June 2011

Ohio Environmental Protection Agency

Division of Surface Water

Biological and Water Quality Study of the Killbuck Creek Watershed, 2009

Medina, Wayne, Holmes and Coshocton Counties, Ohio

John R. Kasich, Governor
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EAS/2011-1-4

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June 20, 2011
OHIO EPA Technical Report EAS/2011-1-4

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INTRODUCTION

Rivers and streams in Ohio support a variety of uses such as recreation, water supply, and aquatic life. Ohio EPA evaluates each stream to determine the appropriate use designation and to also determine if the use is meeting the goals of the federal Clean Water Act. Ambient biological, water column chemical, and sediment sampling occurred in the Killbuck Creek study area from June through October, 2009. The Killbuck Creek watershed is located in northeast Ohio with its headwaters originating in Medina and Wayne Counties and flows generally south past the communities of Wooster, Millersburg and Killbuck before flowing into the Walhonding River. A list of the mainstem and tributary sites evaluated in this study are included in Table 1.

Objectives of the study were to:

1) Monitor and assess the chemical, physical and biological integrity of the water bodies within the Killbuck Creek study area;

2) Assess the physical habitat conditions in streams listed in the study plan to identify their potential to support aquatic biological communities;

3) Characterize the amount of aquatic resource degradation attributable to point sources and various land uses including agricultural practices, rural development, urban and suburban community development; and

4) Evaluate the appropriateness of existing beneficial use designations and assign uses to undesignated streams.

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

Table 1. Sampling locations for the Killbuck Creek study area, 2009. **M** - macroinvertebrate quantitative sample, M - macroinvertebrate qualitative sample, **F** - fish sample (2 passes), F - fish sample (1 pass), C - conventional water chemistry parameters (4-19 runs), B - bacteria (5-18 runs), S - sediment sample (conventional and organics), D - Datasonde© monitor, O - organic water chemistry (1 run). Latitude/longitude coordinates are provided in decimal degrees.

Stream* RM	**Sample Type**	**Lat/Long (DD)**	**Location**	**USGS Quad**
Killbuck Creek				
75.74	C,F,M	40.951600/-81.937800	Canaan Center Road	Creston
72.81	C,F,M	40.974700/-81.911700	Britton Road	Creston
70.82	C,**F**,M,D,B	40.988686/-81.939139	Canaan Center Road	Creston
66.85	C,**F**,M,D,B	40.989972/-81.994778	SR 83	Creston
64.4	C,**M**,D	40.974400/-82.027500	Britton Road	West Salem
59.66	C,**F**,B	40.910800/-82.009200	Pleasant Home Road	West Salem
55.35	C,**F**,**M**,D,B	40.850600/-82.004400	McAfee Road	New Pittsburg
49.95	C,**F**,**M**,S,D,B	40.786164/-81.952014	Upstream Wooster WWTP	Wooster
49.4	C,**F**,**M**,D,B	40.778600/-81.952100	Downstream Apple Creek	Wooster
46.02	C,**F**,**M**,D,B	40.733300/-81.972800	Valley Road	Holmesville
40.05	C,B	40.664400/-81.954700	C 1	Holmesville
37.13	C,**F**,**M**,D,B	40.625000/-81.935600	C 320	Holmesville
35.57	C,**F**,**M**,S,O,D	40.606100/-81.922800	T 346	Millersburg
31.76	C,**F**,**M**,D,B	40.555400/-81.922400	Clinton Avenue	Millersburg
28.93	C,**F**,**M**,D	40.516400/-81.932500	T 92	Millersburg
24.9	C,**F**,**M**,D	40.495000/-81.986400	C 621	Killbuck
23.91	C,**F**,**M**,D,B	40.481400/-81.986100	US 62	Killbuck
20.7	C,**F**,**M**,D,B	40.449400/-81.967800	SR 60, adjacent T 499	Killbuck
13.28	C,**F**,**M**,D,B	40.392800/-81.943300	T 25	Killbuck
2.1	C,**F**,**M**	40.345000/-81.948900	Adjacent C 24	Randle
Camel Creek				
3.76	C,**F**,**M**,S,O,	41.026900/-81.952800	Greenwich Road	Westfield Center
0.52	C,F,M,D	40.995100/-81.941400	Westfield Road	Creston
Repp Run				
0.9	C,F,M,D	40.998799/-82.036124	Franchester Road	West Salem
Cedar Run				
1.45	C,F,M,S	40.873200/-82.024100	Rice Hill Road	New Pittsburg
Little Killbuck Creek				
6.55	C,F,M	40.855300/-82.066400	Smithville Western Road	New Pittsburg
0.55	C,**F**,**M**,S,O,D,B	40.816900/-81.992500	SR 302	Wooster
Rathburn Run				
2.5	C,F,M	40.825500/-82.041400	Adjacent Lehr Road	New Pittsburg
Clear Creek				
3.71	C,F,M	40.843700/-81.969800	Mechanicsburg Road	Wooster
1.08	C,F,M,D	40.813300/-81.968800	Silver Road	Wooster
Apple Creek				
10.51	C,M,D	40.737600/-81.824200	Criswell Road	Fredericksburg
8.3	C,F,M	40.757950/-81.853600	Barnard Road	Orrville
6.28	C,**F**,**M**,S,O,D	40.777100/-81.872600	Ely Road	Orrville
1.95	C,**F**,**M**,B	40.796100/-81.919200	Pittsburg Road	Wooster
1.6	C,**F**,**M**	40.792800/-81.924200	From end of Freedlander Road	Wooster
0.6	C,**F**,**M**	40.788300/-81.941400	Spruce Road	Wooster

Stream RM*	Sample Type	Lat/Long (DD)	Location	USGS Quad
0.1	C,**F**,**M**,O,D,B	40.785300/-81.950000	Old Columbus Avenue	Wooster
Little Apple Creek				
1.1	C,F,M	40.755500/-81.819000	Hackett Road	Orrville
Spring Run				
0.36	C,F,M	40.806500/-81.889600	Canal Road	Wooster
Little Apple Creek				
5.0	F	40.865000/-81.913900	Schellin Road	Wooster
4.45	C,F,M	40.857500/-81.917800	Smithville-Western Road	Wooster
1.7	C,F,M	40.816725/-81.919005	Portage Road	Wooster
0.2	C,F,M,B	40.807200/-81.916100	Bowman Street	Wooster
Tributary to Killbuck Creek @ RM 43.60 (Millbrook trib.)				
2.68	C,F,M	40.727800/-82.014800	Kister Road	Shreve
Shreve Creek				
3.06	C,F,M,D,B	40.696100/-82.005000	Shreve Eastern Road	Shreve
Salt Creek				
8.5	C,F,M	40.674500/-81.833900	Salt Creek Road	Fredericksburg
5.07	C,**F**,**M**,D	40.668500/-81.874700	Holmesville Road	Fredericksburg
3.02	C,**F**,**M**,D,B	40.645097/-81.888375	C 192	Holmesville
0.8	C,**F**,**M**,D	40.635300/-81.924400	SR 83	Holmesville
North Branch Salt Creek				
3.29	C,F,M,D,B	40.711281/-81.872078	Moreland Road	Fredericksburg
Paint Creek				
8.68	C,F,M	40.600400/-82.059800	C 51	Glenmont
5.27	C,F,M,B	40.589200/-82.011700	T 262	Glenmont
1.84	C,F,M,D,B	40.608900/-81.958900	T 556	Millersburg
Tributary to Paint Creek @ RM 3.01				
1.5	C,F,M,D	40.606500/-81.996200	T 525	Millersburg
Martins Creek				
3.5	C,F,M,D,B	40.612800/-81.868100	T 601	Berlin
Honey Run				
1.03	C,F,M	40.578100/-81.907500	T 332	Millersburg
Sapps Run				
0.63	C,F,M	40.555433/-81.929911	C 349	Millersburg
Corns Run				
1.5	C,F,M	40.570500/-81.970300	SR 39	Millersburg
0.6	C,F,M,D	40.563900/-81.955000	C 400	Millersburg
Bear Run				
0.8	C,F,M	40.560300/-81.967500	C 400	Millersburg
Sand Run				
0.29	C,F,M	40.532600/-81.915600	US 62 / SR 83	Millersburg
Shrimplin Creek				
2.86	C,F,M	40.533200/-82.015200	T 252	Glenmont
Black Creek				
9.75	C,F,M	40.541353/-82.126983	T 225	Greer
4.58	C,F,M,D,B	40.505000/-82.055600	T 31	Glenmont
Tributary to Black Creek @ RM 7.35				
0.66	C,F,M	40.510800/-82.108300	T 14	Glenmont
Wolf Creek				
4.07	C,F,M	40.476900/-82.052800	T 31	Spring Mountain
2.08	C,F,M,B	40.478300/-82.016100	T 78	Spring Mountain

Stream* RM	**Sample Type**	**Lat/Long (DD)**	**Location**	**USGS Quad**
Tributary to Wolf Creek @ RM 6.49				
1.36	C,F,M	40.443600/-82.103400	C 452	Spring Mountain
Big Run				
3.55	C,F,M	40.430100/-82.009600	T 330	Spring Mountain
Doughty Creek				
18.74	C,F,M	40.564800/-81.813500	T 359	Berlin
15.9	C,**F**,**M**,S,O,D	40.535400/-81.807600	C 120	Berlin
14.64	C,F,M,D	40.521700/-81.804700	T 355	Berlin
14.29	C,F,M,D,B	40.517400/-81.804800	T 123	Berlin
11.7	C,F,M,D	40.487200/-81.815300	C 19	New Bedford
4.89	C,**F**,**M**,D,B	40.452069/-81.901514	SR 83	Killbuck
0.63	C,**F**,**M**,S,O,D	40.416700/-81.942200	C 343	Killbuck
Tributary to Doughty Creek @ RM 14.34 (Charm trib.)				
1.35	C,M,B	40.505600/-81.784500	T 156	Berlin
0.6	C,F,M,D,B	40.512800/-81.795800	SR 557	Berlin
Tributary to Tributary to Doughty Creek @ RM 14.34, 1.35				
0.01	C,B	40.506186/-81.783916	Upstream mouth	Berlin
Military Run				
0.9	C,F,M	40.485800/-81.855300	C 58	New Bedford
Bucklew Run				
1.45	C,F,M	40.345900/-81.925600	T 413	Randle

* RM = River Mile of the sample. The RM in this table is for the chemistry sampling, the biological samples and Datasonde© monitors may have been conducted a few tenths of a mile upstream or downstream.

METHODS

All physical, chemical, and biological field, laboratory, data processing, and data analysis methodologies and procedures adhere to those specified in the Ohio EPA Manual of Surveillance Methods and Quality Assurance Practices, Updated Edition (Ohio Environmental Protection Agency 2009) and Biological Criteria for the Protection of Aquatic Life, Volumes I-III (Ohio Environmental Protection Agency 1987a, 1987b, 1989a, 1989b, 2008a, 2008b), The Qualitative Habitat Evaluation Index (QHEI): Rationale, Methods, and Application (Ohio EPA 2006, Rankin 1989, 1995) for aquatic habitat assessment, and the Ohio EPA Sediment Sampling Guide and Methodologies (Ohio EPA 2001). Sampling locations are listed in Table 1.

Determining Use Attainment Status

Use attainment status is a term describing the degree to which environmental indicators are either above or below criteria specified by the Ohio Water Quality Standards (WQS; Ohio Administrative Code 3745-1). Assessing aquatic use attainment status involves a primary reliance on the Ohio EPA biological criteria (OAC 3745-1-07; Table 7-15). These are confined to ambient assessments and apply to rivers and streams outside of mixing zones. Numerical biological criteria are based on multimetric biological indices including the IBI and MIwb, indices measuring the response of the fish community, and the ICI, which indicates the response of the macroinvertebrate community. Three attainment status results are possible at each sampling location - full, partial, or non-attainment. Full attainment means that all of the applicable indices meet the biocriteria. Partial attainment means that one or more of the applicable indices fails to meet the biocriteria. Non-attainment means that none of the applicable indices meet the biocriteria or one of the organism groups reflects poor or very poor performance. An aquatic life use attainment table (Table 2) is constructed based on the sampling results and is arranged from upstream to downstream and includes the sampling locations indicated by river mile, the applicable biological indices, the use attainment status (*i.e.,* full, partial, or non), the Qualitative Habitat Evaluation Index (QHEI), and a sampling location description.

Habitat Assessment

Physical habitat was evaluated using the QHEI developed by the Ohio EPA for streams and rivers in Ohio (Ohio EPA 2006, Rankin 1989, 1995). Various attributes of the habitat are scored based on the overall importance of each to the maintenance of viable, diverse, and functional aquatic faunas. The type(s) and quality of substrates, amount and quality of instream cover, channel morphology, extent and quality of riparian vegetation, pool, run, and riffle development and quality, and gradient are some of the habitat characteristics used to determine the QHEI score which generally ranges from 20 to less than 100. The QHEI is used to evaluate the characteristics of a stream segment, as opposed to the characteristics of a single sampling site. As such, individual sites may have poorer physical habitat due to a localized disturbance yet still support aquatic communities closely resembling those sampled at adjacent sites with better habitat, provided water quality conditions are similar. QHEI scores from hundreds of segments around the state have indicated that values greater than 60 are *generally* conducive to the existence of warmwater faunas whereas scores less than 45

generally cannot support a warmwater assemblage consistent with the WWH biological criteria. Scores greater than 75 frequently reflect habitat conditions which have the ability to support exceptional warmwater faunas.

Sediment and Surface Water Assessment

Fine grain sediment samples were collected in the upper 4 inches of bottom material at each location using decontaminated stainless steel scoops and excavated using nitrile gloves. Decontamination of sediment sampling equipment followed the procedures outlined in the Ohio EPA sediment sampling guidance manual (Ohio EPA 2001). Sediment grab samples were homogenized in stainless steel pans (material for VOC analysis was not homogenized), transferred into glass jars with teflon® lined lids, placed on ice (to maintain 4°C) in a cooler, and shipped to the Ohio EPA DES lab. Sediment data is reported on a dry weight basis. Surface water samples were collected, preserved and delivered in appropriate containers to either an Ohio EPA contract lab or the Ohio EPA Division of Environmental Services. Surface water samples were evaluated using comparisons to Ohio Water Quality Standards criteria, reference conditions as outlined in the Associations document (Ohio EPA 1999), or published literature. Sediment evaluations were conducted using guidelines established in MacDonald *et al.* (2000) and Ohio Sediment Reference Values (Ohio EPA 2008).

Recreational Use Assessment

Support of the recreation use was assessed using *E. coli* bacteria as the indicator organism. Its presence indicates that the water has been contaminated with feces from warm blooded animals. Bacteria counts are reported in colony forming units (cfu)/100 ml. To determine if the recreation use criterion of a site is being attained, the geometric mean bacteria concentration for each site under evaluation is compared to the applicable geometric mean bacteria criterion codified in OAC 3745-1-07. The geometric mean of a site is based upon the collection of data from multiple grab samples (typically five to ten samples) collected at the site over the course of the recreation season (May 1st through October 31st). The applicable *E. coli* criteria are 126 cfu/100 ml for waters designated as bathing waters or primary contact class A, 161 cfu/100 ml for waters designated as primary contact class B, 206 cfu/100 ml for waters designated as primary contact class C, and 1,030 cfu/100 ml for waters designated as secondary contact.

Macroinvertebrate Community Assessment

Macroinvertebrates were collected from artificial substrates and from the natural habitats. The artificial substrate collection provided quantitative data and consisted of a composite sample of five modified Hester-Dendy multiple-plate samplers colonized for six weeks. At the time of the artificial substrate collection, a qualitative multihabitat composite sample was also collected. This sampling effort consisted of an inventory of all observed macroinvertebrate taxa from the natural habitats at each site with no attempt to quantify populations other than notations on the predominance of specific taxa or taxa groups within major macrohabitat types (e.g., riffle, run, pool, margin). Stations with insufficient flow to place artificial substrates or where the artificial substrates were missing were only sampled qualitatively from the natural substrates. These stations were evaluated and assigned a narrative evaluation based on community attributes such as EPT (Ephemeroptera – mayfly, Plecoptera – stonefly, and

Trichoptera – caddisfly) diversity and predominance, sensitive taxa (ST) diversity and predominance, and tolerant taxa predominance. Detailed discussion of macroinvertebrate field and laboratory procedures is contained in Biological Criteria for the Protection of Aquatic Life: Volume III, Standardized Biological Field Sampling and Laboratory Methods for Assessing Fish and Macroinvertebrate Communities (Ohio EPA 1989b) and 2008 updates to Biological Criteria for the Protection of Aquatic Life: Volume III. Standardized biological field sampling and laboratory methods for assessing fish and macroinvertebrate communities (Ohio EPA 2008b).

Fish Community Assessment

Fish were sampled using pulsed DC electrofishing methods. Fish were processed in the field, and included identifying each individual to species, counting, weighing, and recording any external abnormalities. Discussion of the fish community assessment methodology used in this report is contained in Biological Criteria for the Protection of Aquatic Life: Volume III, Standardized Biological Field Sampling and Laboratory Methods for Assessing Fish and Macroinvertebrate Communities (Ohio EPA 1989b) and 2008 updates to Biological Criteria for the Protection of Aquatic Life: Volume III. Standardized biological field sampling and laboratory methods for assessing fish and macroinvertebrate communities (Ohio EPA 2008b).

Causal Associations

Using the results, conclusions, and recommendations of this report requires an understanding of the methodology used to determine the use attainment status and assigning probable causes and sources of impairment. The identification of impairment in rivers and streams is straightforward - the numerical biological criteria are used to judge aquatic life use attainment and impairment (partial and non-attainment). The rationale for using the biological criteria, within a weight of evidence framework, has been extensively discussed elsewhere (Karr *et al.* 1986; Karr 1991; Ohio EPA 1987a,b; Yoder 1989; Miner and Borton 1991; Yoder 1991; Yoder 1995). Describing the causes and sources associated with observed impairments relies on an interpretation of multiple lines of evidence including water chemistry data, sediment data, habitat data, effluent data, land use data, and biological results (Yoder and Rankin 1995). Thus the assignment of principal causes and sources of impairment in this report represent the association of impairments (based on response indicators) with stressor and exposure indicators. The reliability of the identification of probable causes and sources is increased where many such prior associations have been identified, or have been experimentally or statistically linked together. The ultimate measure of success in water resource management is the restoration of lost or damaged ecosystem attributes including aquatic community structure and function. While there have been criticisms of misapplying the metaphor of ecosystem “health” compared to human patient “health” (Suter 1993), in this document we are referring to the process for evaluating biological integrity and causes or sources associated with observed impairments, not whether human health and ecosystem health are analogous concepts.

SUMMARY

A summary of monitoring results, attainment status for current or recommended aquatic life uses, and causes and sources of impairment to attainment in the Killbuck Creek study area can be found in Table 2. Biological, physical habitat, and surface water chemistry information was collected from 78 stations in 33 streams in the Killbuck Creek watershed. Of these, 60 were fully attaining (81%) their existing or recommended aquatic life use, 10 were partially attaining (14%), and four were not attaining (5%) (Figure 1). Four stations were sampled only with qualitative macroinvertebrate methods and did not receive a use attainment status.

Three state listed fish species were found during this study. The river redhorse (*Moxostoma carinatum* – Species of Concern) was found at seven stations in Killbuck Creek from RM 37.1 to 2.1, the bluebreast darter (*Etheostoma camurum* – Treatened) was found in Killbuck Creek at RM 2.1, and the eastern sand darter (*Ammocrypta pellucid* – Species of Concern) was found in Killbuck Creek at RMs 32.0 and 13.3 and Doughty Creek at RM 4.9. The state endangered caddisfly *Brachycentrus numerosus* was found in Killbuck Creek at RMs 23.9, 13.3 and 1.7. Nine state listed freshwater mussels were found in Killbuck Creek by Hoggarth et al. (1995) and Hoggarth (1997) including the state and federally endangered purple catspaw (*Epioblasma obliquata obliquata*). The other state listed freshwater mussels were the elktoe (*Alasmidonta marginata* – Species of Concern), purple wartyback (*Cyclonaias tuberculata* – Species of Concern), snuffbox (*Epioblasma triquetra* – Endangered), sharp-ridged pocketbook (*Lampsilis ovate* - Endangered), creek heelsplitter (*Lasmigona compressa* – Species of Concern), black sandshell (*Ligumia recta* – Threatened), round pigtoe (*Pleurobema sintoxia* – Species of Concern), and kidneyshell (*Ptychobranchus fasciolaris* – Species of Concern).

Killbuck Creek Mainstem

Biological communities were sampled from 19 stations on the Killbuck Creek mainstem. All of the stations were fully attaining the Warmwater Habitat (WWH) use with the exception of two stations where the fish communities were underperforming.

The sample at SR 83 in Burbank (RM 66.9) was located in a bedrock reach, and therefore lacked sufficient depth for large fishes. Consequently, the Modified Index of Well-being (MIwb), an index that rewards biomass, narrowly missed the criterion.

Fish index scores for samples collected at the Valley Road site (RM 46.0), within a highly channelized stream channel (QHEI=54.5), have historically failed to meet the biocriteria due to industrial and municipal wastewater loadings from Wooster, and the influence of adjacent wetlands on dissolved oxygen. However, compared to 1983 and 1993, the scores in 2009 improved, especially with respect to the MIwb, and especially compared to 1983, when the MIwb and IBI scored in the poor range. However, compared to similar reaches sampled further downstream, the fish community at Valley Road underperformed the available habitat, and was skewed compositionally toward tolerant and omnivorous fishes. Water chemistry results found low dissolved oxygen concentrations at this station, as low as 0.51 mg/l with an average of 3.03 mg/l during a

48 hr Datasonde® deployment picked up on 20 August 2009. To date, the Wooster WWTP has experienced significant problems operating the plant as designed. The plant had 454 violations in 2006, 528 in 2007, 258 in 2008, and 112 in 2009. In 2009, Ohio EPA proceeded with escalated enforcement against the City of Wooster. As a result, Wooster built an industrial wastewater trickle filter as a pre-treatment component, which went on-line in February 2011.

Killbuck Creek Tributaries from the Headwaters to above Apple Creek

Biological communities were sampled from 9 stations on 6 streams. All of the stations were fully attaining the WWH, Coldwater Habitat (CWH), or dual Exceptional Warmwater Habitat/Coldwater Habitat (EWH/CWH) uses with the exception of the fish community at one station. Underperformance of the fish community sampled in Camel Creek (RM 0.5) was attributed to excessive siltation. The biological communities in Cedar Run, Little Killbuck Creek, Rathburn Run and Clear Creek were supporting sufficient coldwater organisms to reclassify the streams as CWH or EWH/CWH.

Killbuck Creek Tributaries from above Apple Creek to below Salt Creek

Biological communities were sampled from 19 stations on 8 streams. Of these, 12 stations were fully attaining their designated or recommended aquatic life use. The biological communities in Spring Run and Tributary to Killbuck Creek @RM 43.60 (Millbrook Trib.) were supporting sufficient coldwater organisms to reclassify the streams as Coldwater Habitat.

Little Apple Creek flows through northwest Wooster with percent impervious cover of 7.4% at RM 4.5 and 12.9% at RM 1.7. The stream was relocated and straightened (from about RM 2.4 to mouth) when the SR 3/83 bypass was constructed, at which time five substantial grade control impoundments were constructed along its length. Two smaller structures that would also impede the migration of fish were located near the mouth. Biological communities were sampled at four stations on Little Apple Creek. The fish communities at all of these stations were not meeting WWH expectations as opposed to the three stations sampled for macroinvertebrates which were meeting WWH expectations. The degradation of the fish communities was attributed to the inability of fish to repopulate the stream after any kind of impairment event due to the seven impoundments on the stream. The stream was also potentially impacted by urban runoff and channelization.

The Tributary to Killbuck Creek @RM 43.60 (Millbrook Trib.) was sampled in the middle of a pasture where cattle had unrestricted access to the stream. High nitrate+nitrite-N concentrations (min.-max., med. of 3.61-4.51, 4.08 mg/l) may have been the major contributing factor to the impacted fish community (IBI=32) at this station.

The macroinvertebrate community in Shreve Creek (RM 3.1) was not meeting WWH expectations. Heavy silt cover, channelized stream channel, and nutrient enrichment were considered major contributing factors to the decline in biological integrity at this station. Evidence of nutrient enrichment included observed heavy algal growth and elevated nitrate+nitrate-N concentrations (min.-max., med. of 1.42-3.72, 3.38 mg/l) at

this station. The Shreve WWTP, which discharges its effluent about 0.3 miles upstream, is a likely contributor to the nutrient enrichment at this station.

North Branch Salt Creek (RM 3.3) was sampled in 2009 in an area that was channelized and had thick silt deposits. Both the fish (IBI=32) and macroinvertebrate (EPT=7, ST=8) communities were not meeting WWH expectations. The station was reevaluated in 2010 after streambed silt was removed from the highly channelized stream channel immediately downstream from Moreland Road. At that time, the fish community (IBI=42) had improved into the good range, but the macroinvertebrate community (EPT=10, ST=8) remained in the fair range. Continued heavy silt cover, low D.O. concentrations (48 hr Datasonde® min., ave. of 3.39, 4.79 mg/l picked up on 20 August 2009) and channelization at this station (QHEI=33.5) were considered major causes of impairment. This station was located downstream from a pasture with unrestricted cattle access.

Killbuck Creek Tributaries from below Salt Creek to below Black Creek

Biological communities were sampled from 13 stations on 10 streams. Of these, 11 stations were fully attaining their designated or recommended aquatic life use. The biological communities in Paint Creek, Tributary to Paint Creek @RM 3.01, Honey Run, Bear Run, Sand Run, Shrimplin Creek, Black Creek, and Tributary to Black Creek @RM 7.35 were supporting sufficient coldwater organisms to reclassify the streams as CWH or EWH/CWH.

