2 CWH macroinvertebrate taxa and 1 CWH fish (mottled sculpin) were collected near RMs 12.8 and 9.1. The strong ground water contribution by Beaver Creek springs at the confluence of Beaver Creek with Green Creek inhibits longitudinal zonation of fish species (Swaidner and Berra, 1979). As discussed in the Fish Community Results section above, fish community sampling in 2009 confirmed that the fish community of Green Creek resembles a headwater community at larger drainage areas, both in diversity and abundance. This explains why few overall fish and only one CWH fish species were collected. In addition, Swaidner and Berra (1979) found maximum yearly water temperatures to remain ≤19.5C in the stretch of Green Creek below Beaver Creek springs, while temperatures could reach 22C above Beaver Creek Spring (which is referred to in the Ohio WQS as Beaver Creek). While the biological communities of Green Creek may not be typical CWH assemblages, the significant cold water contribution of Beaver Creek spring into Green Creek combined with the biological communities present indicate that the CWH, native fauna aquatic life use designation is appropriate in Green Creek from Beaver Creek spring to State Route 20. Downstream of State Route 20, the appropriate aquatic life use designation is WWH and extends to the confluence with Lake Erie. Biological species representative of CWH aquatic life use were absent from samples collected downstream of State Route 20.

- The aquatic life use designation of Beaver Creek should be changed from CWH to WWH based upon biological sampling results in 2009. Historically, Beaver Creek was listed with the CWH aquatic life use designation without biological sampling. Biological sampling of Beaver Creek demonstrated a WWH community from the confluence with Westerhouse Ditch to its confluence with Green Creek (which occurs at Beaver Creek spring). In addition, Swaidner and Berra (1979) found water temperatures to reach 22C in Beaver Creek, which they refer to as Green Creek above Beaver Creek spring. The remaining streams sampled within the study area should retain the associated designated aquatic life use.

- Little Pickerel Creek has an unverified CWH aquatic life use designation in the Ohio WQS. Sampling results from 2009 included the presence of 3 CWH macroinvertebrate taxa and 3 CWH fish species (rainbow trout, brown trout, and mottled sculpin). Contact with ODNR resulted in a determination that sampling had been conducted downstream of a small fish hatchery licensed to raise brown trout and rainbow trout, among other fish species (copy of permit is included in Appendix K). In addition, Rockwell Springs Trout Club is licensed to raise trout and release them on their property adjacent to Little Pickerel Creek (see Appendix K). The presence of a hatchery in addition to a trout club indicates that the "CWH, inland trout streams" is the most appropriate aquatic life use designation for Little Pickerel Creek.

The remaining streams in this study should retain the Primary Contact Recreation use, or Secondary Contact Recreation use, along with the Agricultural Water Supply and Industrial Water Supply uses.

Table 17. Waterbody use designation recommendations for the Sandusky Bay tributaries study area. The entire Use Designation Table of streams within the Sandusky River basin is not included in this table; only the pages containing streams within the study area are contained in this table. The complete Use Designation Table for streams within the Sandusky River basin is available at: http://www.epa.ohio.gov/dsw/rules/3745_1.aspx . Designations based on the 1978 and 1985 water quality standards appear as asterisks (*). A plus sign (+) indicates a new recommendation or confirmation of an existing 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	
Muddy creek		+							+*	+*		+		
Little Muddy creek		+*							+*	+*		+*		
Fishing Creek		Δ+							Δ+	Δ+		Δ+		
Gries ditch		+							+	+			+	
North branch		+							*	*		*		
South branch		+							*	*		*		
Sandusky river - at RMs 18.02, 41.08, 82.9, 83.15 and 115.45		+						o	+	+		+		PWS intakes - Fremont (RM 18.02), Tiffin (RM 41.08), Upper Sandusky (RMs 82.9 and 83.15), and Bucyrus (RM 115.45)
- Fremont STP (RM 13.85) to Muskellunge creek (RM 9.37)		+o							+*	+*		+*		
- Ella st. dam (RM 42.1) to RM 19.0 (upstream from Fremont)		+							+	+		+		
- RM 45.0 to Ella st. dam (RM 42.1)				+					+	+		+		ECBP ecoregion - impounded
- headwaters to RM 45.0		+							+	+		+		
- all other segments		*							*	*		*		
Yellow slough		*							*	*		*		
Green creek - confluence with Beaver creek to State Route 20						+*			+*	+*		+*		Native fauna
- State Route 20 to confluence with Lake Erie		+*							+*	+*		+*		
Flag run		*							*	*		*		
Beaver creek - confluence with Westerhouse ditch (RM 4.73) to confluence with Green Creek		Δ+				*			+*	+*		+*		

Table 17. Waterbody use designation recommendations for the Sandusky Bay tributaries study area. The entire Use Designation Table of streams within the Sandusky River basin is not included in this table; only the pages containing streams within the study area are contained in this table. The complete Use Designation Table for streams within the Sandusky River basin is available at: http://www.epa.ohio.gov/dsw/rules/3745_1.aspx . Designations based on the 1978 and 1985 water quality standards appear as asterisks (*). A plus sign (+) indicates a new recommendation or confirmation of an existing use based on the findings of this report.