Biological communities in Corns Run and Sapps Run were impaired by discharges from the Holmes Cheese WWTP which discharges to Corns Run at RM 1.1. Extremely high phosphorus-T (min.-max., med. of 39.5-83.6, 65.35 mg/l), low D.O. (2.43 mg/l), and elevated ammonia-N (0.272-1.39, 0.484 mg/l) and TDS (1320-1480, 1330 mg/l) concentrations were recorded downstream from the Holmes Cheese WWTP in Corns Run (RM 0.6). Phosphorus-T concentrations (1.81-4.31, 2.44 mg/l) remained high further downstream in Sapps Run (RM 0.8). In addition to nutrient enrichment, the Sapps Run station was stressed by low flows and the effects of past channelization (QHEI=47.0). The Holmes Cheese WWTP has been in significant noncompliance of its NPDES permit for effluent limit violations, compliance schedule violations, and the periodic discharges of sludge to Corns Run. Some of the highest in-stream phosphorus concentrations ever measured in the state were found downstream from the plant in Corns Run and Sapp's Run. As a result of the noncompliance issues, the facility has been referred to the Ohio Attorney General for enforcement actions. Holmes Cheese is currently constructing a new WWTP.

Killbuck Creek Tributaries from below Black Creek to the Walhonding River

Biological communities were sampled from 14 stations on 7 streams. Of these, 12 stations were fully attaining their designated or recommended aquatic life use. The biological communities in upper Wolf Creek and Tributary to Wolf Creek @RM 6.49 were supporting sufficient coldwater organisms to reclassify the streams as CWH or EWH/CWH.

The fish community (IBI=26) sampled in Doughty Creek at T-359 (RM 18.7) was limited by poor habitat (QHEI=48.5) from channelization and heavy silt cover. The fish community (IBI=26) sampled in the Tributary to Doughty Creek @RM 14.34 (Charm tributary) (RM 0.6) was limited by a combination of poor habitat (QHEI=51.5) and organic enrichment. Excessive algal growth and silt cover were observed at this station. D.O. concentrations as low as 3.03 mg/l were recorded by a Datasonde® continuous monitor deployed for 48 hr and picked up on 20 August 2009. This station is downstream from the unsewered community of Charm and a pasture where cows had unrestricted access to the stream.

Recreational Use Attainment

Bacteriological samples (*E. coli*) were collected from 31 stations in 13 streams in the Killbuck Creek watershed to evaluate attainment of their existing or recommended recreation use designations. All of the stations sampled were evaluated with the Class A (Killbuck Creek from RM 59.66 to 13.28) or Class B Primary Contact Recreation (PCR) use criteria. None of the sampled stations met the seasonal geometric mean criteria, indicating an impairment of the recreation use at these locations. In fact, eight stations had geometric means over the Secondary Contact Recreation (SCR) use criterion (1030 cfu/100 ml).

Stations with readily identified sources contributing to elevated bacteria counts were Martins Creek (RM 3.5) and North Branch Salt Creek (RM 3.29) which were downstream from pastures with unrestricted cattle access to the streams, Tributary to Doughty Creek @RM 14.34/1.35 (RM 0.01) which was within the unsewered community of Charm, Tributary to Doughty Creek @RM 14.34 (RM 0.6) which was downstream from the unsewered community of Charm and downstream from a pasture with unrestricted cattle access to the stream, and Doughty Creek (RM 14.29) which was downstream from the Tributary to Doughty Creek (@RM 14.34) and pastures with unrestricted horse access to the stream. In general, *E. coli* may be entering surface waters from sewage treatment plant effluent; overflows from combined sewer systems, which are usually associated with wet weather events; discharges by on-lot wastewater treatment systems; runoff from domestic livestock operations, especially if they have unrestricted access to the stream; or runoff of manure which was not properly applied to agricultural fields as fertilizer.

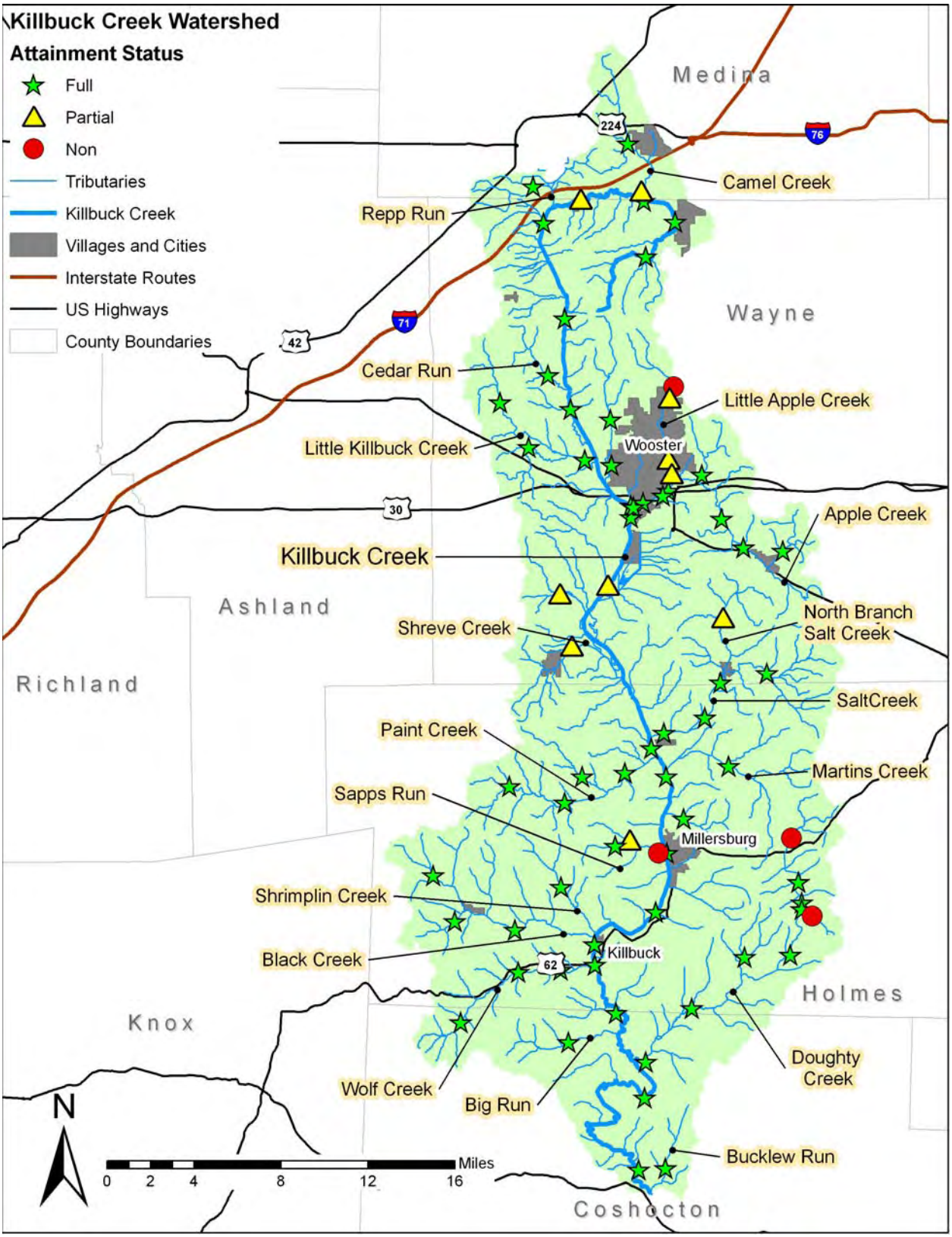


Figure 1. Map of the aquatic life use attainment status in the Killbuck Creek watershed, 2009.

Table 2. Aquatic life use attainment status for stations sampled in the Killbuck Creek 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) 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.

River Mile - Location	12 Digit HUC	IBI	MIwb[a]	ICI[b]	QHEI	Attainment Status[c]	Causes	Sources
HUC 0504000305 - Killbuck Creek (headwaters to above Apple Creek)								
Killbuck Creek (17-150) *Erie/Ontario Lake Plain Ecoregion – WWH Existing*								
75.7[H] – Canaan Center Rd.	01	58	NA	E	75.5	FULL		
72.8[H] – Britton Rd.	01	44	NA	E	59.0	FULL		
70.9[W] – Canaan Center Rd.	01	40	7.5[NS]	VG	57.5	FULL		
66.9[W] – SR 83	02	42	7.0*	G	59.0	PARTIAL	Natural Conditions	Natural Sources
64.4 – Britton Rd.	04	-	-	44	-	(FULL)		
60.5[W] – Pleasant Home Rd.	04	39[NS]	8.9	-	71.5	(FULL)		
54.3[W]/55.4 – McAfee Rd.	04	44	8.7	48	62.0	FULL		
49.9[B]/50.3 – SR 3	05	38[NS]	8.9	50	50.0	FULL		
HUC 0504000306 – Killbuck Creek (above Apple Creek to below Salt Creek)								
49.4[B] – dst. Apple Cr.	04	42	9.0	46	59.0	FULL		
46.0[B] – Valley Rd.	04	29*	8.3[NS]	44	54.5	PARTIAL	Direct Habitat Alterations, Dissolved Oxygen, Organic Enrichment	Channelization, Wooster WWTP, Natural Sources
HUC 0504000307 – Killbuck Creek (below Salt Creek to below Black Creek)								
37.1[B] – C 320	03	46	8.7	36	62.5	FULL		
35.6[B] – T 346	03	42	8.6[NS]	48	67.0	FULL		
Western Allegheny Plateau Ecoregion – WWH Existing								
32.0[B]/31.9 – Clinton Ave.	05	56	10.1	46	-	FULL		

River Mile - Location	12 Digit HUC	IBI	MIwb[a]	ICI[b]	QHEI	Attainment Status[c]	Causes	Sources
28.9[B] – T 92	05	50	9.5	46	65.0	FULL		
HUC 0504000308 – Killbuck Creek (below Black Creek to Walhonding River)								
24.9[B] – C 621	04	44	9.0	42	59.0	FULL		
23.9[B] – US 62	04	41	8.7	44	60.0	FULL		
20.7[B] – ust. SR 60, adj. T 499	04	41	8.4[NS]	38	58.0	FULL		
13.3[B] – T 25	05	47	9.2	44	67.0	FULL		
2.1[B]/1.7 – adj. C 24	05	50	9.6	52	75.0	FULL		
HUC 0504000305 - Killbuck Creek (headwaters to above Apple Creek)								
Camel Creek (17-190) *Erie/Ontario Lake Plain Ecoregion – WWH Existing*								
3.8[H] – Greenwich Rd.	02	48	NA	50	72.5	FULL		
0.5[H] – Westfield Rd.	02	34*	NA	G	58.0	PARTIAL	Sedimentation/Siltation	Channelization
Repp Run (17-189) *Erie/Ontario Lake Plain Ecoregion – WWH Existing*								
0.9[H] – Franchester Rd.	02	46	NA	VG	71.0	FULL		
Cedar Run (17-186) *Erie/Ontario Lake Plain Ecoregion – WWH Existing / CWH Recommended*								
1.5[H] – Rice Hill Rd.	04	44	NA	E	65.0	FULL		
Little Killbuck Creek (17-184) *Erie/Ontario Lake Plain Ecoregion – WWH Existing / CWH Recommended*								
6.5[H] – Smithville Western Rd.	03	48	NA	G	70.5	FULL		
0.5[W] – SR 302	03	43	8.4	50	54.5	FULL		
Rathburn Run (17-185) *Erie/Ontario Lake Plain Ecoregion – WWH Existing / CWH Recommended*								
2.5[H] – adj. Lehr Rd.	03	54	NA	MG[NS]	63.5	FULL		
Clear Creek (17-183) *Erie/Ontario Lake Plain Ecoregion – WWH Existing / EWH and CWH Recommended*								
3.7[H] – Mechanicsburg Rd.	05	50	NA	E	68.5	FULL		
1.1[H] – Silver Rd.	05	58	NA	E	71.5	FULL		

River Mile - Location	12 Digit HUC	IBI	MIwb[a]	ICI[b]	QHEI	Attainment Status[c]	Causes	Sources
HUC 0504000306 – Killbuck Creek (above Apple Creek to below Salt Creek)								
Apple Creek (17-181) *Erie/Ontario Lake Plain Ecoregion – WWH Existing*								
10.5 – Criswell Rd.	02	-	-	G	-			
8.3[H] – Barnard Rd.	02	38[NS]	NA	G	74.0	FULL		
6.3[W] – Ely Rd.	02	47	8.6	52	75.5	FULL		
2.0 – Pittsburgh Ave.	02	-	-	42	-	(FULL)		
1.6[W] – end of Sylvan Rd.	02	45	8.3	56	77.5	FULL		
0.6[W] – Spruce St.	02	43	8.5	50	65.5	FULL		
0.1[W] – Old Columbus Ave.	02	43	8.4	50	62.5	FULL		
Little Apple Creek (Trib. to Apple Cr. @ RM 9.79) (17-149 / 17-181-003) *EOLP Ecoregion* - Undesignated / WWH Recommended								
1.1[H] – Hackett Rd.	02	42	NA	G	59.0	FULL		
Spring Run (17-198 / 17-181-001) *Erie/Ontario Lake Plain Ecoregion* - Undesignated / CWH Recommended								
0.4[H] – Canal Rd.	02	48	NA	G	64.5	FULL		
Little Apple Creek (Tributary to Apple Creek @ RM 2.60) (17-182) *Erie/Ontario Lake Plain Ecoregion – WWH Existing*								
5.0[H] – Schellin Rd.	01	30*[d]	NA	-	75.0[d]	(**NON**)	Direct Habitat Alterations	Channelization, Dam or Impoundment
4.5[H] – Smithville-Western Rd.	01	28*	NA	G	67.5	PARTIAL	Direct Habitat Alterations	Channelization, Dam or Impoundment
1.7[H] – Portage Rd.	01	28*	NA	G	49.0	PARTIAL	Direct Habitat Alterations	Channelization, Dam or Impoundment, Urban Runoff/Storm Sewers
0.2[H] – ust. Bowman St.	01	34*[d]	NA	G	67.0[d]	PARTIAL	Direct Habitat Alterations	Channelization, Dam or Impoundment, Urban Runoff/Storm Sewers

River Mile - Location	12 Digit HUC	IBI	MIwb[a]	ICI[b]	QHEI	Attainment Status[c]	Causes	Sources
Trib. to Killbuck Creek @ RM 43.60 (Millbrook Trib.) (17-144 / 17-150-011) *EOLP Ecoregion* - Undesignated / CWH Recommended								
3.3[H]/2.7 – Kister Rd.	04	32*	NA	G	61.5	PARTIAL	Nitrate/Nitrite	Unrestricted Cattle Access
Shreve Creek (17-180) *Erie/Ontario Lake Plain Ecoregion – WWH Existing*								
3.1[H] – Shreve Eastern Rd.	03	36[NS]	NA	F*	53.0	PARTIAL	Sedimentation/Siltation Nitrate/Nitrite	Channelization, Shreve WWTP
Salt Creek (17-175) *Erie/Ontario Lake Plain Ecoregion – WWH Existing*								
8.5[H] – Salt Creek Rd.	06	42	NA	G	61.5	FULL		
5.0[W] – Holmesville Rd.	06	42	8.6	54	75.0	FULL		
3.0[W] – C 192	06	38[NS]	8.8	58	64.0	FULL		
0.7[W] – SR 83	06	38[NS]	8.0	54	53.5	FULL		
North Branch Salt Creek (17-176) *Erie/Ontario Lake Plain Ecoregion – WWH Existing*								
3.3[H] – Moreland Rd.	05	42[d]	NA	F*[d]	33.5[d]	PARTIAL	Dissolved Oxygen, Sedimentation/Siltation	Unrestricted Cattle Access, Channelization
HUC 0504000307 – Killbuck Creek (below Salt Creek to below Black Creek)								
Paint Creek (17-173) *Erie/Ontario Lake Plain Ecoregion – EWH Existing / CWH Recommended*								
8.7[H] – C 51	01	40	NA	E	68.5	FULL		
5.3[H] – T 262	01	48	NA	E	67.0	FULL		
1.6[W] – T 556	01	40	8.8	E	70.5	FULL		
Trib. to Paint Creek @ RM 3.01 (17-148 / 17-173-001) *EOLP Ecoregion* - Undesignated / EWH and CWH Recommended								
1.5[H] – T 525	01	50	NA	E	71.5	FULL		
Martins Creek (17-172) *Erie/Ontario Lake Plain Ecoregion – WWH Existing*								
3.5[H] – T 601	02	40	NA	G	59.5	FULL		
Honey Run (17-170) *Erie/Ontario Lake Plain Ecoregion – WWH Existing / CWH Recommended*								
1.0[H] – T 332	03	46	NA	G	60.5	FULL		

River Mile - Location	12 Digit HUC	IBI	MIwb[a]	ICI[b]	QHEI	Attainment Status[c]	Causes	Sources
Sapps Run (17-166) *Western Allegheny Plateau Ecoregion – WWH Existing*								
0.8[H] – C 349	05	28*	NA	F*	47.0	**NON**	Direct Habitat Alterations, Phosphorus (Total)	Channelization, Holmes Cheese WWTP
Corns Run (17-169) *Western Allegheny Plateau Ecoregion – WWH Existing*								
1.5 – SR 39	05	-	-	G	-	-		
0.6[H]/0.7 – C 400	05	42[NS]	NA	F*	61.0	PARTIAL	Dissolved Oxygen, Ammonia (Total), Total Dissolved Solids, Phosphorus (Total)	Holmes Cheese WWTP
Bear Run (17-168) *Western Allegheny Plateau Ecoregion – WWH Existing / CWH Recommended*								
0.8[H] – C 400	05	36	NA	VG	55.5	FULL		
Sand Run (17-164) *Western Allegheny Plateau Ecoregion – WWH Existing / CWH Recommended*								
0.4 – US 62/SR 83	05	-	-	E	-	-		
Shrimplin Creek (17-162) *Western Allegheny Plateau Ecoregion – WWH Existing / EWH and CWH Recommended*								
2.9[H] – T 252	05	54	NA	E	76.0	FULL		
Black Creek (17-161) *Western Allegheny Plateau Ecoregion – WWH Existing / CWH Recommended*								
9.8[H] – T 225	04	54	NA	E	73.0	FULL		
4.6[W] – T 31	04	40	7.7	E	69.0	FULL		
Trib. to Black Creek @ RM 7.35 (17-147 / 17-161-001) *WAP Ecoregion – Undesignated / CWH Recommended*								
0.7[H] – T 14	04	48	NA	E	70.5	FULL		
HUC 0504000308 – Killbuck Creek (below Black Creek to Walhonding River)								
Wolf Creek (17-160) *Western Allegheny Plateau Ecoregion – WWH Existing / EWH and CWH Recommended*								
4.1[H] – T 31	01	52	NA	E	61.5	FULL		
Western Allegheny Plateau Ecoregion – WWH Existing								

River Mile - Location	12 Digit HUC	IBI	MIwb[a]	ICI[b]	QHEI	Attainment Status[c]	Causes	Sources
2.5[H]/2.1 – T 76 / T 78	01	44	NA	VG	62.0	FULL		
Tributary to Wolf Creek @ RM 6.49 (17-146 / 17-160-001) *WAP Ecoregion - Undesignated / EWH and CWH Recommended*								
1.4[H] – C 452	01	58	NA	E	62.0	FULL		
Big Run (17-157) *Western Allegheny Plateau Ecoregion – EWH Existing*								
3.6[H] – T 330	04	50	NA	E	53.5	FULL		
Doughty Creek (17-153) *Western Allegheny Plateau Ecoregion – WWH Existing*								
18.7[H] – T 359	02	26*	NA	MG[NS]	48.5	**NON**	Sedimentation/Siltation	Channelization
15.9[H] – C 120	02	50	NA	46	68.0	FULL		
14.7[H] – T 355	02	48	NA	G	63.0	FULL		
14.3[H] – T 123	02	46	NA	MG[NS]	55.5	FULL		
11.7[H] – C 19	02	42	NA	G	53.5	FULL		
4.9[W] – SR 83	03	50	9.4	52	63.0	FULL		
0.6[W] – C 343	03	48	9.3	48	58.0	FULL		
Tributary to Doughty Creek @ RM 14.34 (Charm Trib.) (17-138 / 17-153-001) *WAP Ecoregion* – Undesignated / WWH Recommended								
1.4 – T 156	02	-	-	F*	-	-		
0.6[H] – SR 557	02	26*	NA	MG[NS]	51.5	**NON**	Dissolved Oxygen, Sedimentation/Siltation	Unrestricted Cattle Access, Sewage Discharges in Unsewered Areas
Military Run (17-155) *Western Allegheny Plateau Ecoregion – WWH Existing*								
0.8[H] – C 58	02	50	NA	G	55.5	FULL		
Bucklew Run (17-151) *Western Allegheny Plateau Ecoregion – EWH Existing / WWH Recommended*								
1.5[H] – T 413	05	48	NA	G	65.5	FULL		

Ecoregion Biocriteria

	IBI			MIwb			ICI		
				Erie/Ontario Lake Plain Ecoregion					
Site Type	WWH	EWH	MWH	WWH	EWH	MWH	WWH	EWH	MWH
Headwaters	40	50	24	-	-	-	34	46	22
Wading	38	50	24	7.9	9.4	6.2	34	46	22
Boat	40	48	24	8.7	9.6	5.8	34	46	22
				Western Allegheny Plateau Ecoregion					
Site Type	WWH	EWH	MWH	WWH	EWH	MWH	WWH	EWH	MWH
Headwaters	44	50	24	-	-	-	36	46	22
Wading	44	50	24	8.4	9.4	6.2	36	46	22
Boat	40	48	24	8.6	9.6	5.8	36	46	22

H - Headwater site.

W - Wading site.

B - Boat site.

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

b - 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 were 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

c - Attainment status is given for the existing or if a change is proposed, then the proposed use designation(s). Attainment status was not assigned to isolated stream segments that were sampled with only qualitative macroinvertebrate methods.

d Sampled in 2010.

NS - Nonsignificant departure from biocriteria ($\leq$4 IBI or ICI units, or $\leq$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.

RECOMMENDATIONS

Changes in Use Designations

Current and recommended aquatic life, water supply and recreation uses are presented in Table 3. A number of the tributary streams evaluated in this study were originally assigned aquatic life use designations in the 1978 and 1985 Ohio WQS based largely on best professional judgment, while others were left undesignated. The current biological assessment methods and numerical criteria did not exist then. This study, as an objective and robust evaluation of beneficial uses, is precedent setting in comparison to the 1978 and 1985 designations. Several subbasin streams have been evaluated for the first time using a standardized biological approach as part of this study. Ohio EPA is obligated by a 1981 public notice to review and evaluate all aquatic life use designations outside of the Warmwater Habitat (WWH) use prior to basing any permitting actions on the existing, unverified use designations. Thus, some of the following aquatic life use recommendations constitute a fulfillment of that obligation.

The following is a list of the streams that were sampled for the first time by the Ohio EPA or have a recommended change to their use designations based on this study and the justification for that change. The current use designations for Military Run, Sapps Run, Corns Run, Salt Creek and Repp Run were verified by the findings of this study.

Bucklew Run is currently designated Exceptional Warmwater Habitat (EWH) based on a single fish collection in 1994. The 1994 collection was made at the mouth of Bucklew Run (RM 0.1) and contained at least six species of fish (gizzard shad, silver redhourse, golden redhourse, emerald shiner, spotfin shiner, mimic shiner) that are generally not expected to be residents of an 8 mi^2 stream, but were considered to be temporary visitors to the stream from the adjacent Killbuck Creek and Walhonding River. Therefore, the fish collection site on Bucklew Run was not representative of the stream as a whole. The current study does not support the EWH aquatic life use designation because both organism groups were not fully meeting EWH expectations. The macroinvertebrate community was only meeting WWH expectations and the fish community was marginally meeting EWH expectations. The macroinvertebrate EPT diversity was 13 which is within the WWH expectations. Of particular note is the low mayfly diversity (4 taxa) and abundance (not represented in the riffle's predominant or common taxa). Therefore, since neither organism group has ever fully met EWH expectations at a representative station, it is recommended that the aquatic life use of Bucklew Run be changed to WWH. This use designation change does not represent a lowering of the use due to a decline in water quality, rather, a setting of the appropriate use based on the first time the stream was sampled using both organism groups at a representative station instead of an earlier designation based on incomplete information. It has been the usual practice of the Ohio EPA to designate a stream EWH only if a sufficient number of sites are biologically achieving the use (OEPA 1987b: p. 8-4, paragraph 1).

The Charm tributary (Tributary to Doughty Creek @ RM 14.34) is currently undesignated. The Charm tributary is a small stream with a drainage area of 2.5 mi^2 at the one station

sampled for fish (RM 0.6) and only had a fair rating for habitat (QHEI = 51.5). However, the stream had consistent flow with enough natural morphology that the WWH aquatic life use is the most appropriate designation. Based on the findings from this study the Charm tributary should be designated WWH and PCR-Class B.

Wolf Creek is currently designated WWH. This study documented exceptional fish and macroinvertebrate communities at T 31 (RM 4.1) along with seven taxa of coldwater macroinvertebrates and five species of coldwater fish. Biological stations sampled downstream from this station have never fully met EWH expectations and the number of coldwater taxa have always been substantially lower than at RM 4.1. Therefore, in recognition of the exceptional biological integrity and high number of coldwater taxa present in this stream, it is recommended that the aquatic life use in the upstream area of Wolf Creek be changed to EWH and Coldwater Habitat (CWH) and that the lower portion remain WWH.

The Tributary to Wolf Creek @ RM 6.49 is currently undesignated. This study documented exceptional fish and macroinvertebrate communities at C 452 (RM 1.4) along with seven taxa of coldwater macroinvertebrates and five species of coldwater fish. Therefore, in recognition of the exceptional biological integrity and high number of coldwater taxa present in this stream, it is recommended that the Tributary to Wolf Creek @ RM 6.49 be designated EWH and CWH along with PCR-Class B.

Black Creek is currently designated WWH. This study documented nine taxa of coldwater macroinvertebrates and four species of coldwater fish at T 225 (RM 9.8) and seven taxa of coldwater macroinvertebrates and three species of coldwater fish at T 31 (RM 4.6). Therefore, in recognition of the high number of coldwater taxa present in this stream, it is recommended that the aquatic life use of Black Creek be changed to CWH.

The Tributary to Black Creek @ RM 7.35 is currently undesignated. This study documented very good fish and exceptional macroinvertebrate communities at T 14 (RM 0.7) along with seven taxa of coldwater macroinvertebrates and three species of coldwater fish. Therefore, since both organism groups were not fully meeting EWH expectations and in recognition of the high number of cold water taxa present in this stream, it is recommended that the Tributary to Black Creek @ RM 7.35 be designated CWH and PCR-Class B.