Water Body Segment	SRW	Aquatic Life Habitat WWH	Aquatic Life Habitat EWH	Aquatic Life Habitat MWH	Aquatic Life Habitat SSH	Aquatic Life Habitat CWH	Aquatic Life Habitat LRW	Water Supply PWS	Water Supply AWS	Water Supply IWS	Recreation BW	Recreation PCR	Recreation SCR	Comments
- at RM 2.88		Δ+				*		o	+*	+*		+*		PWS intake - Clyde
Owl creek		*							*	*		*		
Westerhouse ditch		+*							+*	+*		+*		
Albright ditch		*							*	*		*		
Noel ditch		*							*	*		*		
Emerson creek		+*							+*	+*		+*		
Royer ditch		+*							+*	+*		+*		
Bark creek		+*							+*	+*		+*		
Muskellunge creek		+*							+*	+*		+*		
Indian creek		*							*	*		*		
Wolf creek		*							*	*		*		
East branch		*							*	*		*		
Snuff creek		*							*	*		*		
East branch		*							*	*		*		
Middle branch		*							*	*		*		
John Smith ditch (East branch Wolf cr. RM 20.37)							+		*	*			+	Small drainageway maintenance
Michael Gruss ditch (John Smith ditch RM 3.97)							+		*	*			+	Small drainageway maintenance.

Table 17. Waterbody use designation recommendations for the Sandusky Bay tributaries study area. The entire Use Designation Table of streams within the Sandusky River basin is not included in this table; only the pages containing streams within the study area are contained in this table. The complete Use Designation Table for streams within the Sandusky River basin is available at: http://www.epa.ohio.gov/dsw/rules/3745_1.aspx . Designations based on the 1978 and 1985 water quality standards appear as asterisks (*). A plus sign (+) indicates a new recommendation or confirmation of an existing 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	
Sugar creek		*							*	*		*		
Spicer creek		*							*	*		*		
Morrison creek		*							*	*		*		
Rock run		+							+	+		+		
South creek		+*							+*	+*		+*		
Raccoon creek - headwaters to U.S. rte. 6 (RM 3.1)		+							+	+		Δ+	+	
- at RM 13.1		+						+	+	+		Δ+	+	PWS intake - Clyde
- Clyde community park pond		+							+	+		+		
- RM 3.1 to mouth		+							+	+		+		
Little Raccoon creek		+							+	+			+	
Buck Creek		Δ+							Δ+	Δ+		Δ+		
Pickerel creek		+							+	+		+*		
Strong creek		*							*	*		*		
Fuller creek		*							*	*		*		
Little Pickerel creek						*			+*	+*		+*		Inland trout streams
Cold creek and tributaries - Blue Hole to confluence with Lake Erie						+*			+*	+*		+*		Inland trout streams
- all other segments		*							*	*		*		
Mills creek		+*							+*	+*		Δ+	*	

Table 17. Waterbody use designation recommendations for the Sandusky Bay tributaries study area. The entire Use Designation Table of streams within the Sandusky River basin is not included in this table; only the pages containing streams within the study area are contained in this table. The complete Use Designation Table for streams within the Sandusky River basin is available at: http://www.epa.ohio.gov/dsw/rules/3745_1.aspx . Designations based on the 1978 and 1985 water quality standards appear as asterisks (*). A plus sign (+) indicates a new recommendation or confirmation of an existing 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	
Caswell ditch		+							+	+		Δ+	+	
Snyders ditch - at RMs 5.0 and 5.5				+				o	+	+			+	HELP ecoregion - channel modification; PWS intakes - Bellevue.
- all other segments				+					+	+			+	HELP ecoregion - channel modification.
Pipe creek		+*							+*	+*		+*		
Plum brook		*							*	*		*		

Table 18. Waterbody use designation recommendations for Sawmill Creek within the Huron River basin. Sawmill Creek was the only stream from the Huron River basin included within the Sandusky Bay tributaries study area. Designations based on the 1978 and 1985 water quality standards appear as asterisks (*). A plus sign (+) indicates a new recommendation or confirmation of an existing 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	
Sawmill Creek		+*							+*	+*		+*		

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