Shrimplin Creek is currently designated WWH. This study documented exceptional fish and macroinvertebrate communities at T 252 (RM 2.9) along with 11 taxa of coldwater macroinvertebrates and three species of coldwater fish. Therefore, in recognition of the exceptional biological integrity and high number of coldwater taxa present in this stream, it is recommended that the aquatic life use of Shrimplin Creek be changed to EWH and CWH.

Sand Run is currently designated WWH. This study documented eight taxa of coldwater macroinvertebrates at US 62/SR 83 (RM 0.4). Therefore, in recognition of the high

number of coldwater taxa present in this stream, it is recommended that the aquatic life use of Sand Run be changed to CWH.

Bear Run is currently designated WWH. This study documented seven taxa of coldwater macroinvertebrates and one species of coldwater fish at C 400 (RM 0.8). Therefore, in recognition of the high number of coldwater taxa present in this stream, it is recommended that the aquatic life use of Bear Run be changed to CWH.

Honey Run is currently designated WWH. This study documented six taxa of coldwater macroinvertebrates and two species of coldwater fish at T 332 (RM 1.0). Therefore, in recognition of the high number of coldwater taxa present in this stream, it is recommended that the aquatic life use of Honey Run be changed to CWH.

Paint Creek is currently designated EWH based on a single biological collection station at RM 1.6/1.8 in 1993. At the time, the station was considered to be a headwater fish site and the IBI was calculated to be 50 (exceptional). With the publication of a new stream gazetteer, the station is now considered to be a wading fish site (drainage area ≥ 20 sq mi) and the IBI is now 39 (marginally good). The current study does not support the EWH aquatic life use designation because both organism groups were not fully meeting EWH expectations. The macroinvertebrate community was meeting EWH expectations at all three stations and the fish community was marginally meeting EWH expectations at one station and only meeting WWH expectations at the other two stations. This study documented five taxa of coldwater macroinvertebrates and three species of coldwater fish at C 51 (RM 8.7), seven taxa of coldwater macroinvertebrates and three species of coldwater fish at T 262 (RM 5.3), and three taxa of coldwater macroinvertebrates and four species of coldwater fish at T 556 (RM 1.6). Therefore, since both organism groups have never fully met EWH expectations and in recognition of the high number of coldwater taxa present in this stream, it is recommended that the aquatic life use of Paint Creek be changed to CWH.

The Tributary to Paint Creek @ RM 3.01 is currently undesignated. This study documented exceptional fish and macroinvertebrate communities at T 525 (RM 1.5) along with six taxa of coldwater macroinvertebrates and three species of coldwater fish. Therefore, in recognition of the exceptional biological integrity and high number of coldwater taxa present in this stream, it is recommended that the Tributary to Paint Creek @ RM 3.01 be designated EWH and CWH along with PCR-Class B.

The recreation use in Shreve Creek is currently SCR. However, the stream's size and access potential are consistent with the PCR use; therefore, it is recommended that the recreation use be changed to PCR-Class B.

The Millbrook tributary (Tributary to Killbuck Creek @ RM 43.60) is currently undesignated. This study documented fair fish and good macroinvertebrate communities at Kister Road (RM 3.3/2.7) along with 11 taxa of coldwater macroinvertebrates and two species of coldwater fish. Therefore, in recognition of the high number of coldwater taxa

present in this stream, it is recommended that the Millbrook tributary be designated CWH and PCR-Class B.

The recreation use in Apple Creek is currently SCR. However, the stream's size and access potential are consistent with the PCR use; therefore, it is recommended that the recreation use be changed to PCR-Class B.

The recreation use of Little Apple Creek (Tributary to Apple Creek @ RM 2.60) is currently SCR. However, the stream's size and access potential are consistent with the PCR use; therefore, it is recommended that the recreation use be changed to PCR-Class B.

Spring Run is currently undesignated. This study documented very good fish and good macroinvertebrate communities at Canal Road (RM 0.4) along with five taxa of coldwater macroinvertebrates and two species of coldwater fish. Therefore, in recognition of the high number of coldwater taxa present in this stream, it is recommended that Spring Run be designated CWH and PCR-Class B.

Little Apple Creek (Tributary to Apple Creek @ RM 9.79) is currently undesignated. This study documented good fish and macroinvertebrate communities and good in-stream habitat (QHEI = 59.0). Based on the findings from this study Little Apple Creek should be designated WWH and PCR-Class B.

Clear Creek is currently designated WWH. This study documented exceptional fish and macroinvertebrate communities at both collection stations along with four taxa of coldwater macroinvertebrates and two species of coldwater fish at Mechanicsburg Road (RM 3.7) and six taxa of coldwater macroinvertebrates and three species of coldwater fish at Silver Road (RM 1.1). Therefore, in recognition of the exceptional biological integrity and high number of coldwater taxa present in this stream, it is recommended that the aquatic life use of Clear Creek be changed to EWH and CWH.

Little Killbuck Creek is currently designated WWH. This study documented two taxa of coldwater macroinvertebrates (both primary coldwater indicators) and two species of coldwater fish at Smithville Western Road (RM 6.5) and five taxa of coldwater macroinvertebrates and five species of coldwater fish at SR 302 (RM 0.5). Therefore, in recognition of the high number of coldwater taxa present in this stream, it is recommended that the aquatic life use of Little Killbuck Creek be changed to CWH.

Rathburn Run is currently designated WWH. This study documented three taxa of coldwater macroinvertebrates (all primary cold water indicators) and three species of coldwater fish adjacent to Lehr Road (RM 2.5). Therefore, in recognition of the high number of coldwater taxa present in this stream, it is recommended that the aquatic life use of Rathburn Run be changed to CWH.

Cedar Run is currently designated WWH. This study documented 10 taxa of coldwater macroinvertebrates and one species of coldwater fish adjacent to Lehr Road (RM 2.5).

Therefore, in recognition of the high number of coldwater taxa present in this stream, it is recommended that the aquatic life use of Cedar Run be changed to CWH

Improvements to Water Quality

Improvements may be made to water quality throughout the study area by addressing the causes and sources identified within the aquatic life use attainment table (Table 2). The causes and sources associated with agricultural practices may be addressed by improving riparian buffers, proper fertilizer and pesticide application, and ceasing of traditional 'cleaning' of streams. Funding opportunities should be sought to improve agricultural practices and could include any of the above listed improvements.

In particular, it would be beneficial to fence the cattle out of the headwaters of the Tributary to Killbuck Creek @RM 43.50 (Millbrook Trib.), Martins Creek, North Branch Salt Creek, and Tributary to Doughty Creek @RM 14.34 (Charm Trib.). However, the biological impairment and recreation use non-attainment noted for the Charm Trib. may also be due to the unsewered community of Charm, so further study is needed to elucidate the relative contribution of these two sources.

Urbanization impairments could be addressed through a combination of regulatory, educational and funding actions including improvements at each WWTP, management of failing septic systems, advances in storm water management, controlled development and alternatives to traditional stream channelization and riparian removal. One method to reduce polluted urban runoff would be to incorporate bioretention areas into existing and new infrastructure. A summary of these structures can be found in the fact sheet http://ohioline.osu.edu/cl-fact/1000.html .

Table 3. Waterbody use designation recommendations for the Killbuck Creek watershed. Designations based on the 1978 and 1985 water quality standards appear as asterisks (*). Designations based on Ohio EPA biological field assessments appear as a plus sign (+) and a delta (▲) indicates a new recommendation based on the findings of this report. Plus sign designations shaded in gray are to be replaced by the new recommendations (▲). Designations based on the 1978 and 1985 standards for which the results of a biological and habitat assessment are now available are displayed to the left of the existing markers.

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	
Killbuck Creek - wetland area	+	+							+	+		+		
Killbuck Creek - all other segments		+							+	+		+		
Bucklew Run		▲	+						+	+		+		
Hoagland Run		*							*	*		*		
Doughty Creek		+							+	+		+		
Bucks Run		*							*	*		*		
Military Run		*/+							*/+	*/+		*/+		
Mullet Run		*							*	*		*		
Charm tributary (Doughty Creek RM 14.34)		▲							▲	▲		▲		
Big Run			+						+	+		+		
Laurel Creek		*							*	*		*		
Lepley Run		*							*	*		*		
Wolf Creek – headwaters to Twp Rd 31 (RM 4.1)		+	▲			▲			+	+		+		
Wolf Creek – Twp Rd. 31 (RM 4.1) to the mouth		+							+	+		+		
Unnamed tributary (Wolf Creek RM 6.49)			▲			▲			▲	▲		▲		
Black Creek		*				▲			*/+	*/+		*/+		
Unnamed tributary (Black Creek RM 7.35)						▲			▲	▲		▲		
Shrimplin Creek		*	▲			▲			*/+	*/+		*/+		
Hardy Run		*							*	*		*		
Sand Run		*				▲			*/+	*/+		*/+		
Upper Sand Run		*							*	*		*		
Sapps Run		*/+							*/+	*/+		*/+		
Uhl Run		*							*	*		*		
Bear Run		*				▲			*/+	*/+		*/+		
Corns Run		*/+							*/+	*/+		*/+		
Honey Run		*				▲			*/+	*/+		*/+		
Colliers Run		*							*	*		*		
Martins Creek		+							+	+		+		
Paint Creek			+			▲			+	+		+		
Coffee Run		*							*	*		*		
Unnamed tributary (Paint Creek RM 3.01)			▲			▲			▲	▲		▲		
Salt Creek		*/+							*/+	*/+		*/+		
North Branch		+							+	+		+		
Tea Run		*							*	*		*		

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	
Rush Run		*							*	*		*		
Savage Run		*							*	*		+		
Shreve Creek		+							+	+		▲	+	
Millbrook tributary (Killbuck Creek RM 44.58)						▲			▲	▲		▲		
Apple Creek		+							+	+		▲	+	
Little Apple Creek		+							+	+		▲	+	
Spring Run						▲			▲	▲		▲		
Little Apple Creek		▲							▲	▲		▲		
Clear Creek		*	▲			▲			*/+	*/+		*/+		
Little Killbuck Creek		+				▲			+	+		+		
Rathburn Run		*				▲			*/+	*/+		*/+		
Cedar Run		*				▲			*/+	*/+		*/+		
Shade Creek		+							+	+		+		
Little Killbuck Creek		*							*	*		*		
Repp Run		*/+							*/+	*/+		*/+		
Camel Creek		+							+	+		+		
Killbuck ditch (Killbuck Creek RM 71.7)							+		+	+			+	Small drainageway maintenance

RESULTS

Study Area Description

Killbuck Creek and tributaries drain a 609 mi^2 watershed within the Muskingum River basin in northeast Ohio (Figure 2). From its headwaters in southern Medina and Wayne counties, Killbuck Creek flows south 81.7 miles through Wayne and Holmes counties and into Coshocton County before discharging into the Walhonding River. Major tributaries to Killbuck Creek with their drainage areas include: Apple Creek (51.5 mi^2), Salt Creek (43.6 mi^2), Black Creek (35.2 mi^2), and Doughty Creek (60.9 mi^2). Population centers in the Killbuck Creek watershed include Wooster and Millersburg. There are no significant dams or impoundments on the Killbuck Creek mainstem.

Wetland areas in the watershed may be found intermittently throughout the basin. The most extensive and important of these wetlands lie along both banks of the Killbuck Creek from RM 47.1 to RM 38.0 in the vicinity of the border between Wayne and Holmes counties. This valuable wetland area provides habitat for unique wildlife and plant species and is the largest remaining wetland area in Ohio outside the Lake Erie coastal region. Within this large wetland area the Ohio Department of Natural Resources-Division of Wildlife maintains a 5,492 acre nature preserve called the Killbuck Marsh Wildlife Area. The creek in this wetland area has maintained its channelized character and has a very low gradient.

Figure 2. Killbuck Creek Watershed Location.

The Killbuck Creek watershed is bisected by two ecoregions, which are the Erie/Ontario Lake Plain (EOLP) in the northern part of the watershed and the Western Allegheny Plateau (WAP) in the southern part of the watershed (Omernik 1988). The northern half of Holmes County and all of Medina and Wayne Counties are in the EOLP ecoregion, which is characterized by irregular plains of cropland and pasture with scattered woodlands, forests, and urban centers. The southern half of Holmes County and Coshocton County are in the WAP ecoregion. This region is characterized by low to high hills dominated by woodlands and forests with some cropland and pasture.

The Killbuck Creek watershed is largely rural, with approximately 52 percent of the land used for cropland and pasture, and 35 percent for woodland. Agricultural land uses

dominate the northern half of the watershed (Figure 3) while the amount of woodland becomes more prevalent in the southern portion. Although the northeast portion of the watershed is experiencing some urban and suburban growth due to the spread of the Akron-Canton metropolitan area, it is not anticipated that the watershed in general will experience a significant land use change.

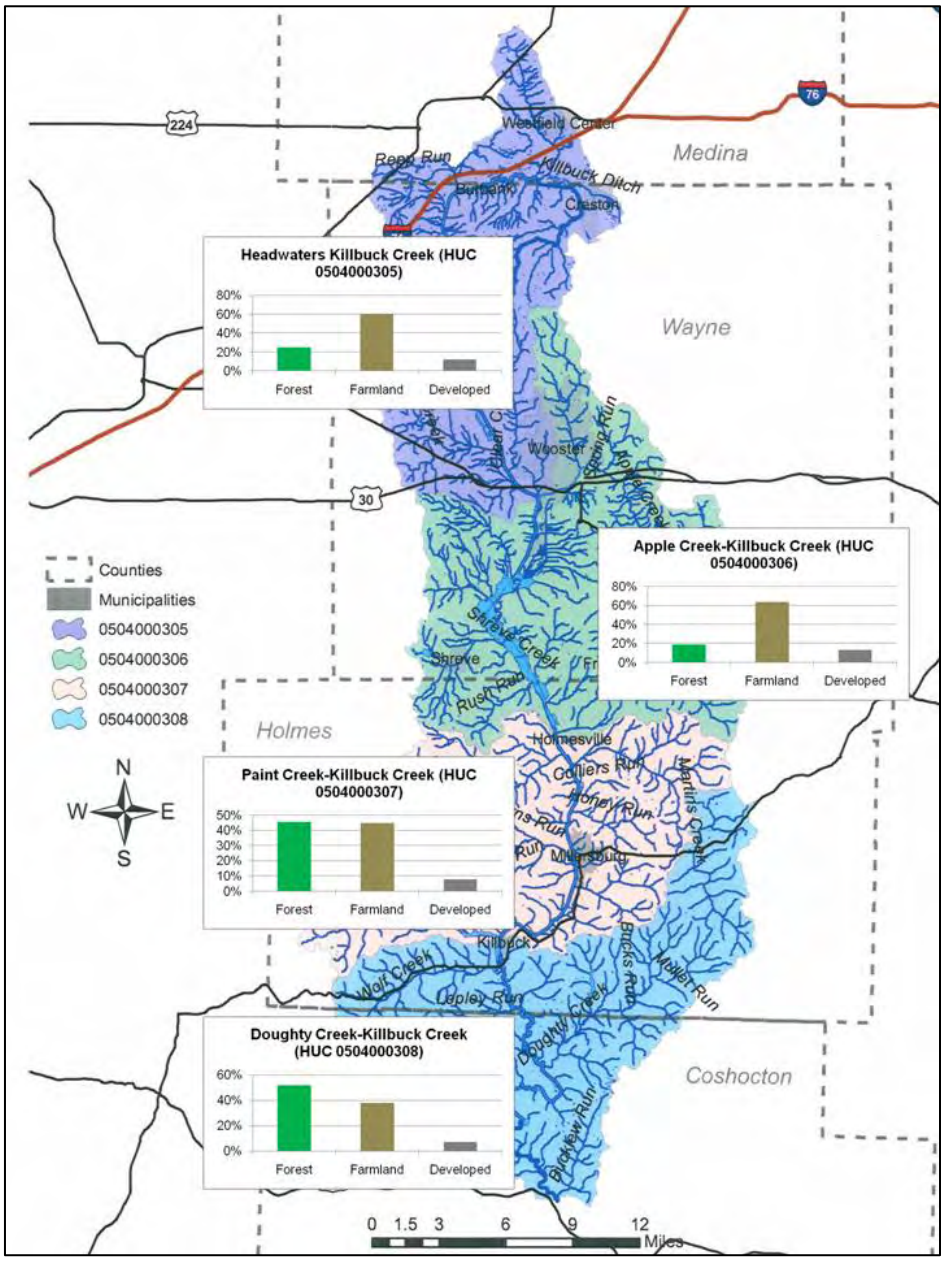


Figure 3. Major land uses by HUC 10.

Previously identified or suspected nonpoint pollution sources in the Killbuck Creek watershed include agricultural runoff from livestock and crop production, on-site sewage disposal system malfunctions, and abandoned or active coal mine drainage.

Agriculture is the main industry in the Killbuck Creek watershed. Wayne County ranks as one of the top dairy producing counties in the nation (45th) and is the leading county in Ohio in the production of milk cows, hay, and dairy products; the county also ranks third in total cash receipts from farming, and ninth in hog production. Holmes County ranks third in Ohio in production of milk and dairy products, second in sheep/goats, and 13th in total cash receipts from farming. Coshocton County ranks seventh in the state for aquaculture production and sixth in the number of broilers housed. Medina County is less dominated by agriculture yet ranks eighth in the production of cut Christmas trees. The most recent Census of Agriculture data from 2007 was used (http://www.agcensus.usda.gov/Publications/2007/Online_Highlights/County_Profiles/Ohio/index.asp).

Killbuck Creek can also be viewed in terms of gradient changes over its length. The stream begins at a relatively high gradient, as defined using the 2006 QHEI manual (Ohio EPA 2006). It continues as a stream of moderate-high gradient until it begins to flatten out just above Wooster. Killbuck Creek now becomes a stream with low to very low gradient throughout the Killbuck Marsh area. Stream gradient increases over the remaining thirteen miles to the low-moderate range prior to the confluence of Killbuck Creek with the Walhonding River. A gradient profile is included as Figure 4.

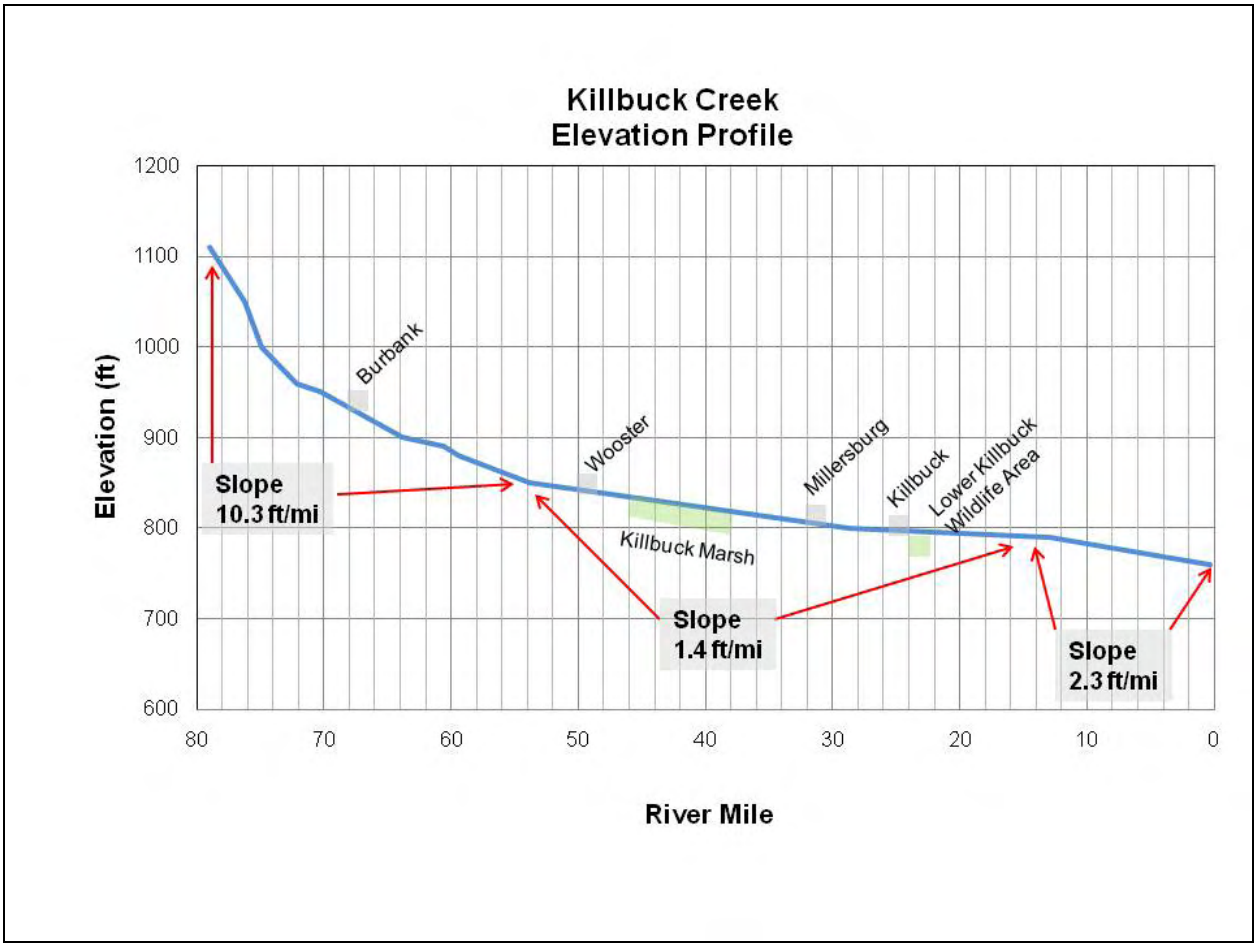


Figure 4. Killbuck Creek elevation profile.

Water Chemistry

Summary

Surface water chemistry samples were collected from 79 sites in the Killbuck Creek watershed (Appendix Table 1). Sites were sampled from May 2009 thru October 2009. Eight sentinel sites throughout the watershed were sampled more frequently from May 2009 thru March 2010. All samples were analyzed for a variety of parameters including nutrients and metals. Sites were sampled from free flowing sections of streams and were primarily collected from bridge crossings. Surface water samples were collected in appropriate containers, preserved and delivered to Ohio EPA's Environmental Services laboratory. Sample collection followed the methods as outlined in the Manual of Ohio EPA Surveillance Methods and Quality Assurance Practices (Ohio EPA, 2009).

Data are grouped by three ranges of stream and river size for some analyses as follows: headwater streams (0-20 sq.mi.); wadable streams (20-200 sq.mi.); and small rivers (200-1000 sq.mi.), in addition to being segregated by HUC 12 units. In addition to the discussion based on drainage area, each named stream for which data was collected will be individually reviewed.

Generally, chemistry water quality sampling was conducted to capture a wide variety of stream flow conditions, however, a majority of samples collected during the summer of 2009 were collected at flows below the historical median (Figure 5). Data from the Killbuck Creek United States Geological Survey (USGS) gage station near Killbuck Ohio (# 03139000) were examined to show flow trends in the Killbuck Creek watershed during the 2009 survey. Dates when surface water chemistry samples were collected are noted on the graph. Two additional sample events were conducted in 2010 for purposes of gathering data at elevated flows to assist in water quality model development. A sample event on January 27, 2010 had a gage flow of 1250 cfs (historic daily mean 670 cfs) and a sample event on March 15, 2010 had a gage flow of 2550 cfs (historic daily mean 995 cfs).

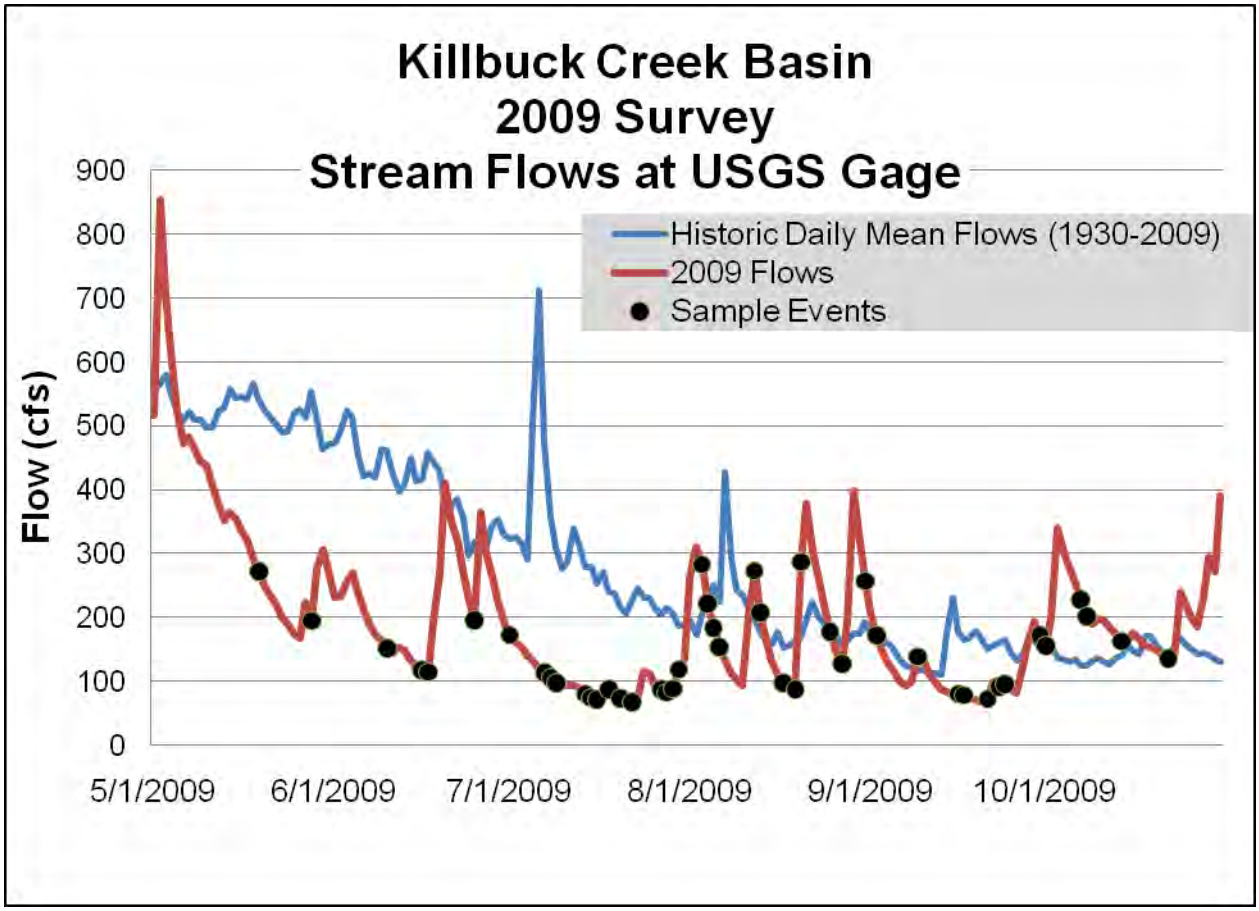


Figure 5. USGS Gage flows during 2009 Killbuck Creek Basin Survey.

Chemistry Results by Stream Size

Using the three stream size categories, headwater, wadable, and small river, several parameters were evaluated to determine if differences exist across the basin based on stream size. For analysis it was assumed that data was non-normal in its distribution. This was confirmed by using the Anderson-Darling Test for normality. Representative parameters will be compared for differences based on watershed size.

While Ohio does not currently have criteria for the nutrient parameters nitrate and phosphorus, it does have target values associated with biocriteria attainment. The target values for nitrate and phosphorus are defined on a state-wide level in Ohio EPA (1999), and are presented in Table 4 below.

Table 4. State-Wide Nutrient Targets.

Parameter	Target Concentration (mg/l) for WWH designation		
	Headwaters	Wadable Streams	Small Rivers
Nitrate+Nitrite (75%ile)	1.0	1.0	1.5
Total Phosphorus (median)	0.08	0.10	0.17

Nutrient concentration results are presented in Table 5. Overall, the seventy-fifth percentile of nitrate+nitrite concentrations in the Killbuck Creek watershed are above the target values for headwaters and wadable streams and below the target value for small rivers. Median concentrations for total phosphorus are below target values at all stream size categories. A graphical depiction of values above target concentrations is included as Figure 6.

Table 5. Nutrient Concentrations from 2009 Killbuck Creek Survey.

Parameter	Headwaters	Wadable Streams	Small Rivers
75%ile Nitrate+Nitrite (mg/l)	3.2875	2.565	1.45
Median Total Phosphorus (mg/l)	0.0465	0.062	0.083

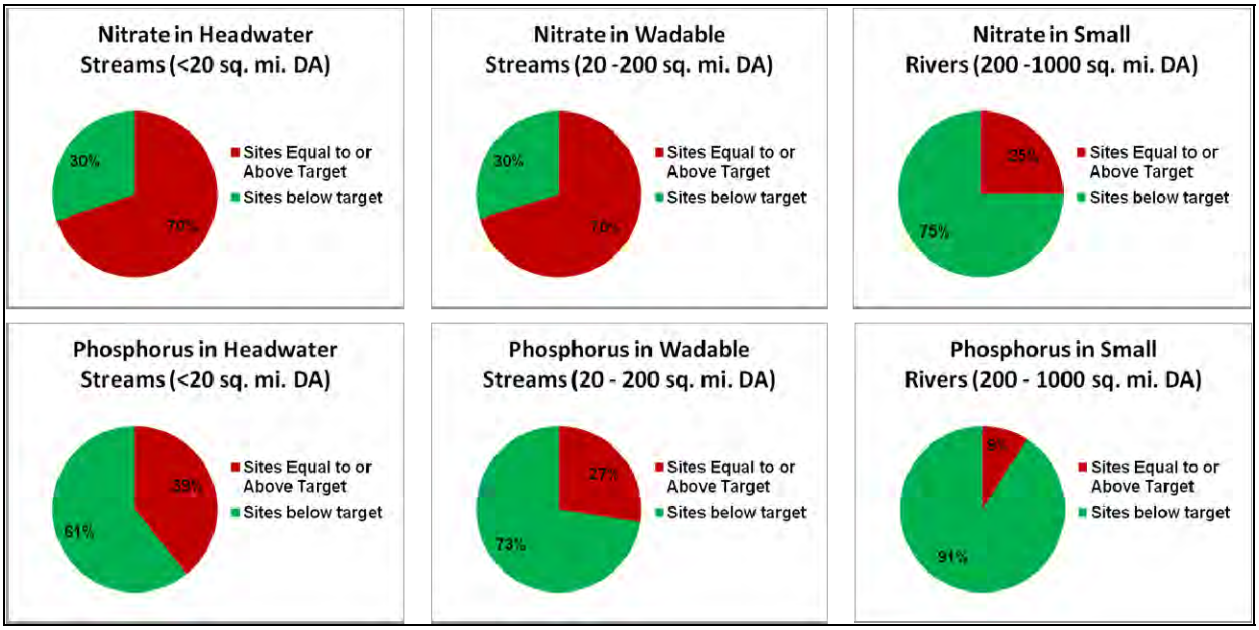


Figure 6. Nutrient concentrations and relationships to target values.

There are significant differences between small river nutrient concentrations and those found in either headwater or wadable streams when using a nonparametric Mann-Whitney test (results in Table 6). These results are consistent with what is expected based on Ohio EPA (1999). Boxplots of the nutrient data are presented in Figure 7.

Table 6. Mann-Whitney Test Results.

	p Values	
Comparison	**Nitrate**	**Phosphorus**
Headwater and Wadable	0.2768	0.1645
Wadable and Small River	**0.0092**	**0.0011**
Headwater and Small River	**0.0000**	**0.0026**
Significant values in **BOLD**		

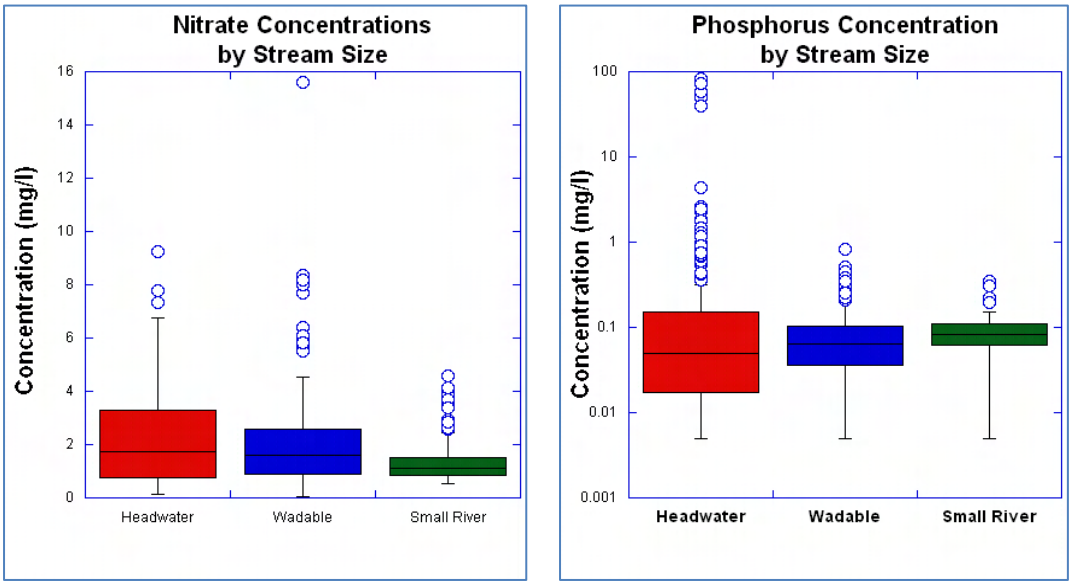


Figure 7. Nitrate and phosphorus concentrations by stream size.

Ammonia sample results for the watershed were generally very low. Median concentrations were generally near the detection limit of 0.025 mg/l with maximum concentrations detected at 1.39 mg/l, 1.02 mg/l, and 0.414 mg/l for headwater, wadable, and small rivers, respectively. As with the nutrients, concentrations of ammonia were significantly different between headwater and wadable streams when compared to small rivers.

Data for corrected conductivity, total dissolved solids and total suspended solids were also evaluated using the same three watershed size categories. Median values are presented in Table 7 below. As with the nutrients, significant differences exist between some of the parameters, in this case corrected conductivity and total suspended solids, presented in Table 8. Analysis of TDS data did not indicate significant differences between any of the stream sizes. Boxplots of corrected conductivity, total dissolved solids, and total suspended solids data are presented in Figures 8, 9, and 10.

Table 7. Median Conductivity, TDS, and TSS values from 2009 Killbuck Creek Survey.

Parameter	Headwaters	Wadable Streams	Small Rivers
Corrected Conductivity (umho/cm)	551	559	542
Total Dissolved Solids (mg/l)	337	337	340
Total Suspended Solids (mg/l)	2.5	2.5	18

Table 8. Mann-Whitney Test Results.

Comparison	p Values Corr. Conductivity	TDS	TSS
Headwater and Wadable	0.1669	0.5779	**0.0000**
Wadable and Small River	**0.0141**	0.3142	**0.0000**
Headwater and Small River	**0.0131**	0.3666	**0.0000**
Significant values in **BOLD**			

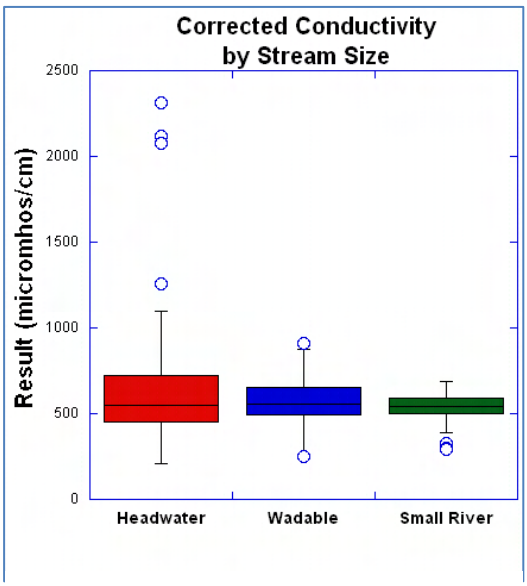


Figure 8. Corrected conductivity by stream size.

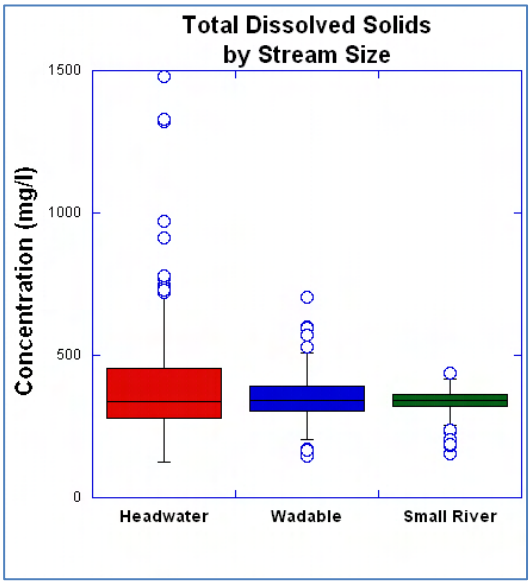


Figure 9. Total dissolved solids by stream size.

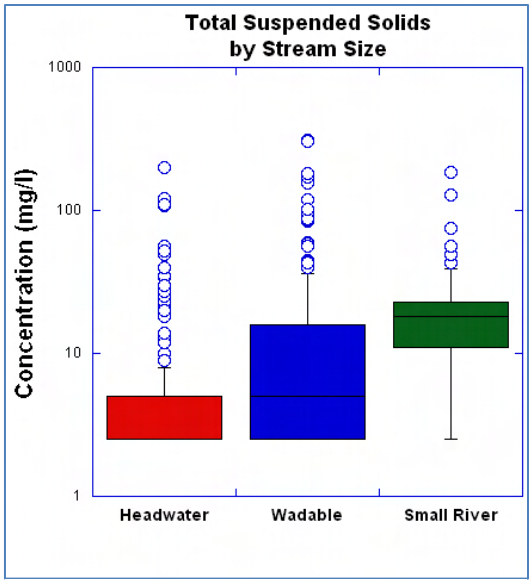


Figure 10. Total suspended solids by stream size.

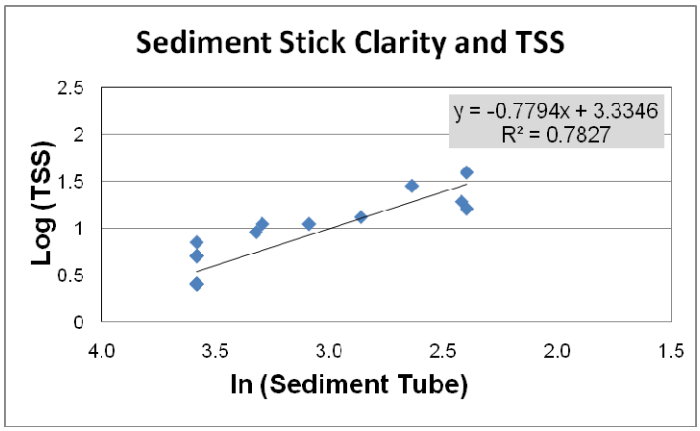


Figure 11. Sediment stick regression analysis.

<u>Sediment Stick and TSS</u>

Clarity readings using the Ohio Sediment Stick were taken at several sites to compare with laboratory results for total suspended solids. Results of the measurements are presented in Figure 11. The regression line compares favorably to the results presented by Anderson and Davic (2004) indicating that the correlation between total suspended solids and the Ohio Sediment Stick is valid in this watershed. The sediment

stick may be a useful tool in monitoring solids in discharges associated with agriculture and storm water.

Detected WQS Exceedences

Exceedences of Ohio Water Quality Standards detected during the 2009 survey are presented in Table 9. The low D.O. and high copper concentrations in Corns Run were recorded downstream from the Holmes Cheese WWTP. The low D.O. concentration in Killbuck Creek at Valley Road was from a highly channelized section that was downstream from the Wooster WWTP and receives inflow from adjacent wetland areas. The high iron concentrations were likely due to groundwater inputs and usually are not associated with declines in biological integrity at those concentrations.

Table 9. WQS Exceedences detected during 2009 Survey.

Stream	Date	Parameter	Result	WQS	Violation
MILITARY RUN @ TWP. RD. 128, RM 0.9	8/19/2009	Copper (µg/l)	16.5	10.97	OMZA
CORNS RUN W OF MILLERSBURG @ CO. RD. 400, RM 0.6	8/12/2009	Copper (µg/l)	13.5	7.70 11.34	OMZA OMZM
CAMEL CREEK W OF WESTFIELD CENTER @ GREENWICH RD., RM 0.52	8/12/2009	Dissolved Oxygen (mg/l)	4.83	5.0 (min)	OMZA
CORNS RUN W OF MILLERSBURG @ CO. RD. 400, RM 0.6	6/17/2009	Dissolved Oxygen (mg/l)	2.66	5.0 (min) 4.0 (min)	OMZA OMZM
CORNS RUN W OF MILLERSBURG @ CO. RD. 400, RM 0.6	7/9/2009	Dissolved Oxygen (mg/l)	4.4	5.0 (min)	OMZA
KILLBUCK CREEK AT HOLMESVILLE @ CO. RD. 320, RM 37.13	6/23/2009	Dissolved Oxygen (mg/l)	4.81	5.0 (min)	OMZA
KILLBUCK CREEK AT HOLMESVILLE @ CO. RD. 320, RM 37.13	8/4/2009	Dissolved Oxygen (mg/l)	4.81	5.0 (min)	OMZA
KILLBUCK CREEK S OF WOOSTER @ VALLEY RD., RM 46.02	7/28/2009	Dissolved Oxygen (mg/l)	2.14	5.0 (min) 4.0 (min)	OMZA OMZM
MARTINS CREEK AT MARTINSVILLE @ TWP. RD. 601, RM 3.5	7/1/2009	Dissolved Oxygen (mg/l)	4.86	5.0 (min)	OMZA
BUCKLEW RUN N OF RANDLE @ TWP. RD. 413, RM 1.45	9/9/2009	Iron (µg/l)	5010	5000	AWS
KILLBUCK CREEK AT BURBANK @ ST. RT. 83, RM 66.85	5/28/2009	Iron (µg/l)	8230	5000	AWS
KILLBUCK CREEK DST. HOLMESVILLE @ TWP. RD. 346, RM 35.57	8/20/2009	Iron (µg/l)	7330	5000	AWS
KILLBUCK CREEK NEAR WESTWOOD, DST. APPLE CREEK, RM 49.4	5/28/2009	Iron (µg/l)	7860	5000	AWS
KILLBUCK CREEK NW OF HOLMESVILLE @ CO. RD. 1, RM 40.05	8/20/2009	Iron (µg/l)	5020	5000	AWS
KILLBUCK CREEK UPST. WOOSTER WWTP, RM 49.95	5/28/2009	Iron (µg/l)	7390	5000	AWS
PAINT CREEK NW OF MILLERSBURG @ TWP. RD. 262, RM 5.27	8/20/2009	Iron (µg/l)	6030	5000	AWS
PAINT CREEK SW OF HOLMESVILLE @ TWP. 556, RM 1.84	8/20/2009	Iron (µg/l)	7650	5000	AWS
SALT CREEK N OF HOLMESVILLE @ ST. RT. 83, RM 0.8	8/20/2009	Iron (µg/l)	6390	5000	AWS

Water Quality by HUC

Overall water quality was evaluated by HUC for selected parameters. Average values were compiled for each 12-digit HUC and then compared to the overall 2009 watershed sample average for all stream data. Values above the basin average are highlighted in yellow in Table 10. Values greater than one standard deviation above the average are underlined in Table 10. Phosphorus averages were extremely elevated in the Shrimplin Creek-Killbuck Creek HUC (05040003 07 05). This elevation is due to the discharge from Holmes Cheese Company (permit # 3IH00102), Ohio EPA is currently in enforcement with the entity.

Table 10. Average sample result values by 12-Digit HUC

12 Digit HUC	Assessment Unit Name	NH_3 mg/l	Chloride mg/l	Iron ug/l	Nitrate mg/l	TDS mg/l	T Phos. mg/l	TSS mg/l
05040003 05 01	Headwaters Killbuck Creek	0.06	46.15	314.42	1.55	442.15	0.11	5.42
05040003 05 02	Little Killbuck Creek-Killbuck Creek	0.08	72.86	865.32	2.06	514.94	0.08	18.21
05040003 05 03	Rathburn Run-Little Killbuck Creek	0.05	33.11	119.56	4.02	333.29	0.10	4.50
05040003 05 04	Cedar Run-Killbuck Creek	0.03	47.28	637.79	2.88	399.85	0.06	16.65
05040003 05 05	Clear Creek-Killbuck Creek	0.05	44.13	889.86	3.43	323.03	0.05	24.53
05040003 06 01	Little Apple Creek	0.03	69.38	178.00	2.15	327.50	0.06	3.29
05040003 06 02	Apple Creek	0.05	50.61	168.02	1.77	345.85	0.08	6.42
05040003 06 03	Shreve Creek	0.08	36.40	385.80	3.13	418.33	0.18	2.50
05040003 06 04	Jennings Ditch-Killbuck Creek	0.17	58.21	938.18	2.69	376.77	0.12	21.56
05040003 06 05	North Branch Salt Creek	0.16	19.52	501.75	1.29	315.60	0.16	14.40
05040003 06 06	Salt Creek	0.04	23.71	788.76	2.13	297.15	0.10	21.33
05040003 06 07	Tea Run-Killbuck Creek	0.11	48.59	1340.29	1.63	344.31	0.11	29.38
05040003 07 01	Paint Creek	0.05	18.27	1191.06	1.61	269.60	0.07	30.00
05040003 07 02	Martins Creek	0.06	31.52	566.20	1.46	365.33	0.13	8.75
05040003 07 03	Honey Run-Killbuck Creek	0.10	46.95	1179.50	1.70	347.07	0.11	24.48
05040003 07 04	Black Creek	0.03	16.78	323.75	1.39	160.77	0.03	8.92
05040003 07 05	Shrimplin Creek-Killbuck Creek	0.12	48.83	368.33	0.89	415.08	8.43	8.42
05040003 08 01	Wolf Creek	0.03	15.61	632.79	1.33	149.14	0.01	2.50
05040003 08 02	Headwaters Doughty Creek	0.10	52.44	327.31	2.95	466.36	0.53	9.62
05040003 08 03	Bucks Run-Doughty Creek	0.06	36.04	503.61	1.35	303.20	0.10	12.85
05040003 08 04	Big Run-Killbuck Creek	0.04	37.08	787.08	1.43	300.06	0.09	15.31
05040003 08 05	Bucklew Run-Killbuck Creek	0.03	33.91	1063.71	0.67	448.93	0.07	23.10
Highlighted values are 1 SD above average								
Average of All Data		0.07	44.01	619.95	2.05	360.24	0.75	14.76
Maximum Individual Value		1.39	310	8230	15.6	1480	83.6	310
Standard Deviation		0.14	25.65	1083.50	1.70	136.77	6.22	31.18
Average + SD		0.21	69.66	1703.45	3.75	497.01	6.97	45.94

Median values were also compiled for each 12-digit HUC and then compared to the overall 2009 watershed sample median for all stream data. Values above the overall basin median are highlighted in yellow in Table 11. With the exception of nitrate,

measured concentrations were indicative of good water quality. Nitrate levels were commonly above our recommended target value of 1.0 mg/l, indicating some nutrient enrichment within the basin.

Table 11. Median sample result values by 12-Digit HUC.

12 Digit HUC	Assessment Unit Name	NH_3 mg/l	Chloride mg/l	Iron ug/l	Nitrate mg/l	TDS mg/l	T Phos. mg/l	TSS mg/l
05040003 05 01	Headwaters Killbuck Creek	0.062	44.4	295.5	1.48	444	0.084	2.5
05040003 05 02	Little Killbuck Creek-Killbuck Creek	0.025	60	452.5	1.47	478	0.078	8
05040003 05 03	Rathburn Run-Little Killbuck Creek	0.025	33.7	86.5	3.64	337	0.025	2.5
05040003 05 04	Cedar Run-Killbuck Creek	0.025	47.7	366	2.54	370	0.049	8
05040003 05 05	Clear Creek-Killbuck Creek	0.025	42.8	313	2.51	312	0.035	13
05040003 06 01	Little Apple Creek	0.025	63.7	150.5	2.21	342	0.042	2.5
05040003 06 02	Apple Creek	0.025	55.35	138	1.39	343	0.047	2.5
05040003 06 03	Shreve Creek	0.073	35.9	389	3.38	420	0.166	2.5
05040003 06 04	Jennings Ditch-Killbuck Creek	0.064	65.8	508	2.34	394	0.073	13
05040003 06 05	North Branch Salt Creek	0.137	20.3	527	0.80	304	0.134	6
05040003 06 06	Salt Creek	0.025	24.1	111.5	1.53	308	0.048	2.5
05040003 06 07	Tea Run-Killbuck Creek	0.076	45.8	1050	1.23	349	0.090	22.5
05040003 07 01	Paint Creek	0.025	17.45	196.5	1.73	270	0.024	3.75
05040003 07 02	Martins Creek	0.025	28.5	598	1.75	348	0.113	8
05040003 07 03	Honey Run-Killbuck Creek	0.100	46.85	1056	1.28	358	0.098	19
05040003 07 04	Black Creek	0.025	14.4	381.5	0.86	150	0.005	2.5
05040003 07 05	Shrimplin Creek-Killbuck Creek	0.025	42.1	91	0.66	330	0.084	2.5
05040003 08 01	Wolf Creek	0.025	14.35	577.5	0.99	152	0.010	2.5
05040003 08 02	Headwaters Doughty Creek	0.038	51.05	270.5	2.70	477	0.245	2.5
05040003 08 03	Bucks Run-Doughty Creek	0.025	35.6	350	0.89	320	0.079	2.5
05040003 08 04	Big Run-Killbuck Creek	0.025	42	692	1.17	325	0.077	14
05040003 08 05	Bucklew Run-Killbuck Creek	0.025	38.9	741	0.68	344	0.049	15
Highlighted values are greater than overall median								
Median of All Data		0.025	41.8	332	1.56	339	0.066	5
Maximum Individual Value		1.39	310	8230	15.6	1480	83.6	310

Water Chemistry Trends

Killbuck Creek monitoring results from this survey were compared to results from Ohio EPA's 1993 basin survey. The 1993 survey indicated that only dissolved oxygen was found at several sites to be in violation of Ohio water quality standards. Dissolved oxygen still remains a problem at several sites in the 2009 survey, and will be discussed in the data sonde results.

Three parameters were chosen to track trends on Killbuck Creek and Apple Creek: nitrate, phosphorus, and total dissolved solids (Figure 12).

Killbuck Creek has shown an increase from upstream to downstream in nitrate concentrations from 1993 to 2009. Potential sources of this nitrate include WWTP expansions and additional land developed for agricultural purposes. There were noted decreases downstream from Wooster and Apple Creek. A number of WWTPs on Apple Creek have been eliminated during this time period. Phosphorus concentrations have decreased downstream from the Wooster WWTP following installation of phosphorus removal. There is a noted average concentration increase downstream of Sapps Run and the Millersburg WWTP. Holmes Cheese discharges extremely elevated levels of phosphorus to Corns Run which enters Sapps Run. The average phosphorus effluent concentration at Holmes Cheese (Permit #3IH00102) from June thru August 2009 was 76.5 mg/l. Holmes Cheese has been referred to the Ohio Attorney General for enforcement. Total dissolved solids concentrations have decreased from 1993 to 2009.

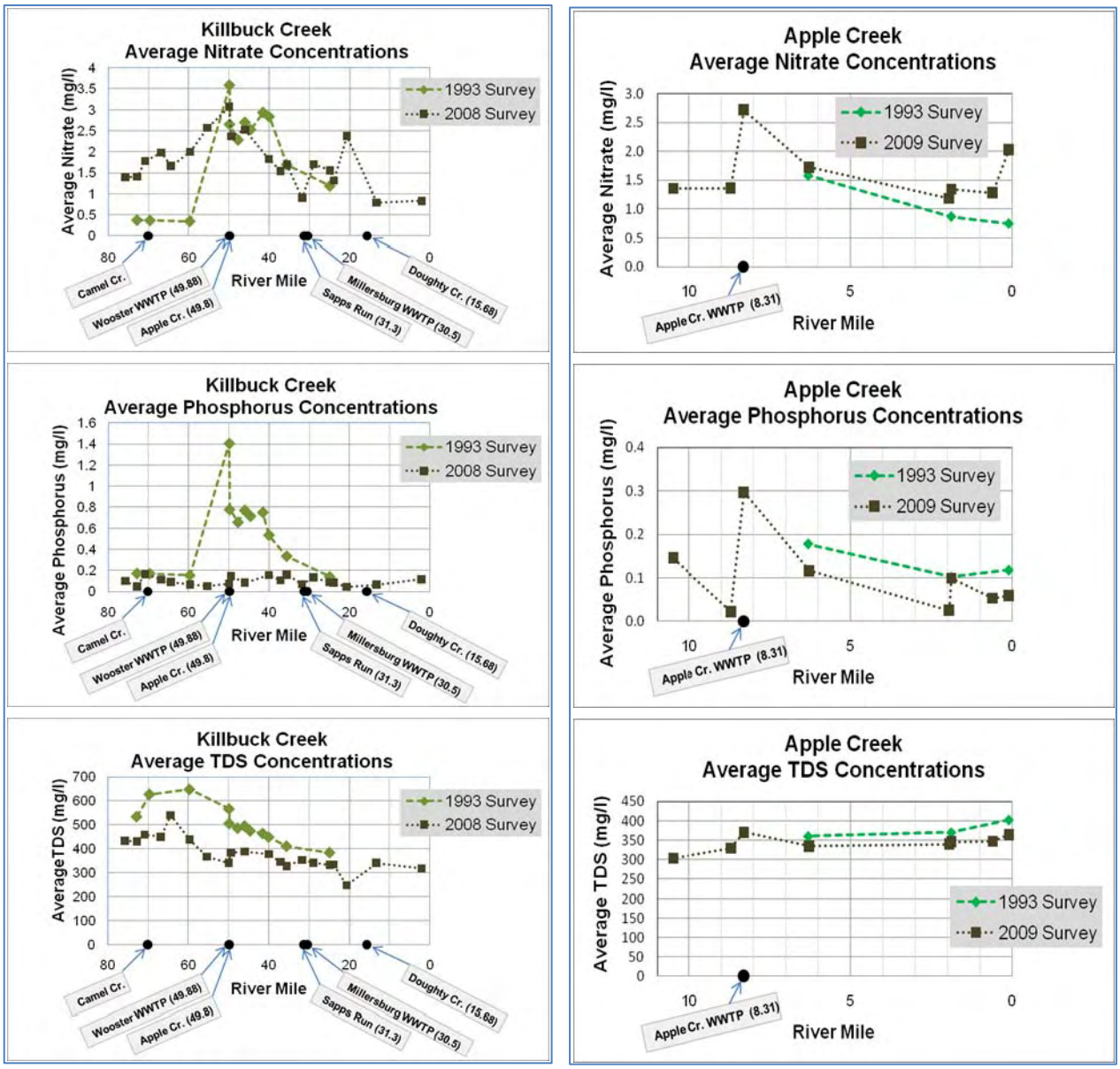


Figure 10. Killbuck Creek and Apple Creek water quality trends.

Apple Creek has not changed substantially between 1993 and 2009. There has been a slight increase in nitrate between 1993 and 2009. The concentrations are above the ecoregion target of 1.0 mg/l. Phosphorus and TDS have decreased a slight bit between watershed surveys. Phosphorus and nitrate were elevated at the river mile 8.3 sample site, which was located within the mix zone of the Apple Creek WWTP discharge.

Datasonde® Results

Tabular results of the Datasonde® deployments are included as table 12. The sondes identified several violations of the WQS for dissolved oxygen (red cells in Table 12).

Table 12. Datasonde® results

Dates	Waterbody	River Mile	Temp Min	Temp Avg	Temp Max	Temp Range	SpC Min	SpC Avg	SpC Max	SpC Range	DO Min	DO Avg	DO Max	DO Range
8-4-09 to														
8-20-09	Doughty Creek	4.9	16.77	22.55	28.37	11.60	0.356	0.546	0.638	0.282	5.53	8.88	15.45	9.92
	Doughty Creek	4.9	21.90	23.55	26.12	4.22	0.490	0.523	0.555	0.065	5.65	7.63	11.51	5.86
	Killbuck Creek	64.4	18.41	22.22	25.16	6.75	0.715	0.801	0.979	0.264	4.79	7.06	10.02	5.23
8-4-09 to														
8-6-09	Apple Creek	6.3	17.06	19.61	22.20	5.14	0.519	0.526	0.540	0.021	7.60	8.71	10.90	3.30
	Apple Creek	0.1	17.10	20.31	23.47	6.37	0.618	0.628	0.634	0.016	7.62	8.70	10.98	3.36
	Camel Creek	0.3	17.56	21.17	25.03	7.47	0.654	0.702	0.756	0.102	6.09	7.83	10.40	4.31
	Clear Creek	1.1	16.73	19.60	22.15	5.42	0.483	0.486	0.490	0.007	8.04	8.49	9.36	1.32
	Doughty Creek	14.3	17.83	22.35	27.02	9.19	0.695	0.781	0.868	0.173	6.51	8.11	11.55	5.04
	Killbuck Creek	70.9	17.52	20.67	22.47	4.95	0.633	0.659	0.690	0.057	6.47	7.44	8.96	2.49
	Killbuck Creek	66.9	18.77	20.93	22.30	3.53	0.611	0.636	0.653	0.042	6.43	7.38	8.49	2.06
	Killbuck Creek	55.4	19.26	20.82	22.22	2.96	0.483	0.515	0.556	0.073	7.19	7.76	8.48	1.29
	Killbuck Creek	50.3	18.96	21.36	24.36	5.40	0.476	0.480	0.487	0.011	6.97	7.86	9.01	2.04
	Killbuck Creek	49.4	18.73	20.97	23.01	4.28	0.574	0.603	0.648	0.074	7.51	8.21	9.15	1.64
	Killbuck Creek	46	20.60	21.43	22.22	1.62	0.556	0.590	0.618	0.062	6.52	7.11	7.71	1.19
	Killbuck Creek	37.1	20.34	21.75	22.72	2.38	0.455	0.480	0.498	0.043	3.99	4.38	4.88	0.89
	Killbuck Creek	35.6	20.42	21.52	22.31	1.89	0.452	0.474	0.493	0.041	4.79	5.24	5.68	0.89
	Killbuck Creek	31.9	20.21	21.46	23.24	3.03	0.447	0.470	0.496	0.049	6.04	6.36	6.84	0.80
	Killbuck Creek	28.9	19.98	21.37	22.95	2.97	0.469	0.493	0.516	0.047	6.33	6.55	6.90	0.57
	Killbuck Creek	24.9	19.82	21.28	22.46	2.64	0.455	0.479	0.505	0.050	6.93	7.11	7.55	0.62
	Killbuck Creek	23.9	19.90	21.32	22.41	2.51	0.463	0.484	0.508	0.045	6.61	6.82	7.34	0.73
	Killbuck Creek	20.7	20.79	21.50	22.28	1.49	0.454	0.469	0.486	0.032	6.53	6.86	7.37	0.84
	Killbuck Creek	13.3	20.92	21.45	22.02	1.10	0.433	0.445	0.463	0.030	6.63	6.85	7.16	0.53
	Salt Creek	5	16.44	20.70	24.09	7.65	0.468	0.484	0.499	0.031	7.07	8.19	10.29	3.22
	Salt Creek	3	16.26	20.69	26.53	10.27	0.429	0.492	0.519	0.090	6.61	9.21	15.20	8.59
	Salt Creek	0.7	16.85	20.81	25.11	8.26	0.471	0.501	0.529	0.058	6.60	8.65	13.07	6.47
	Shreve Creek	3.1	15.69	18.83	22.21	6.52	0.569	0.624	0.658	0.089	6.23	7.97	11.30	5.07
8-18-09 to														
8-20-09	Apple Creek	10.51	18.43	21.35	24.75	6.32	0.248	0.448	0.520	0.272	5.85	7.62	12.14	6.29
	Apple Creek	6.3	20.53	21.89	23.98	3.45	0.236	0.469	0.566	0.330	6.65	8.00	10.90	4.25
	Apple Creek	0.1	20.95	22.71	25.43	4.48	0.117	0.505	0.659	0.542	6.75	9.57	15.63	8.88
	Black Creek	4.6	20.47	21.70	22.83	2.36	0.191	0.241	0.256	0.065	7.07	7.95	9.06	1.99
	Camel Creek	0.3	21.70	24.01	26.82	5.12	1.421	1.503	1.670	0.249	5.41	7.94	11.73	6.32
	Corns Run	0.7	21.76	25.46	28.20	6.44	0.556	2.376	3.403	2.847	2.43	5.35	10.32	7.89

Table 12. Datasonde® results

Dates	Waterbody	River Mile	Temp Min	Temp Avg	Temp Max	Temp Range	SpC Min	SpC Avg	SpC Max	SpC Range	DO Min	DO Avg	DO Max	DO Range
	Doughty Creek	15.9	21.25	23.72	27.50	6.25	0.423	0.829	1.057	0.634	5.52	7.50	11.25	5.73
	Doughty Creek	14.7	21.37	24.36	26.83	5.46	0.448	0.790	1.067	0.619	5.70	7.88	11.98	6.28
	Doughty Creek	14.3	21.31	24.16	26.61	5.30	0.422	0.728	0.887	0.465	5.99	7.65	10.48	4.49
	Doughty Creek	11.7	21.71	23.45	26.09	4.38	0.446	0.722	0.796	0.350	6.69	8.28	11.97	5.28
	Doughty Creek	0.6	22.38	23.89	25.39	3.01	0.402	0.453	0.474	0.072	6.54	7.21	8.50	1.96
	Killbuck Creek	66.9	22.25	23.36	24.40	2.15	0.767	0.847	0.882	0.115	5.44	6.49	8.27	2.83
	Killbuck Creek	50.3	21.26	23.90	26.62	5.36	0.294	0.494	0.773	0.479	5.45	8.24	10.81	5.36
	Killbuck Creek	46	21.29	25.22	26.85	5.56	0.227	0.348	0.380	0.153	0.51	3.03	6.42	5.91
	Killbuck Creek	37.1	21.43	23.71	24.71	3.28	0.324	0.524	0.573	0.249	4.32	5.32	6.48	2.16
	Little Killbuck Creek	0.5	20.52	23.49	27.76	7.24	0.233	0.435	0.500	0.267	6.45	9.10	13.91	7.46
	Martins Creek	3.5	18.51	21.32	24.63	6.12	0.227	0.539	0.637	0.410	6.76	8.66	12.83	6.07
	N. Branch Salt Creek	3.3	20.69	22.14	24.03	3.34	0.219	0.438	0.667	0.448	3.39	4.79	6.14	2.75
	Paint Creek	1.6	19.17	21.44	24.47	5.30	0.266	0.406	0.466	0.200	6.66	7.50	12.11	12.11
	Repp Run	0.9	21.00	21.96	22.78	1.78	0.983	1.070	1.088	0.105	1.21	3.19	5.92	4.71
	Salt Creek	5	20.70	22.93	25.27	4.57	0.220	0.407	0.492	0.272	6.39	7.54	9.70	3.31
	Salt Creek	3	20.74	22.88	26.75	6.01	0.243	0.438	0.524	0.281	6.81	8.57	12.85	6.04
	Salt Creek	0.7	20.89	22.98	25.81	4.92	0.279	0.429	0.512	0.233	0.22	7.96	14.90	14.68
	Trib to Doughty Creek	0.6	20.91	23.95	27.57	6.66	0.283	0.653	0.813	0.530	3.03	6.34	9.21	6.18
	Trib to Paint Creek	3	20.09	21.86	24.56	4.47	0.279	0.427	0.496	0.217	4.64	7.58	10.63	5.99

When comparing the aquatic life use attainment table to Datasonde® results there were ten sites in partial attainment (12.98% of sites assessed), four sites in non attainment (5.19% of sites assessed), and sixty-three sites in full attainment (81.81% of sites assessed). Table 13 includes all sites with a DO-related stress and presents the aquatic life attainment status for the site. About half (4/7, 63%) of the sites with low minimum DO were associated with stations with partial or non attainment of the aquatic life use.

Table 13. Aquatic Life Use attainment status of DO-stressed streams

Dates	Waterbody	River Mile	Aquatic Life Use Attainment Status	DO Min	DO Avg	DO Max	DO Range
8-4-09 to 8-20-09	Doughty Creek	4.9	Full	5.53	8.88	15.45	9.92
	Doughty Creek	4.9	Full	5.65	7.63	11.51	5.86
	Killbuck Creek	64.4	Full	4.79	7.06	10.02	5.23
8-4-09 to 8-6-09	Doughty Creek	14.3	Full	6.51	8.11	11.55	5.04
	Killbuck Creek	37.1	Full	3.99	4.38	4.88	0.89
	Salt Creek	0.7	Full	6.61	9.21	15.20	8.59
	Salt Creek	3.0	Full	6.60	8.65	13.07	6.47
	Shreve Creek	3.1	Partial	6.23	7.97	11.30	5.07
8-18-09 to 8-20-09	Apple Creek	10.51	N/A	5.85	7.62	12.14	6.29
	Apple Creek	0.1	Full	6.75	9.57	15.63	8.88

Table 13. Aquatic Life Use attainment status of DO-stressed streams

Dates	Waterbody	River Mile	Aquatic Life Use Attainment Status	DO Min	DO Avg	DO Max	DO Range
	Camel Creek	0.3	Partial	5.41	7.94	11.73	6.32
	Corns Run	0.7	Non	2.43	5.35	10.32	7.89
	Doughty Creek	15.9	Full	5.52	7.50	11.25	5.73
	Doughty Creek	14.7	Full	5.70	7.88	11.98	6.28
	Doughty Creek	11.7	Full	6.69	8.28	11.97	5.28
	Killbuck Creek	50.3	Full	5.45	8.24	10.81	5.36
	Killbuck Creek	46	Partial	0.51	3.03	6.42	5.91
	Little Killbuck Creek	0.5	Full	6.45	9.10	13.91	7.46
	Martins Creek	3.5	Full	6.76	8.66	12.83	6.07
	N. Branch Salt Creek	3.3	Partial	3.39	4.79	6.14	2.75
	Paint Creek	1.6	Full	6.66	7.50	12.11	12.11
	Repp Run	0.9	Full	1.21	3.19	5.92	4.71
	Salt Creek	3.0	Full	6.81	8.57	12.85	6.04
	Salt Creek	0.7	Full	0.22	7.96	14.90	14.68
	Trib to Doughty Creek (Charm)	0.6	Non	3.03	6.34	9.21	6.18
	Trib to Paint Creek	3..0	Full	4.64	7.58	10.63	5.99

Recreation Use

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

Escherichia coli (*E. coli*) bacteria are microscopic organisms that are normally present in large numbers in the feces and intestinal tracts of humans and other warm-blooded animals. *E. coli* typically comprises approximately 97 percent of the organisms found in the fecal coliform bacteria of human feces (Dufour 1977). There is currently no simple way to differentiate between human and animal sources of coliform bacteria in surface waters, although methodologies for this type of analysis are becoming more feasible. These microorganisms can enter water bodies where there is a direct discharge of human and animal wastes, or may enter water bodies along with runoff from soils where these wastes have been deposited.

Pathogenic (disease-causing) organisms are typically present in the environment in such small amounts that it is impractical to monitor every type of pathogen. Fecal indicator bacteria by themselves, including *E. coli*, are usually not pathogenic. However, some strains of *E. coli* can be pathogenic, capable of causing serious illness. Although not necessarily agents of disease, fecal indicator bacteria such as *E. coli* may indicate the potential presence of pathogenic organisms that enter the environment through the same pathways. When *E. coli* are present in high numbers in a water sample, it invariably means that the water has received fecal matter from one or multiple sources. Swimming or other recreation-based contact with water having a high *E. coli* count may result in ear, nose, and throat infections, as well as stomach upsets, skin

rashes, and diarrhea. Young children, the elderly, and those with depressed immune systems are most susceptible to infection.

Streams in the Killbuck Creek study area are designated as primary contact recreation (PCR) and/or secondary contact recreation (SCR) use in OAC Rule 3745-1-24. Water bodies with a designated recreation use of PCR "...are suitable for one or more full-body contact recreation activities such as, but not limited to, wading, swimming, boating, water skiing, canoeing, kayaking, and scuba diving" [OAC 3745-1-07 (B)(4)(b)]. There are three classes of PCR use to reflect differences in the potential frequency and intensity of use. Streams designated PCR class A support, or potentially support, frequent primary contact recreation activities. Streams designated PCR class B support, or potentially support, occasional primary contact recreation activities. Streams designated as PCR class C support, or potentially support, infrequent primary contact recreation activities. Streams designated as SCR use are rarely used for water-based recreation. The streams in the Killbuck Creek study area are designated PCR Class A, PCR Class B, and SCR.

In addition, some waters that are used heavily for swimming can be designated as bathing waters. The geometric mean criterion for bathing waters is ≤126 cfu/100 ml. There are no currently designated bathing waters in the study area.

The *E. coli* criterion that applies to PCR class A streams is a geometric mean of ≤126 cfu/100 ml. The *E. coli* criterion that applies to PCR class B streams is a geometric mean of ≤161 cfu/100 ml. The criterion that applies to PCR class C streams is a geometric mean of ≤206 cfu/100 ml. The criterion that applies to SCR streams is ≤1,030 cfu/100 ml. The geometric mean is based on two or more samples and is used as the basis for determining the attainment status of the recreation use (Table 14)

Summarized bacteria results are listed in Table 14 and the complete dataset is reported in Appendix Table 2. Downloadable bacteria results are also available from the Ohio EPA geographic information systems (GIS) interactive maps at the following link: http://www.epa.ohio.gov/dsw/gis/index.aspx. Thirty-one locations in the watershed were tested for *E. coli* levels five to eighteen times between May 28 and October 22, 2009. Evaluation of *E. coli* results revealed that 100% of the 31 locations sampled failed to attain the applicable geometric mean criterion, indicating an impairment of the recreation use at these locations. The locations not attaining the recreation use were most likely not attaining because of a combination of agricultural runoff from livestock and domestic sewage from both permitted discharges and unpermitted discharges (e.g., failing septic systems).

No designated PCR site was meeting the *E. coli* standard. Four sites had a single sample event and could not be assessed for attainment.

Table 14. Bacteria Sampling Results and Attainment Status

Station	RM	Rec. Use	Number of Samples	Geometric Mean	Maximum	Attainment Status
APPLE CREEK AT WOOSTER @ OLD COLUMBUS AVE.	0.1	Primary Class B	18	183	590	NON
APPLE CREEK AT WOOSTER @ PITTSBURGH AVE.	1.95	Primary Class B	7	330	1600	NON
APPLE CREEK UPST. APPLE CREEK WWTP @ ST. RT. 250	8.7	Primary Class B	1	390	390	N/A
BLACK CREEK W OF KILLBUCK @ TWP. RD. 31	4.58	Primary Class B	6	511	2000	NON
CLEAR CREEK NW OF WOOSTER @ MECHANICSBURG RD.	3.71	Primary Class B	1	80	80	N/A
DOUGHTY CREEK @ ST. RT. 83	4.89	Primary Class B	16	876	16000	NON
DOUGHTY CREEK DST. GUGGISBURG CHEESE CO. @ TWP. RD. 123	14.29	Primary Class B	7	4814	17000	NON
KILLBUCK CREEK @ SR 39	31.7	Primary Class A	9	262	440	NON
KILLBUCK CREEK 0.1 MI. DST. HOLMES/COSHOCTON CO. LINE	20.7	Primary Class A	8	392	1400	NON
KILLBUCK CREEK AT ARMSTRONG @ PLEASANT HOME RD.	59.66	Primary Class A	7	355	630	NON
KILLBUCK CREEK AT BURBANK @ ST. RT. 83	66.85	Primary Class B	13	387	1600	NON
KILLBUCK CREEK AT HELMICK @ COVERED BRIDGE (TWP. RD. 25)	13.28	Primary Class A	8	345	960	NON
KILLBUCK CREEK AT HOLMESVILLE @ CO. RD. 320	37.13	Primary Class A	14	293	590	NON
KILLBUCK CREEK AT MILLERSBURG @ CLINTON AVE.	31.76	Primary Class A	5	211	480	NON
KILLBUCK CREEK DST. KILLBUCK WWTP @ U.S. RT. 62	23.91	Primary Class A	15	345	2000	NON
KILLBUCK CREEK NEAR WESTWOOD, DST. APPLE CREEK	49.4	Primary Class A	14	541	9800	NON
KILLBUCK CREEK NW OF HOLMESVILLE @ CO. RD. 1	40.05	Primary Class A	7	445	4500	NON
KILLBUCK CREEK S OF WOOSTER @ VALLEY RD.	46.02	Primary Class A	8	513	4100	NON
KILLBUCK CREEK UPST. WOOSTER @ MCAFEE RD.	55.35	Primary Class A	13	283	1500	NON
KILLBUCK CREEK UPST. WOOSTER WWTP	49.95	Primary Class A	14	569	20000	NON

Table 14. Bacteria Sampling Results and Attainment Status

Station	RM	Rec. Use	Number of Samples	Geometric Mean	Maximum	Attainment Status
KILLBUCK CREEK W OF CRESTON @ CANAAN CENTER RD.	70.82	Primary Class B	7	1282	9900	NON
L. APPLE CREEK JUST E OF WOOSTER @ MOUTH	0.01	Primary Class B	6	273	3100	NON
L. KILLBUCK CREEK NEAR WOOSTER @ ST. RT. 302	0.55	Primary Class B	7	193	2900	NON
MARTINS CREEK AT MARTINSVILLE @ TWP. RD. 601	3.5	Primary Class B	7	999	130000	NON
N. BR. SALT CREEK N OF FREDERICKSBURG @ MORELAND RD.	3.29	Primary Class B	7	1243	4200	NON
PAINT CREEK NW OF MILLERSBURG @ TWP. RD. 262	5.27	Primary Class B	7	1612	110000	NON
PAINT CREEK SW OF HOLMESVILLE @ TWP. 556	1.84	Primary Class B	7	1270	110000	NON
SALT CREEK @ CO. RD. 192, E OF TWP. RD. 566	3.02	Primary Class B	14	164	1300	NON
SHREVE CREEK DST. SHREVE WWTP @ SHREVE EASTERN RD.	3.06	Primary Class B	8	2255	13000	NON
TRIB TO DOUGHTY CRK (14.34/1.35) NEAR CHARM, 25' UPST MOUTH	0.01	Primary Class B	6	2056	9600	NON
TRIB. TO DOUGHTY CREEK (14.34) NEAR CHARM @ TWP. RD. 156	1.35	Primary Class B	5	936	16000	NON
TRIB. TO DOUGHTY CREEK (14.34) NW OF CHARM @ ST. RT. 557	0.6	Primary Class B	6	2620	19000	NON
TRIB. TO KILLBUCK CREEK (43.60) AT MILLBROOK @ KISTER RD.	2.68	Primary Class B	1	3100	3100	N/A
WOLF CREEK @ TWP. RD. 31	4.07	Primary Class B	1	420	420	N/A
WOLF CREEK SW OF KILLBUCK @ TWP. RD. 78	2.08	Primary Class B	7	804	3100	NON
Yellow Highlighted Cells – Insufficient Information **Red Highlighted Cells – Not Meeting Standard**						

Bacteria data were also evaluated by recreational use designation, and are presented in Table 15. Based on the data collected during the 2009 survey, both primary contact recreation classes are not in compliance with the standard on a basin-wide assessment.

Table 15. Bacteria Results by Classification

	Primary Contact Class A		**Primary Contact Class B**	
	Results	***E. coli* Standard**	**Results**	***E. coli* Standard**
Sample Number	122		164	
Maximum (#/100 ml)	20000		130000	
Geometric Mean	373.3	126 (Geo.Mean)	777.0	161 (Geo.Mean)
Exceedances of Max.	76	298 (Max).	88	523 (Max.)

Green Highlighted Cells – Meeting Standard
Red Highlighted Cells – Not Meeting Standard

Organic Water Chemistry

Samples were collected on 10/14/2009 and analyzed for a total of 112 parameters using U.S. EPA methods 624 and 625. No constituents were detected in any of the samples. Results are included in Appendix Table 3.

Sediment Assessment

Sediment samples were collected from seven locations in the Killbuck Creek watershed study area by the Ohio EPA during the 2009 survey (Table 16, Appendix Table 4). Samples were analyzed for metals, semi-volatile organic compounds, nutrients, and particle size. Sediment data were evaluated using guidelines established in Development and Evaluation of Consensus-Based Sediment Quality Guidelines for Freshwater Ecosystems (MacDonald et.al. 2000), and Ohio Specific Sediment Reference Values (SRVs) for metals (Ohio EPA 2008c).

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, and is comparable to background conditions. A Probable Effect Concentration (PEC) indicates a level above which harmful effects are likely to be observed. Sediment samples were conservatively sampled by focusing on depositional areas of fine grain material (silts and clays). Organic chemical parameters were tested at all seven sampling locations. All organic chemicals were reported as not detected - organic chemical measurements in sediment were within acceptable ecological levels.

Of the metals measured in the sediment samples, arsenic, calcium, and zinc were detected above ecological screening guidelines (Table 16). Five arsenic and one zinc result were slightly elevated above the TEC. However, all of the arsenic and zinc values were below Ohio SRV benchmarks. One calcium sample was detected above the Ohio SRV benchmark value. Killbuck Creek watershed sediments were not above any PEC values and are indicated to be protective of biological integrity at the sites sampled.

Table 16. Sediment Sampling Results for Metals

Site Location	Eco-region	% Solids	Al	As	Ba	Cd	Ca	Cr	Cu	Fe	Pb	Mg	Mn	Ni	K	Se	Na	Sr	Zn
		%	Results (mg/kg)																
Apple Cr @ Ely Rd Dup A	EOLP	54.3	8790	10.7	66.3	0.189	8920	11.5	13.7	25400	15.7	3400	873	14.7	735	0.735	1840	11	83.7
Apple Cr @ Ely Rd Dup B	EOLP	56.8	8150	9.48	60.6	0.168	8410	10.5	12	21300	13.3	2810	729	13.2	650	0.65	1630	10	75.7
Camel Ck @ Greenich	EOLP	69.7	6890	10.7	91.9	0.283	8240	9.22	12.6	23000	19.3	3590	381	16.5	550	0.55	1380	18	105
Doughty Cr @ CR 120	WAP	56.9	4030	8.3	58.7	0.069	9220	11.4	12.2	25400	11.8	2010	728	14.3	690	0.69	1725	10.5	79.6
Doughty Cr @ SR 343	WAP	48.4	10800	8.05	119	0.238	7870	13.3	14.2	26700	14.5	2760	1810	18.6	700	0.7	1750	24	96
L. Killbuck Cr @ SR 302	EOLP	52.2	10400	12.8	141	0.161	23100	13.7	13.9	27100	15.5	4140	495	15.9	695	0.695	1740	30	114
Killbuck Cr @ TR 346	EOLP	49.6	11500	13.1	131	0.262	8510	15.1	17.3	30100	19.7	3520	955	17.6	670	0.67	1680	20	126
Killbuck Cr dst SR 3	EOLP	68	8020	10.2	109	0.156	4390	10.7	9.94	21700	12.5	2340	518	12.7	535	0.535	1335	8	85.9
Sediment Reference Values (mg/kg)	**State-wide**										**47**								
	EOLP		**29000**	**25**	**190**	**0.96**	**21000**	**29**	**32**	**41000**		**7100**	**1500**	**33**	**6800**	**1.7**		**62**	**160**
	WAP		**53000**	**19**	**360**	**0.8**	**27000**	**53**	**33**	**51000**		**9900**	**3000**	**61**	**14000**	**2.6**		**250**	**170**
PEC (mg/kg)				**33**		**5**		**111**			**128**			**49**					**459**
TEC (mg/kg)				**9.79**		**0.99**		**43.4**	**31.6**		**35.8**			**22.7**					**121**

Result is above the TEC

Result is above one of the Sediment Reference Values

Result is below detection limit, reported as 1/2 of the MDL

Causal Associations

Table 17 was prepared to help visualize impaired sites and possible causes of impairment. Habitat and TDS concentrations seem to play a factor in a number of sites. Of the four sites listing a point source all had nutrients and TDS elevated above the average values for all sites found in full attainment of the biological standards.

Table 17. Causal Associations Table

Stream	RM-Location	Causes	Sources	Habitat Score (QHEI > 60) QHEI	Site above Ave. for all Full Attainment Sites Nutrients (NO3/P)	Site above Ave. for all Full Attainment Sites TDS
Killbuck Creek	66.9^{W} – SR 83	Natural Conditions		No	No / No	Yes
Killbuck Creek	46.0^{B} – Valley Rd.	Direct Habitat Alterations, Dissolved Oxygen, Organic Enrichment	Channelization, Wooster WWTP, Natural Sources	No	Yes / No	Yes
Camel Creek	0.5^{H} – Westfield Rd.	Sedimentation/Siltation	Channelization	No	Yes / No	Yes
Little Apple Creek	5.0^{H} – Schellin Rd.	Direct Habitat Alterations	Channelization, Dam or Impoundment	Yes		
Little Apple Creek	4.5^{H} – Smithville-Western Rd.	Direct Habitat Alterations	Channelization, Dam or Impoundment	Yes	No / No	No
Little Apple Creek	1.7^{H} – Portage Rd.	Direct Habitat Alterations	Channelization, Dam or Impoundment, Urban Runoff/Storm Sewers	No	No / No	No
Little Apple Creek	0.2^{H} – ust. Bowman St.	Direct Habitat Alterations	Channelization, Dam or Impoundment, Urban Runoff/Storm Sewers	Yes	No / No	Yes
Trib. to Killbuck Creek @ RM 43.60 (Millbrook Trib.)	3.3^{H}/2.7– Kister Rd.	Nitrate/Nitrite	Unrestricted Cattle Access	Yes	Yes / No	No
Shreve Creek	3.1^{H} – Shreve Eastern Rd.	Sedimentation/Siltation Nitrate/Nitrite	Channelization, Shreve WWTP	No	Yes / Yes	Yes
North Branch Salt Creek	3.3^{H} – Moreland Rd.	Dissolved Oxygen, Sedimentation/Siltation	Channelization	No	No / Yes	No
Sapps Run	0.8^{H} – C 349	Direct Habitat Alterations, Phosphorus (Total)	Channelization, Holmes Cheese WWTP	No	No / Yes	Yes
Corns Run	0.6^{H}/0.7 – C 400	Dissolved Oxygen, Ammonia (Total), Total Dissolved Solids, Phosphorus (Total)	Holmes Cheese WWTP	Yes	No / Yes	Yes
Doughty Creek	18.7^{H} – T 359	Sedimentation/Siltation	Channelization	No	No / No	Yes
Tributary to Doughty Creek @ RM 14.34 (Charm Trib.)	0.6^{H} – SR 557	Dissolved Oxygen, Sedimentation/Siltation	Unrestricted Cattle Access, Sewage Discharges in Unsewered Areas	No	No / No	Yes

Yellow: Partial Attainment
Red: Non Attainment

Additional analysis was undertaken to see if specific parameters were more commonly elevated when compared to sites in full attainment. Parameters were considered of potential importance if they were elevated in 75% or more of the biologically impaired sites based on the overall average for attaining sites. A parameter was also considered of potential importance if it was elevated in 25% or more of the biologically impaired sites based on the overall attaining sites average plus one standard deviation. This data is presented in Table 18. As can be seen, there appears to be a strong association with conductivity and TDS. Calcium, chloride, potassium, and sodium are also commonly associated with increases in conductivity.

Table 18. Elevated parameters

	Arsenic	Calcium	Chloride	Potassium	Sodium	Spec. conductance	TKN	TDS	Uncorr. conductivity
Average	53.8%	61.5%	61.5%	61.5%	84.6%	83.3%	76.9%	76.9%	75.0%
Ave. + 1 SD	53.8%	30.8%	46.2%	38.5%	38.5%	58.3%	7.7%	38.5%	41.7%

Cells are highlighted if: Average is exceeded at 75% of the impaired sites
Average plus one standard deviation is exceeded at 25% of the impaired sited

NPDES Permitted Dischargers

A list of NPDES permitted dischargers is included in Table 19 below. There are also brief descriptions of eight specific dischargers and several figures describing their effluent quality.

Table 19. NPDES Discharge permits in the Killbuck Creek Basin

Facility Name	County	Permit Number	Receiving Stream
AC Products Inc	Wayne	3IN00264*CD	Apple Creek
AC Products Inc	Wayne	3IN00264*CD	Apple Creek
Amish Furniture Co	Holmes	3PR00466*AD	Martins Creek
Anmac Home IV Leeda Services	Holmes	3PR00429*AD	Kilbuck Creek
Apple Creek WWTP	Wayne	3PB00004*GD	Apple Creek
Berlin Village WWTP	Holmes	3PG00147*CD	Doughty Creek
Bosch Rexroth Corp	Wayne	3IN00243*DD	Killbuck Creek
BP Amoco Oil Corp Bulk Plant Millersburg	Holmes	3IN00294*CD	Killbuck Creek via Unnamed Trib
Burbank WWTP	Wayne	3PA00032*BD	Kilbuck Creek
CerCo LLC-Diamonite Plt	Wayne	3IN00005*FD	Shreve Run
Charm Engine	Holmes	3PR00409*AD	"Charm Trib"
Charm Post Office & Harness Shop	Holmes	3PR00410*AD	"Charm Trib"
Clark Elem Sch	Holmes	3PT00061*BD	Doughty Creek
Cloverleaf Jr & Sr HS	Medina	3PT00069*BD	Camel Creek
Creston STP	Wayne	3PB00012*HD	Killbuck Ditch, Killbuck Cr
El Rancho Grande	Wayne	3PR00473*AD	Apple Creek
Forest View MHP WWTP	Wayne	3PV00125*AD	Tributary to Apple Creek
Fredericksburg WWTP	Holmes	3PA00031*CD	Salt Creek
Gingery Allot STP	Wayne	3PG00131*DD	Un-named Trib of Little Apple Creek
Golden Veal Corp	Wayne	3IH00074*DD	Killbuck Creek
Graphic Publications Inc	Holmes	3PR00314*BD	ut Honey Run
Guggisberg Cheese Inc	Holmes	3IH00101*DD	Doughty Creek
Guggisberg Swiss Inn	Holmes	3PR00164*BD	Doughty Creek
Harsco Corp GWTP	Wayne	3IN00181*CD	Killbuck Cr via trib
Hilltop Group Home Inc	Holmes	3PR00448*AD	Sapps Run
Holmes Cheese Co Inc	Holmes	3IH00102*DD	Corns Run
Holmes Co Jail and Training Ctr WWTP	Holmes	3PG00151*CD	Martins Creek
Holmes County Landfill	Holmes	3IN00282*BD	UT to Colliers Run
Holmes County Landfill	Holmes	3IN00282*BD	UT to Colliers Run
Holmes County Landfill	Holmes	3IN00282*BD	UT to Honey Run
Holmes County Landfill	Holmes	3IN00282*BD	UT to Honey Run
Holmes Siding Contractors	Holmes	3PR00337*BD	Sand Run trib
Holmesville WWTP	Holmes	3PB00069*BD	Salt Creek
Horse & Harness Pub	Holmes	3PR00443*AD	Salt Creek
IAC Holmesville LLC - Canton Plant	Holmes	3II00002*FD	Salt Creek
Inn at Honey Run	Holmes	3PR00320*AD	Honey Run

Table 19. NPDES Discharge permits in the Killbuck Creek Basin

Facility Name	County	Permit Number	Receiving Stream
Inn Maid Noodles	Holmes	3IH00075*CD	Trib to Sand Run
Inn Maid Noodles	Holmes	3IH00075*CD	Trib to Sand Run
Keim Lumber Co	Holmes	3PR00408*AD	Doughty Creek
Killbuck STP	Holmes	3PB00067*FD	Killbuck Creek
Korner Kitchen	Holmes	3PR00456*AD	Paint Creek
Lecky & Sons Inc WWTP	Holmes	3PR00195*CD	Trib to Sapps Run
Millersburg WWTP	Holmes	3PC00100*GD	Killbuck Creek
Ole Mill Craft Build	Holmes	3PR00414*AD	Doughty Creek
Raber General Store	Holmes	3PR00415*AD	Doughty Creek
RBB Systems Inc	Holmes	3PR00444*AD	Shreve Creek Trib
Sandyville-East Sparta WWTP	Tuscarawas	0PJ00007*GD	Sandy Creek
Shortys Market LLC	Wayne	3PR00304*BD	Little Killbuck
Shreve WWTP	Wayne	3PB00021*FD	Shreve Creek
Southeast Local Sch Dist	Wayne	3PT00056*AD	Apple Creek
Sperry & Rice Mfg Co LLC Killbuck Plt	Holmes	3IR00050*ED	Killbuck Creek
Spruce Tree Village MHP	Wayne	3PV00119*AD	Little Apple Creek
Stahl/Scott Fetzer Co	Wayne	3IS00111*DD	Kilbuck Creek
Sunset MHP	Wayne	3PV00109*BD	Apple Creek
Three M Assoc LTD	Holmes	3PR00251*BD	Tributary to Martins Creek
Tricor Industrial	Wayne	3IS00117*CD	Killbuck Creek via UT
Triway Lanes	Wayne	3PR00312*BD	UT killbuck Creek
Wayne Attention Center	Wayne	3PG00056*ED	Salt Creek
Wayne Co Hillcrest STP	Wayne	3PH00047*ED	Little Apple Creek
Weaver Leather LLC	Holmes	3PR00367*AD	Trib to Martins Creek
West Homes High School	Holmes	3PT00068*BD	Paint Creek
Westfield Center WWTP	Medina	3PB00023*GD	Camel Creek
Wise Elementary School	Holmes	3PT00119*AD	Doughty Creek
Wooster STP	Wayne	3PD00013*ND	Apple Creek
Wooster STP	Wayne	3PD00013*ND	Apple Creek
Wooster STP	Wayne	3PD00013*ND	Killbuck Creek
Wooster Water Plant	Wayne	3IN00129*BD	Apple Creek
Wooster Water Plant	Wayne	3IN00129*BD	Apple Creek
Wooster Water Plant	Wayne	3IN00129*BD	Apple Creek
Wooster Yard	Wayne	3IN00309*BD	Killbuck Creek via Prairie Lane roadside ditch
Yoder Lumber Co - Buckhorn Division	Holmes	3PR00402*AD	Bucks Run

Apple Creek WWTP (NPDES Permit #3PB00004)

The wastewater treatment is designed for a permitted average daily flow of 0.3 mgd and consists of comminution, pre-aeration, primary clarification, trickling filters, secondary clarifiers, rapid sand filtration, and UV disinfection. The plant discharges to Apple Creek at RM 8.3. The current plant outfall was formerly identified as outfall 002 in permit

#3PB00004*FD. When renewed in 2007, the current effective permit (3PB00004*GD), Ohio EPA renamed the outfall 001 to reflect plant operational changes. Figure 13 shows graphs of discharge data for the plant. Compliance issues have placed the plant into significant noncompliance with its NPDES permit. The plant is currently operating at 66% of its design capacity (annual mean / ADF of 0.3 mgd).

Creston WWTP (NPDES Permit #3PB00012)

The Creston WWTP discharges to Killbuck Ditch (RM 1.0) and enters Killbuck Creek at RM 71.7. Treatment consists of secondary extended aeration with ammonia removal. The WWTP has a permitted design capacity of 0.3 MGD. As seen in Figure 14, it appears that there is a general decreasing trend in the number of NPDES permit violations while flow and cBOD seem to have increased. The plant has operated at 95%, 102%, and 81% of its design capacity (annual mean / ADF of 0.3 mgd) in the years 2007, 2008, and 2009 respectively. Winter appears to be time period of greatest stress to the system where it was operating at 117% (2007), 135% (2008), and 104% (2009) of its daily mean discharge capacity.

Holmes Cheese WWTP (NPDES Permit #3IH00102)

Holmes Cheese is a cheese manufacturing facility that discharges treated wastewater to Corns Run at RM 1.1. The facility has historically treated wastewater using a lagoon treatment system. On June 15, 2010, the Ohio EPA issued a Permit-to-Install for a new, 0.120 mgd treatment system. The new system includes screening, equalization, anaerobic digestion, aerobic treatment using a Moving Bed Biofilm Reactor (MBBR), clarification, phosphorus removal and final filtering. The treated wastewater will combine with 0.08 mgd of COW water (Condensate of Whey) from the whey evaporation system for a total discharge volume of 0.200 mgd. The new WWTP is currently under construction and is in start-up phase of the construction project. The facility has been in significant noncompliance of its NPDES permit for effluent limit violations, compliance schedule violations, and the periodic discharges of sludge to Corns Run (Figure 15). Some of the highest instream phosphorus concentrations ever measured in the state was found downstream of the plant in Corns Run and Sapp's Run. As a result of the noncompliance issues, the facility has been referred to the Ohio Attorney General for enforcement actions.

Killbuck WWTP (NPDES Permit #3PB00067)

The Village of Killbuck operates a WWTP with a design capacity of 0.411 mgd which discharges to Killbuck Creek at RM 24.4. The current plant was built following issuance of a PTI in 1986. Treatment at the plant consists of activated sludge secondary settling and disinfection is achieved through a UV system installed in 1997. Sewer lining and manhole rehab have reduced infiltration and inflow at the plant (Figure 16) allowing it to begin to function within its design capacity. Average annual flows from 2006 thru 2008 were 0.516 mgd, 0.555 mgd, and 0.652 mgd respectively. Following collection system rehabilitation average annual flows were 0.226 mgd in 2009 and 0.305 mgd in 2010.

Millersburg WWTP (NPDES Permit #3PC00100)

The village of Millersburg operates a WWTP with a design flow of 1.4 mgd most recently upgraded in 2005. The PTI issued in 2005 was for a plant with an oxidation ditch,

biophos tank, secondary settling, and UV disinfection. The plant was designed to operate as a low sludge yield system. As is shown in Figure 17, NPDES violations dramatically increased following the new system installation. The village discontinued operation of the plant as a low sludge yield system and began operating in a conventional aeration mode. Ohio EPA issued Director's Final Findings and Orders to the village on October 21, 2010. The orders require the village to evaluate the current plant design capacity when operated in a conventional aeration mode. It is possible that the current 1.4 mgd design flow will be adjusted downward.

Shreve WWTP (NPDES Permit #3PB00021)

The Shreve WWTP discharges to Shreve Creek at RM 3.4. The WWTP utilizes primary settling, trickling filtration, and effluent disinfection. For the time period 2002 thru 2009 the plant is operating at 64% of the 0.483 MGD design capacity. Figure 18 contains information on the plant's discharge.

Westfield Center WWTP (NPDES Permit #3PB00023)

The Westfield Center WWTP is located in the Village of Westfield Center in Medina County. The plant discharges to Camel Creek at RM 2.47, and has a permitted design flow of 0.635 mgd. The Westfield Center WWTP is a small tertiary plant with extended aeration and ammonia removal that discharges to Camel Creek at RM 2.47. A PTI was issued to the Village in June of 2006 to install phosphorus removal equipment. Overall the plant is operating at 51% of its daily design capacity. The facility maintains a good compliance record with 1 violation in 2008 and zero in 2009. As can be seen in Figure 19, beginning in 2008 there was a decrease in the discharge of phosphorus, following start up of the removal system.

Wooster WWTP

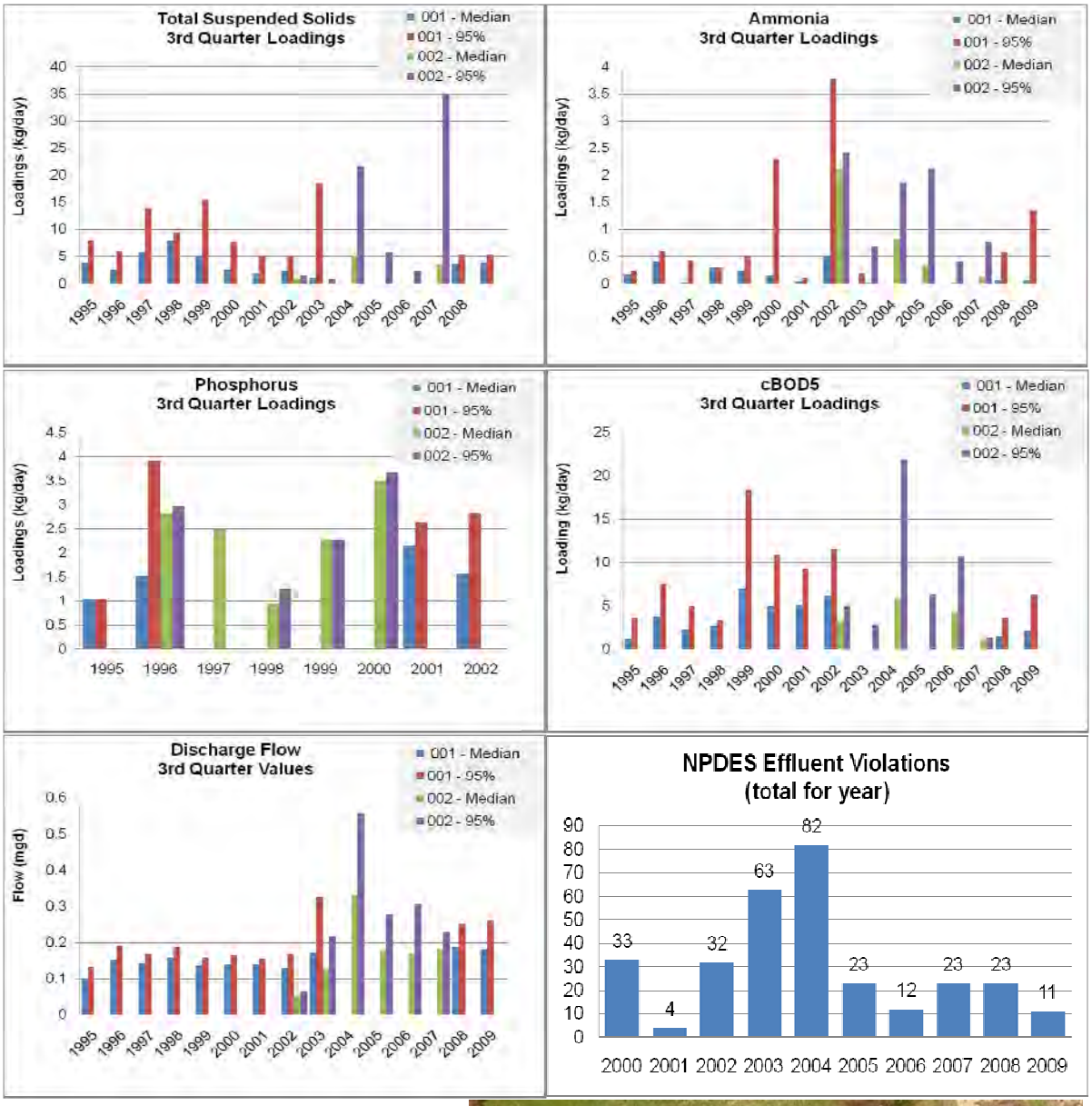
The City of Wooster operates a 7.5 MGD plant that discharges to Killbuck Creek at RM 49.88. The City of Wooster initiated a major upgrade to their wastewater treatment plant beginning in September 2005 and completed construction in November 2007. The upgrade was intended to provide more efficient treatment at the WWTP and to eliminate SSOs within the collection system. The upgraded WWTP was designed to operate as a low sludge yield system.

The new WWTP is a vertical loop reactor system. Current treatment processes include grit and grease removal, primary settling tanks, vertical loop reactor, final settling tanks, anaerobic digesters, phosphorous removal, ultraviolet disinfection, and post aeration.

To date the WWTP has experienced significant problems operating the plant as designed (see Figure 20). They have been forced to forgo the low sludge mode as designed and operate the plant in a more conventional method. The plant had 454 violations in 2006, 528 in 2007, 258 in 2008, and 112 in 2009.

In 2009, Ohio EPA proceeded with escalated enforcement against the City of Wooster. Ohio EPA issued draft orders against the City. The City responded with a proposal to build an industrial wastewater trickle filter as a pretreatment component. The goal is to treat the wastewater from a high strength industrial discharger before it enters the plant.

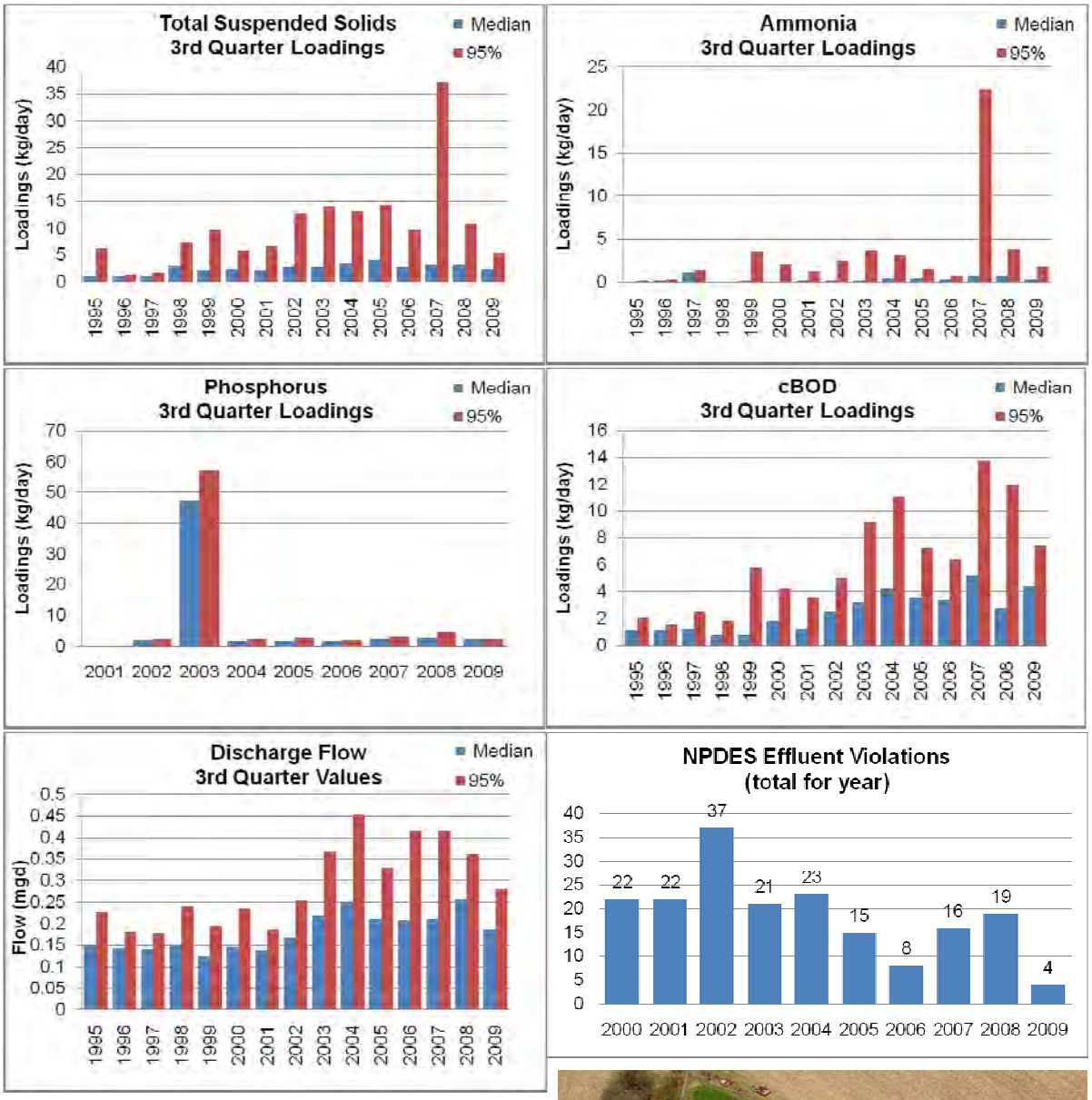
By providing pretreatment, the City hopes that the current treatment plant will be able to operate as designed. The construction on the trickle filter started in 2010 and the component went online February 2011. The impact will be evaluated in the upcoming months. Based on the results, Ohio EPA will issue final findings and orders against the City of Wooster's WWTP.



Apple Creek WWTP
3PB00004

Receiving stream:
Apple Creek

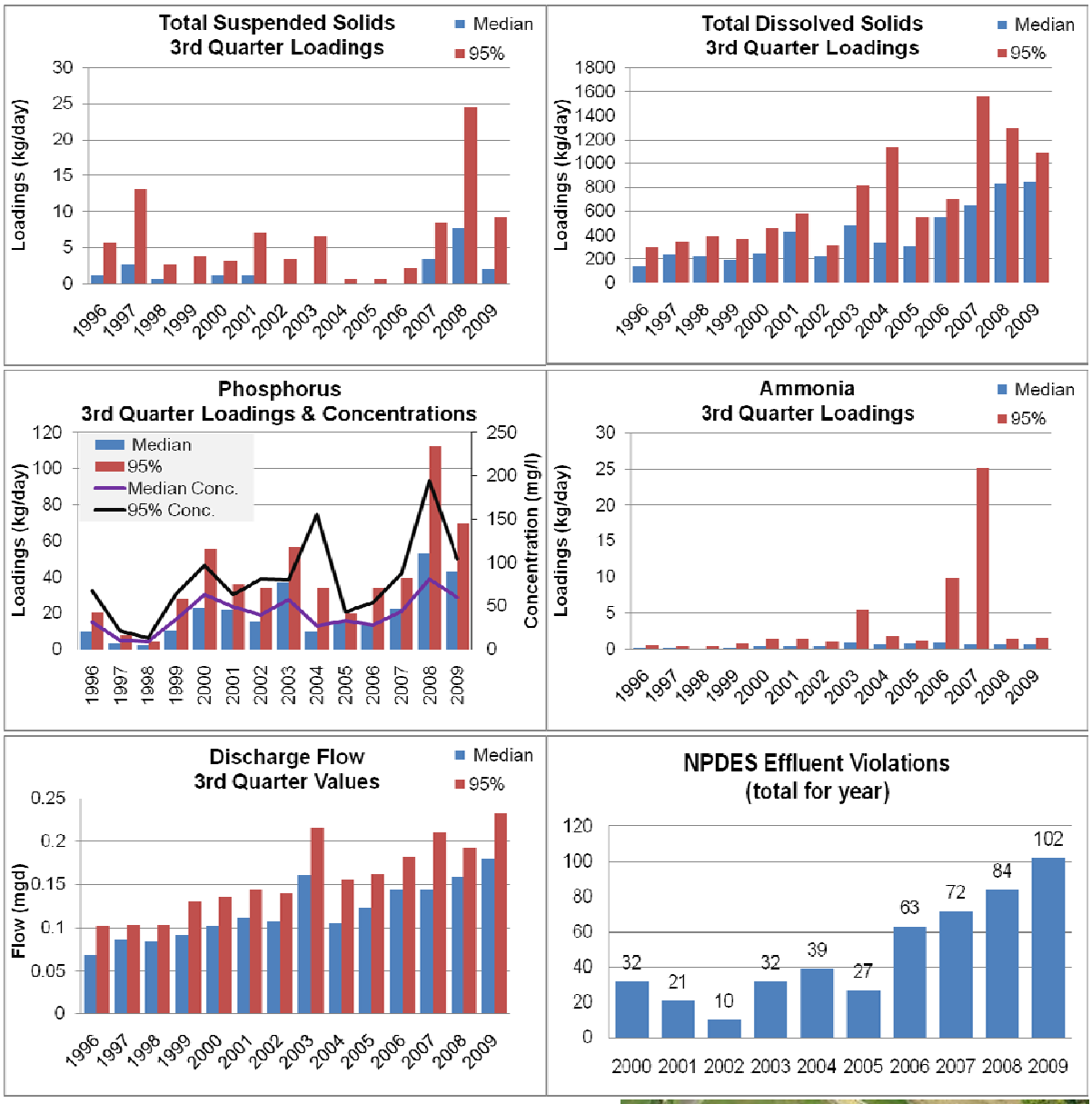
Figure 11. Apple Creek WWTP discharge data summary.



Creston WWTP
3PB00012

Receiving stream:
Killbuck Ditch

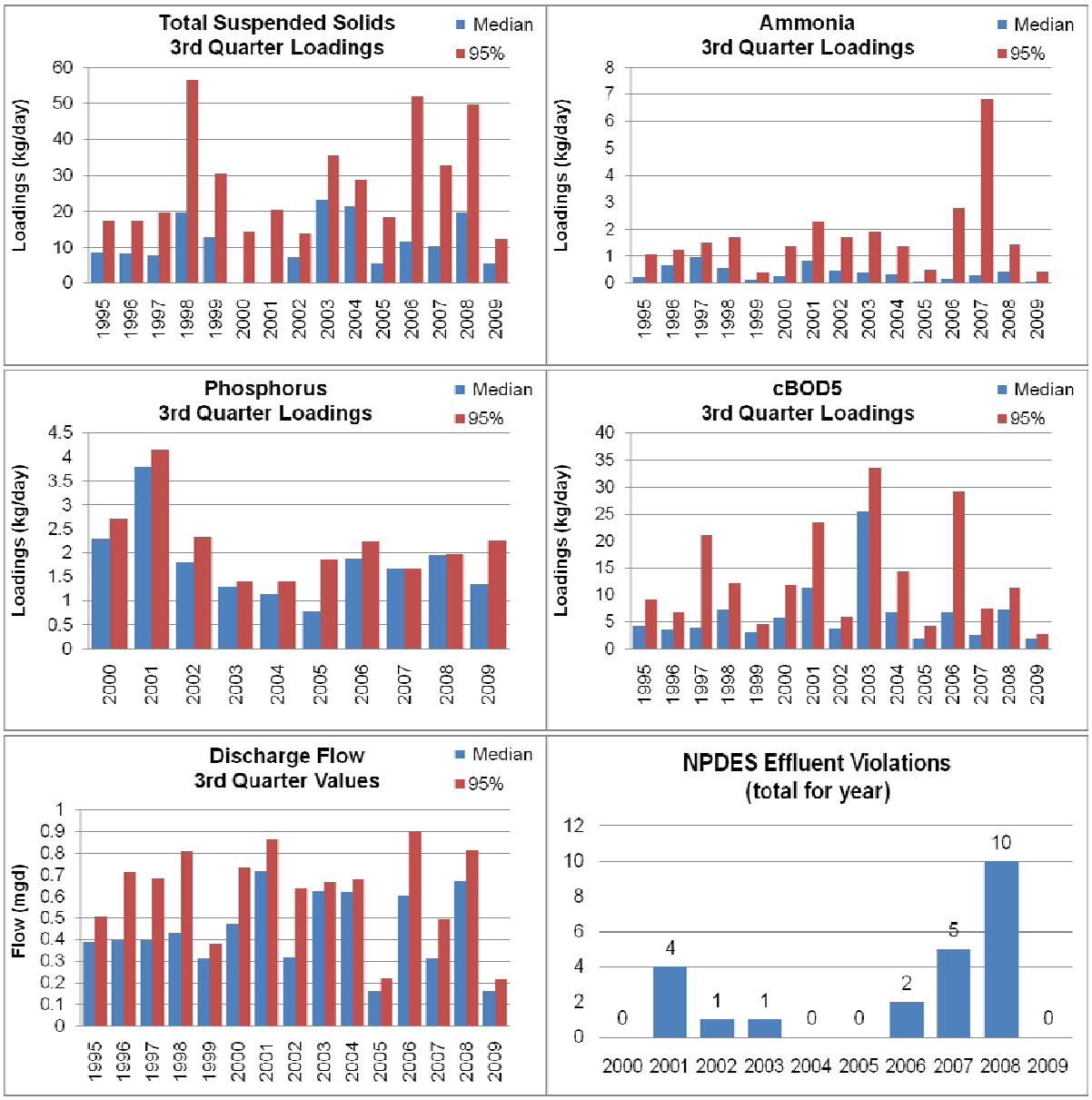
Figure 12. Creston WWTP discharge data summary.



Holmes Cheese
3IH00102

Receiving stream:
Corns Run

Figure 13. Holmes Cheese discharge data summary.



Killbuck WWTP
3PB00067

Receiving stream:
Killbuck Creek

Figure 14. Killbuck WWTP discharge data summary.

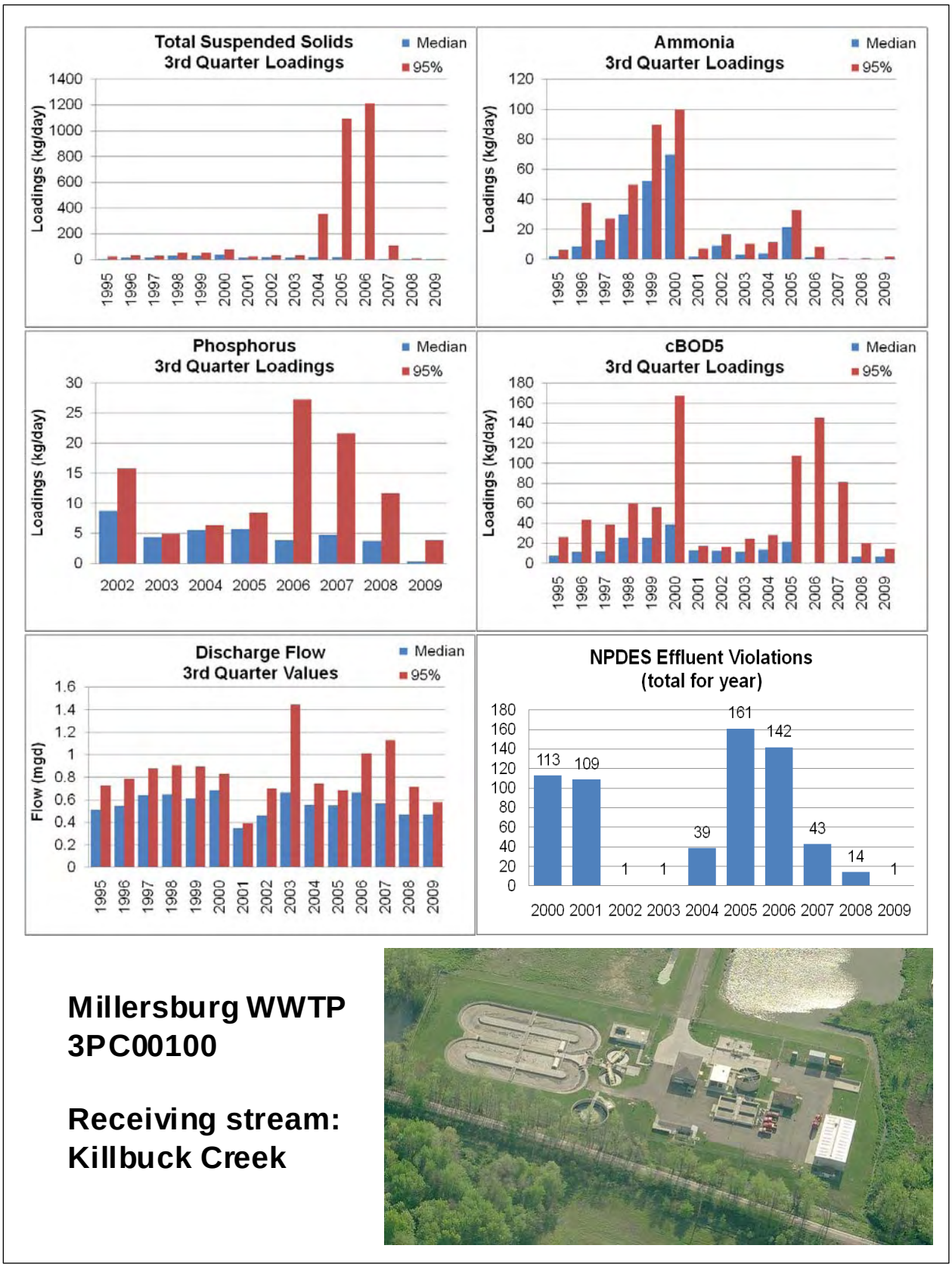
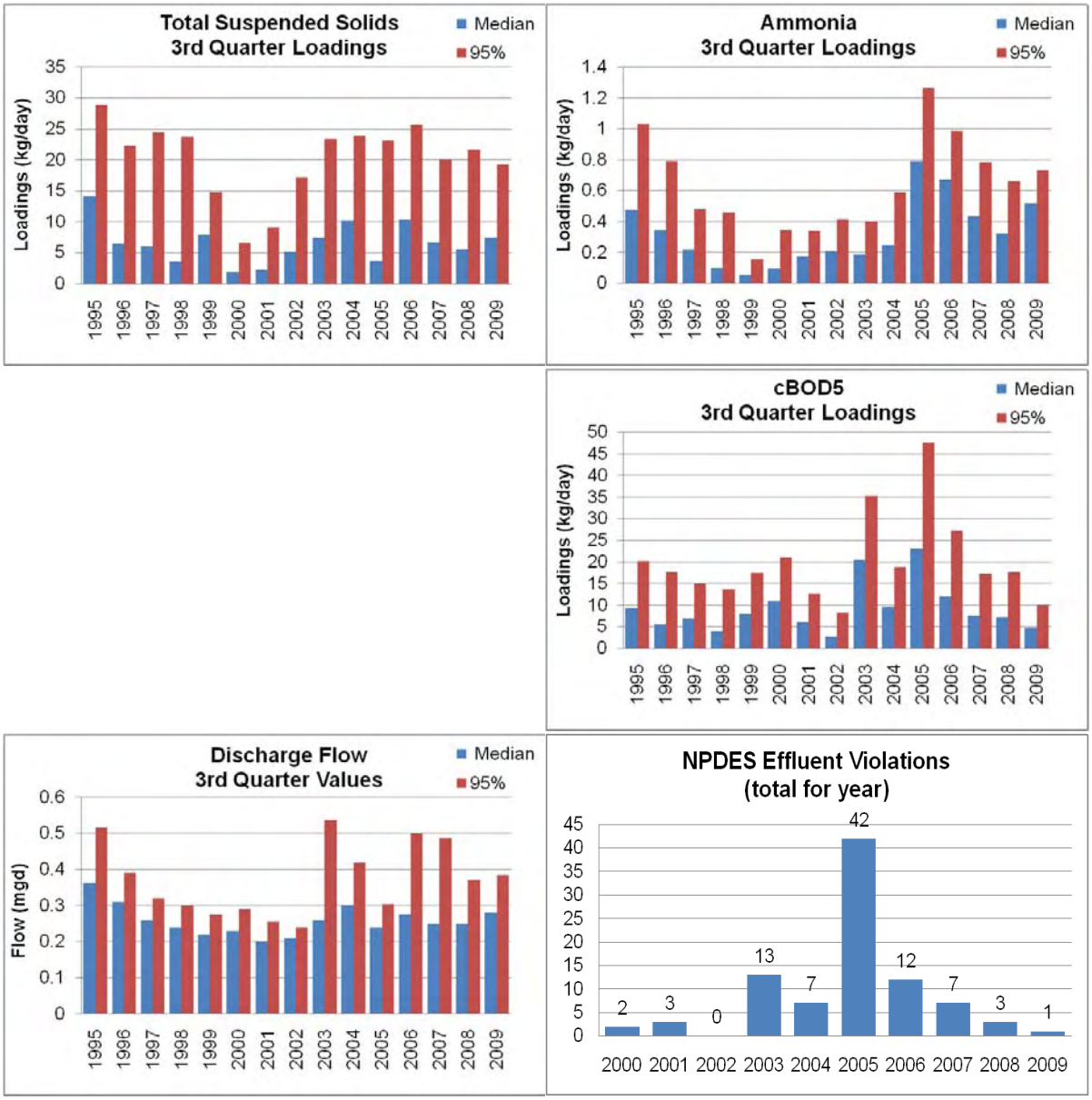


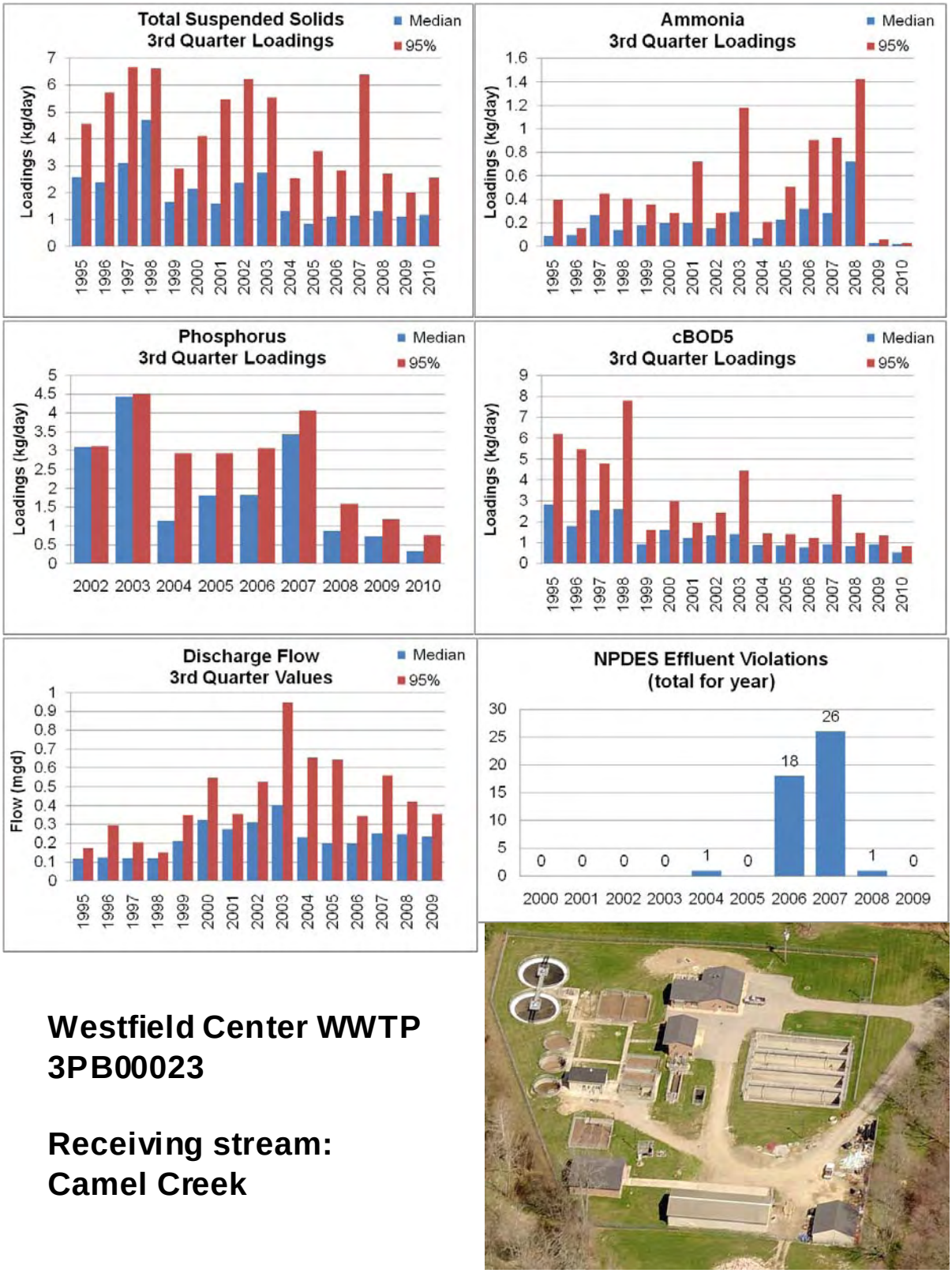
Figure 15. Millersburg WWTP discharge data summary.



Shreve WWTP
3PB00021

Receiving stream:
Shreve Creek

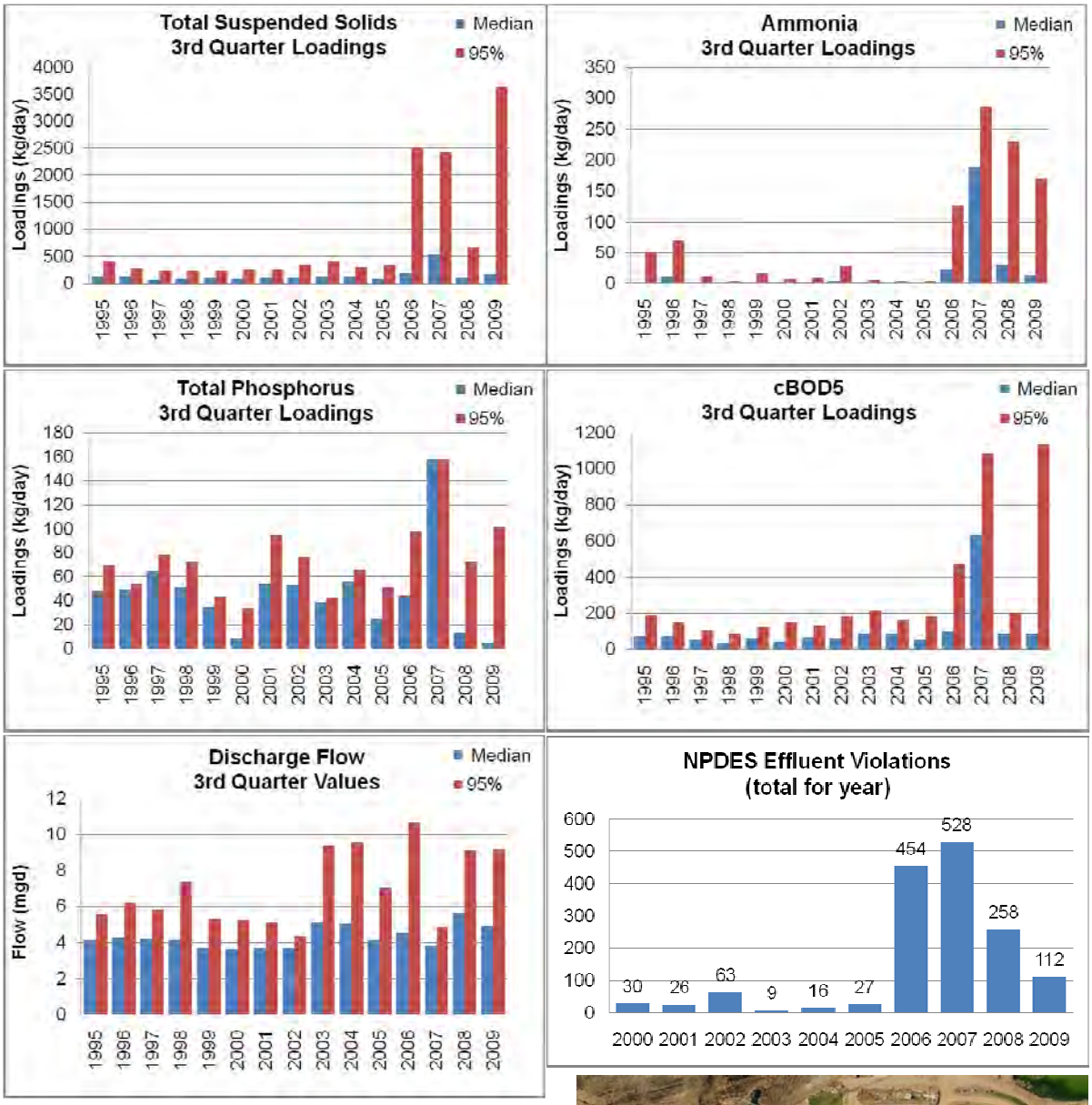
Figure 16. Shreve WWTP discharge data summary**.**



Westfield Center WWTP
3PB00023

Receiving stream:
Camel Creek

Figure 17. Westfield Center WWTP discharge data summary.



Wooster WWTP
3PD00013

Receiving stream:
Killbuck Creek

Figure 18. Wooster WWTP discharge data summary.

Physical Habitat Quality for Aquatic Life

The dominant physiographic feature of the Killbuck watershed is the long, south to north oriented valley of pre-Pleistocene origin. In the wake of the Illinoisan and Wisconsin ice sheets, the drainage was reversed, and the valley flattened and filled with silty-clay glacial till; the primary consequence being that Killbuck Creek was rendered a low gradient stream flanked by extensive wetlands. Average stream gradient for the Killbuck mainstem between the towns of Burbank and Killbuck is approximately 2.11 ft/mi. The secondary consequence was that the rich valley could only be exploited for post-Colonial settlement and farming following systematic ditching and draining of nearly the entire watershed, the legacy of which remained clearly evident in habitat evaluations conducted during the 2009 survey. For example, most sites were noted to have several or more physical hallmarks (aka modified attributes) of anthropogenic modification (Figure 21a; Table 20). However, unlike many watersheds in the western part of Ohio, most of the historically modified stream channels in the Killbuck basin are not maintained as featureless trapezoidal ditches, and have, therefore, passively recovered many attributes of functional streams. The upshot of this is that, despite systemic channelization, Killbuck Creek and its tributaries generally possess the physical habitat capable of supporting aquatic life expected for warmwater streams typical of the ecoregion (Figure 21b; mean QHEI = 63 ± 8 SD). More importantly,

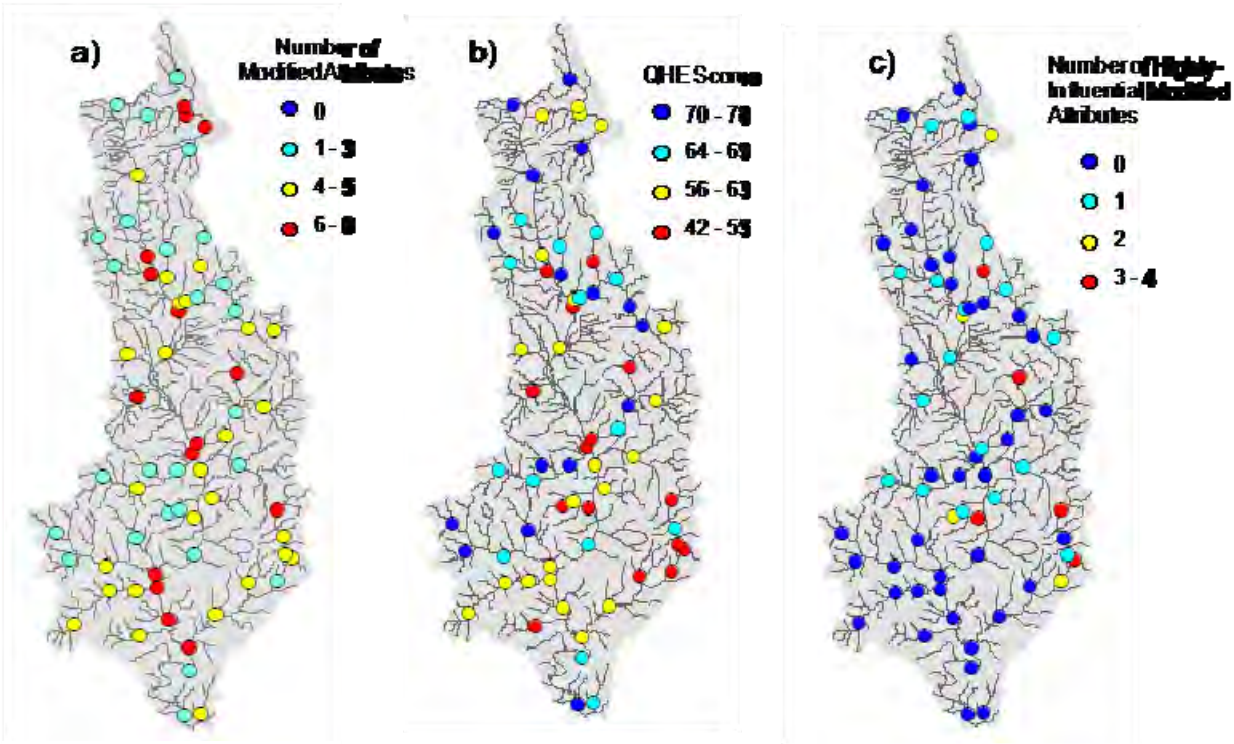


Figure 19. a) The total number of modified attributes, b) QHEI scores, and c) the number of highly-influential modified attributes (that are strongly limiting to aquatic life) at sites sampled in the Killbuck basin, 2009.

locations with poor habitat were isolated, and few sites had the hallmarks of anthropogenic modification known to strongly limit aquatic life (Figure 21c; Table 20). Where poor habitat scores were noted, the channel metric was the QHEI component that best separated scores in an ordination of sites by metric scores (Figure 22). Although this may be a trivial truth, and not apparently insightful on first blush, viewed within the historical context of systemic channelization, and the lack of on-going, active maintenance, one may conclude that streams are recovering at different rates. Indeed, stream gradient (along with depth of flow) largely governs the amount of energy available for a stream to reform channel features (Ward and Trimble 2004). Not surprisingly, gradient formed a second axis explaining habitat scores (Figure 22). Plotted by gradient (Figure 23a), the total number of modified attributes decreases with increasing gradient, and shows a threshold response at a gradient of ~ 15 ft/mi. However, the number of attributes strongly limiting to aquatic life tended to increase with stream gradient (Figure 23b), a result of comparatively recent modifications to upland headwaters. Despite the higher total number of modified attributes for streams with

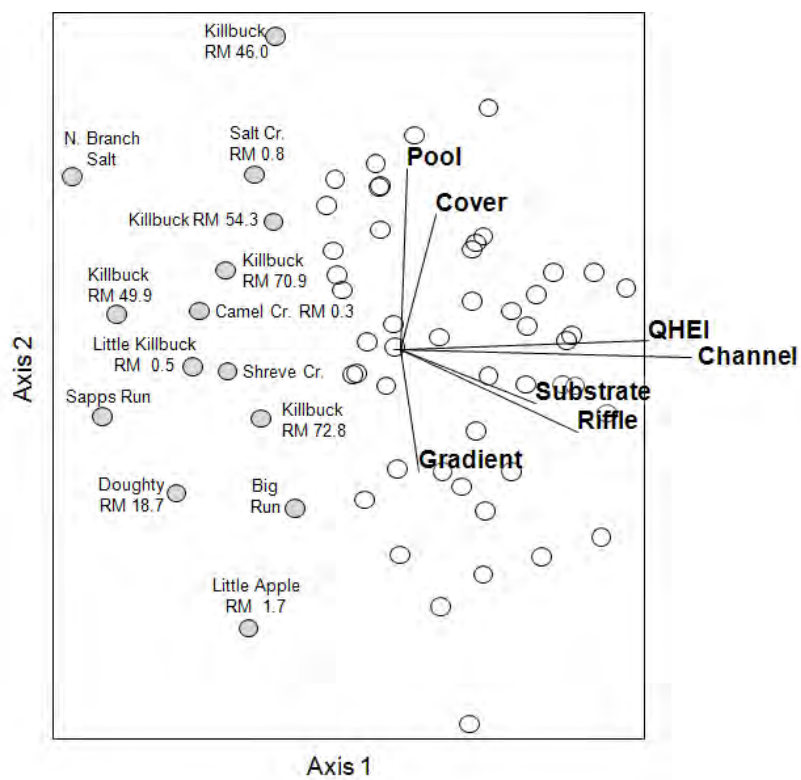


Figure 20. Ordination of habitat attributes (based on a binary matrix for presence-absence) for sites sampled in the Killbuck basin, 2009. The length and orientation of the lines drawn to individual metrics show the relative strength of correlation with the ordination axis.

gradients less than ~ 15 ft/mi, QHEI scores did not show a trend over stream gradient (Figure 23c) or drainage area (Figure 23d), suggesting the potential for most of the streams to passively recover, or to be amenable to passive restoration (e.g., over-wide channels). One key habitat feature not captured in Table 20 that is worthy of note is the absence of bank erosion. All 68 sites evaluated had a riparian border on at least one bank, and of the 26 sites noted for lacking a buffer on one side, most were double-checked, meaning that the bank was not completely bare. Coupled with the observation that the substrates in the Killbuck mainstem were comparatively free from silt and clay, suggests that sediments were being transported effectively, and the system was not being overwhelmed by upland sources, or by channelization of headwaters.

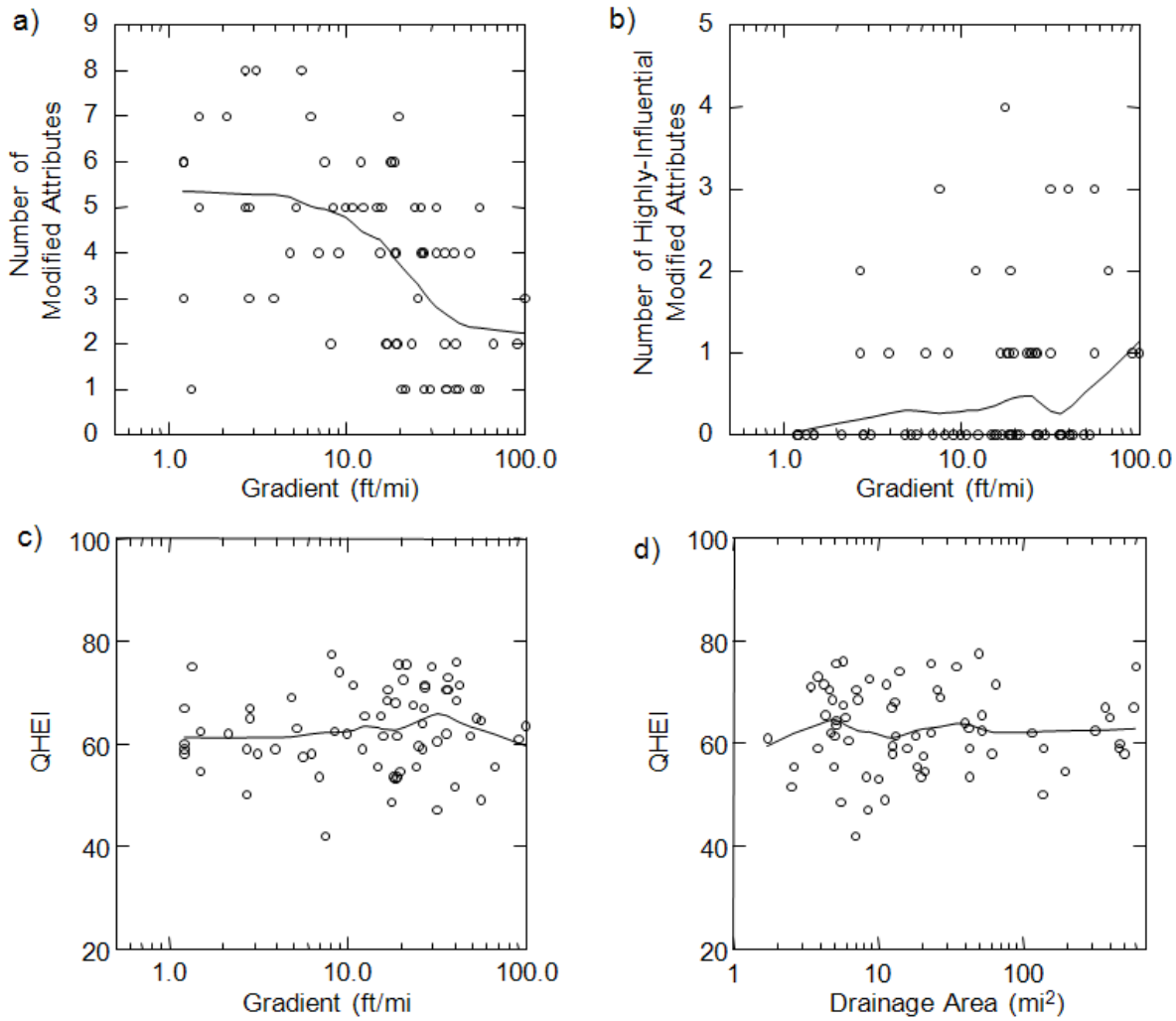


Figure 21. Scatter plots showing a) the total number of modified attributes by gradient, b) the number of high-influence attributes by gradient, c) QHEI scores by gradient, and d) QHEI scores by drainage area for sites sampled in the Killbuck basin, 2009. Trend lines are from LOWESS smoothing.

Table 20. QHEI scores and a matrix of habitat attributes for sites sampled in the Killbuck basin, 2009.

Key QHEI Components

			WWH Attributes											MWH Attributes																		
														High Influence					*Moderate Influence*													
River Mile	QHEI	Gradient (ft/mile)	No Channelization or Recovered	Boulder/Cobble/Gravel Substrates	Silt Free Substrates	Good/Excellent Substrates	Moderate/High Sinuosity	Extensive/Moderate Cover	Fast Current/Eddies	Low/Normal Overall Embeddedness	Max Depth > 40 cm	Low/Normal Riffle Embeddedness	Total WWH Attributes	Channelization or No Recovery	Silt/Muck Substrates	No Sinuosity	Sparse/No Cover	Max Depth < 40 cm (WD, HW)	Total HL MWH Attributes	Recovering Channel	Heavy/Moderate Silt Cover	Sand Substrates (Boat)	Handicap Substrate Origin	Fair/Poor Development	Low Sinuosity	Only 1-2 Cover Types	Intermittent and Poor Pools	No Fast Current	High/Moderate Overall Embeddedness	High/Moderate Riffle Embeddedness	No Riffle	Total ML MWH Attributes	(MWH HL+1)/(WWH+1) Ratio	(MWH HL+1)/(WWH+1) Ratio
(17-138) Trib. to Doughty Creek (RM 14.34)																																		
Year: 2009																																		
0.6	51.5	40.00	■	■		■	■						4				♦	♦	3					●			●		●	●		4	0.80	1.60
(17-144) Trib. to Killbuck Creek (RM 43.60)																																		
Year: 2009																																		
3.3	61.5	48.78	■	■			■	■		■	■	■	7						0		●		●	●			●					4	0.13	0.63
(17-146) Trib. to Wolf Creek (RM 6.49)																																		
Year: 2009																																		
1.4	62.0	35.71	■			■	■	■			■		5						0					●			●		●	●		4	0.17	0.83
(17-147) Trib. to Black Creek (RM 7.35)																																		
Year: 2009																																		
0.7	70.5	36.36	■	■		■	■	■	■	■	■	■	9						0											●		1	0.10	0.20
(17-148) Trib. to Paint Creek (RM 3.01)																																		
Year: 2009																																		
1.5	71.5	42.55	■	■	■	■	■	■		■	■	■	9						0									●				1	0.10	0.20
(17-149) Little Apple Creek (RM 9.80)																																		
Year: 2009																																		
1.1	59.0	26.32	■	■			■	■		■	■		6				♦		1				●	●			●				●	4	0.29	0.86
(17-150) Killbuck Creek																																		
Year: 2009																																		
75.7	75.5	21.28	■	■		■	■	■		■	■	■	8						0									●				1	0.11	0.22
72.8	59.0	12.05		■							■	■	3				♦	♦	2	●	●			●			●		●	●	●	6	0.75	2.25
70.9	57.5	5.59		■				■			■		3						0	●	●		●	●	●		●		●	●		8	0.25	2.25
66.9	59.0	3.91	■			■	■			■	■	■	6					♦	1					●	●		●					3	0.29	0.71
60.5	71.5	10.75	■	■		■		■	■		■	■	7						0	●				●	●				●	●		5	0.13	0.75
54.3	62.0	2.12		■				■			■		3						0	●	●			●	●		●		●	●		7	0.25	2.00
49.9	50.0	2.70		■						■	■		3	♦				♦	2	●			●	●	●	●	●		●		●	8	0.75	2.75
49.4	59.0	2.70	■	■		■	■	■	■		■		7					♦	1	●				●	●				●	●		5	0.25	0.88
46.0	54.5	1.49						■		■	■		3						0	●	●		●	●	●		●				●	7	0.25	2.00
37.1	62.5	1.49	■	■			■	■		■	■		6						0	●				●	●		●				●	5	0.14	0.86
35.6	67.0	2.83	■	■		■	■	■	■	■	■		8						0	●				●	●				●	●		5	0.11	0.67
28.9	65.0	2.83		■		■	■	■	■	■	■		7						0	●					●						●	3	0.13	0.50
24.9	59.0	1.21	■	■				■		■	■		5						0	●				●	●		●		●		●	6	0.17	1.17
23.9	60.0	1.21	■	■				■			■		4						0	●				●	●		●		●		●	6	0.20	1.40
20.7	58.0	1.21	■				■	■			■		4						0	●	●			●			●		●		●	6	0.20	1.40

Table 20. Continued.

Key QHEI Components			WWH Attributes											MWH Attributes																		
														High Influence					*Moderate Influence*													
River Mile	QHEI	Gradient (ft/mile)	No Channelization or Recovered	Boulder/Cobble/Gravel Substrates	Silt Free Substrates	Good/Excellent Substrates	Moderate/High Sinuosity	Extensive/Moderate Cover	Fast Current/Eddies	Low-Normal Overall Embeddedness	Max Depth > 40 cm	Low-Normal Riffle Embeddedness	Total WWH Attributes	Channelized or No Recovery	Silt/Muck Substrates	No Sinuosity	Sparse/No Cover	Max Depth < 40 cm (WD, HW)	Total H.I. MWH Attributes	Recovering Channel	Heavy/Moderate Silt Cover	Sand Substrates (Boat)	Handicap Substrate Origin	Fair/Poor Development	Low Sinuosity	Only 1-2 Cover Types	Intermittent and Poor Pools	No Fast Current	High/Mod. Overall Embeddedness	High/Mod. Riffle Embeddedness	No Riffle	Total M.I. MWH Attributes	(MWH H.I.+1)/(WWH+1) Ratio	(MWH M.I.+1)/(WWH+1) Ratio
(17-150) Killbuck Creek																																
Year: 2009																																
13.3	67.0	1.21	■			■	■	■	■		■		6						0				●						●		●	3	0.14	0.57
2.1	75.0	1.34	■	■		■	■	■	■	■	■	■	9						0		●											1	0.10	0.20
(17-151) Bucklew Run																																
Year: 2009																																
1.5	65.5	12.42	■			■	■	■		■	■	■	7						0		●		●	●				●		●		5	0.13	0.75
(17-153) Doughty Creek																																
Year: 2009																																
18.7	48.5	17.70		■									1	♦		♦	♦	♦	4	●	●		●					●		●	●	6	2.50	5.50
15.9	68.0	18.52	■	■		■	■	■			■		6						0	●								●		●	●	4	0.14	0.71
14.7	63.0	18.35	■			■	■		■		■		5				♦		1		●									●	●	3	0.33	0.83
14.3	55.5	24.10	■	■				■			■	■	5			♦			1		●		●					●		●	●	5	0.33	1.17
11.7	53.5	18.87	■							■	■	■	4			♦	♦		2				●					●				2	0.60	1.00
4.9	63.0	5.19	■			■	■	■			■		5						0	●			●					●		●	●	5	0.17	1.00
0.6	58.0	3.12	■					■			■		3						0	●	●		●	●	●			●		●	●	8	0.25	2.25
(17-155) Military Run																																
Year: 2009																																
0.8	55.5	14.81	■				■	■		■	■		5						0		●		●	●				●			●	5	0.17	1.00
(17-157) Big Run																																
Year: 2009																																
3.6	53.5	6.94	■				■	■			■		4						0				●					●		●	●	4	0.20	1.00
(17-160) Wolf Creek																																
Year: 2009																																
4.1	61.5	15.75	■			■	■	■			■		5						0				●	●				●		●	●	5	0.17	1.00
2.5	62.0	9.85	■					■			■		3						0					●		●		●		●	●	5	0.25	1.50
(17-161) Black Creek																																
Year: 2009																																
9.8	73.0	36.36	■	■		■	■	■		■	■	■	8						0									●				1	0.11	0.22
4.6	69.0	4.80	■	■		■	■	■			■		6						0		●							●		●	●	4	0.14	0.71
(17-162) Shrimplin Run																																
Year: 2009																																
2.9	76.0	40.82	■	■		■	■	■		■	■	■	8						0									●				1	0.11	0.22
(17-166) Sapps Run																																
Year: 2009																																

Table 20. Continued.

Key QHEI Components			WWH Attributes										MWH Attributes																
													High Influence				*Moderate Influence*												
River Mile	QHEI	Gradient (ft/mile)	No Channelization or Recovered	Boulder/Cobble/Gravel Substrates	Silt Free Substrates	Good/Excellent Substrates	Moderate/High Sinuosity	Extensive/Moderate Cover	Fast Current/Eddies	Low-Normal Overall Embeddedness	Max Depth > 40 cm	Low-Normal Riffle Embeddedness	Total WWH Attributes	Channelized or No Recovery	Silt/Muck Substrates	No Sinuosity	Sparse/No Cover	Max Depth < 40 cm (WD, HW)	Total MWH Attributes	Recovering Channel	Heavy/Moderate Silt Cover	Sand Substrates (Boat)	Handicap Substrate Origin	Fair/Poor Development	Low Sinuosity	Only 1-2 Cover Types	Intermittent and Poor Pools	No Fast Current	High/Mod. Overall Embeddedness	High/Mod. Riffle Embeddedness	No Riffle	Total ALL WWH Attributes	(MWH ALL+1)/(WWH+1) Ratio	(MWH ALL+1)/(WWH+1) Ratio
(17-166) Sapps Run																																			
Year: 2009																																			
0.8	47.0	31.74	■	■			■						3			♦	♦	♦	3	●			●			●	●	●		●	5	1.00	2.25
(17-168) Bear Run																																			
Year: 2009																																			
0.8	55.5	66.67	■	■	■	■	■			■		■	7				♦	♦	2				●			●					2	0.38	0.63
(17-169) Corns Run																																			
Year: 2009																																			
0.6	61.0	90.91	■	■				■		■	■	■	6				♦		1				●			●					2	0.29	0.57
(17-170) Honey Run																																			
Year: 2009																																			
1.0	60.5	31.75	■	■		■	■	■		■	■		7				♦		1				●			●			●	●	4	0.25	0.75
(17-172) Martins Creek																																			
Year: 2009																																			
3.5	59.5	25.00	■	■		■	■	■		■	■		7				♦		1				●			●				●	3	0.25	0.63
(17-173) Paint Creek																																			
Year: 2009																																			
8.7	68.5	16.67	■	■			■	■		■	■	■	7				♦		1				●			●					2	0.25	0.50
5.3	67.0	26.67	■	■		■	■	■			■		6				♦		1				●			●		●		●	4	0.29	0.86
1.6	70.5	16.81	■	■		■	■	■		■	■	■	8						0				●			●					2	0.11	0.33
(17-175) Salt Creek																																			
Year: 2009																																			
8.5	61.5	18.87	■	■			■	■			■		5						0				●			●		●		●	4	0.17	0.83
5.0	75.0	29.41	■	■		■	■	■		■	■	■	8						0									●			1	0.11	0.22
3.0	64.0	26.32	■	■		■		■		■	■	■	7						0				●	●		●		●		●	5	0.13	0.75
0.8	53.5	17.86	■					■			■		3		♦				1		●		●	●		●		●		●	6	0.50	2.00
(17-176) North Branch Salt Creek																																			
Year: 2010																																			
3.3	33.5	7.52						■			■		2	♦	♦		♦		3	●	●		●			●		●		●	6	1.33	3.33
Year: 2009																																			
3.3	42.0	7.52						■			■		2		♦		♦	♦	3	●	●		●			●		●		●	6	1.33	3.33
(17-180) Shreve Creek																																			
Year: 2009																																			
3.1	53.0	18.52		■			■	■			■		4				♦		1	●	●		●			●		●		●	6	0.40	1.60

Table 20. Continued.

Key QHEI Components			WWH Attributes											MWH Attributes																		
														High Influence				Moderate Influence														
River Mile	QHEI	Gradient (ft/mile)	No Channelization or Recovered	Boulder/Cobble/Gravel Substrates	Silt Free Substrates	Good/Excellent Substrates	Moderate/High Sinuosity	Extensive/Moderate Cover	Fast Current/Eddies	Low-Normal Overall Embeddedness	Max Depth > 40 cm	Low-Normal Riffle Embeddedness	Total WWH Attributes	Channelized or No Recovery	Silt/Muck Substrates	No Sinuosity	Sparse/No Cover	Max Depth < 40 cm (WD, HW)	Total H.I. MWH Attributes	Recovering Channel	Heavy/Moderate Silt Cover	Sand Substrates (Boat)	Handicap Substrate Origin	Fair/Poor Development	Low Sinuosity	Only 1-2 Cover Types	Intermittent and Poor Pools	No Fast Current	High/Mod. Overall Embeddedness	High/Mod. Riffle Embeddedness	No Riffle	Total M.I. MWH Attributes	(MWH H.I.+1)/(WWH+1) Ratio	(MWH M.I.+1)/(WWH+1) Ratio
(17-181) Apple Creek																																
Year: 2009																																
8.3	74.0	9.01	■	■		■	■	■			■		6						0			●				●		●		●		4	0.14	0.71
6.3	75.5	19.23	■	■		■	■	■		■	■	■	8						0							●				●		2	0.11	0.33
1.6	77.5	8.13	■	■		■		■		■	■	■	7						0					●		●						2	0.13	0.38
0.6	65.5	15.38	■	■		■	■	■			■		6						0					●		●		●		●		4	0.14	0.71
0.1	62.5	8.40	■	■		■	■	■	■		■		7				♦		1	●				●	●				●	●		5	0.25	0.88
(17-182) Little Apple Creek																																
Year: 2010																																
5.0	75.0	23.81	■	■			■	■		■	■	■	7						0		●			●				●				3	0.13	0.50
0.2	67.0	43.48	■	■		■	■	■	■	■	■	■	9			♦			1					●								1	0.20	0.30
Year: 2009																																
4.5	67.5	23.26	■	■		■	■	■		■	■	■	8				♦		1							●			●			2	0.22	0.44
1.7	49.0	55.55		■		■							2			♦	♦	♦	3	●				●		●		●	●	●		5	1.33	3.00
(17-183) Clear Creek																																
Year: 2009																																
3.7	68.5	40.82	■	■		■	■	■		■	■	■	8						0							●				●		2	0.11	0.33
1.1	71.5	27.03	■	■		■	■	■		■	■	■	8						0		●					●		●	●	●		4	0.11	0.56
(17-184) Little Killbuck Creek (lower)																																
Year: 2009																																
6.5	70.5	35.71	■	■		■	■	■		■	■	■	8						0		●					●						2	0.11	0.33
0.5	54.5	19.61		■				■			■		3				♦		1	●	●			●	●	●		●	●	●		7	0.50	2.25
(17-185) Rathburn Run																																
Year: 2009																																
2.5	63.5	100.0	■	■		■	■	■		■	■		7			♦			1			●				●				●		3	0.25	0.63
(17-186) Cedar Run																																
Year: 2009																																
1.5	65.0	52.63	■	■		■	■	■		■	■	■	8						0									●				1	0.11	0.22
(17-189) Repp Run																																
Year: 2009																																
0.9	71.0	27.03	■	■		■	■	■		■	■	■	8						0									●				1	0.11	0.22
(17-190) Camel Creek																																
Year: 2009																																
3.8	72.5	20.41	■	■		■	■	■		■	■	■	8						0									●				1	0.11	0.22
0.5	58.0	6.29	■	■				■			■		4			♦			1	●	●		●	●				●	●	●		7	0.40	1.80
(17-198) Spring Run																																
Year: 2009																																
0.4	64.5	55.55	■	■		■	■	■	■	■	■	■	9			♦			1											●		1	0.20	0.30

Biological Communities – Fish

Watershed Overview

Of the 72 sites evaluated (Table 21, Appendix Tables 5 and 6), biological index scores computed for fish communities met numeric standards for warmwater habitat streams at 61 sites, narrowly missed the standard due to natural limitation at 1 site, and failed to meet the standard at 10 sites due to either organic enrichment, sedimentation, habitat degradation, or a combination thereof (Figure 24). Results from a random sample of terminal node headwaters stratified by land use followed suit with respect to causes of impairment. IBI scores at sites classified as mostly forested averaged higher IBI scores than sites categories as having either predominately row crops, a mixture of row crops and pasture, mostly pasture, or urban land use (Figure 25). Although the difference between the forest and row crop categories was not significant, the row crop category had higher fish abundance (Figure 26a). Similarly, fish abundance was higher in the mixed uses and pasture categories than the forest category, and the relative composition of tolerant and pioneering fishes was highest in the pasture stratum (Figure 26b and 26c). Pollution sensitive fishes were sampled more frequently in the forested group compared to the other categories (Figure 26d). The increased fish abundance, and higher relative composition of tolerant species in the row-crop, mixed and pasture categories relative to the forest group is indicative of enrichment. The IBI score recorded for the one site classified as urban failed to meet the standard for WWH streams. This site had 12.9% of its watershed in impervious cover, a level documented as a threshold beyond which aquatic communities are likely to be degraded (Steedman 1988, Karr and Chu 2000, Miltner et al. 2004).

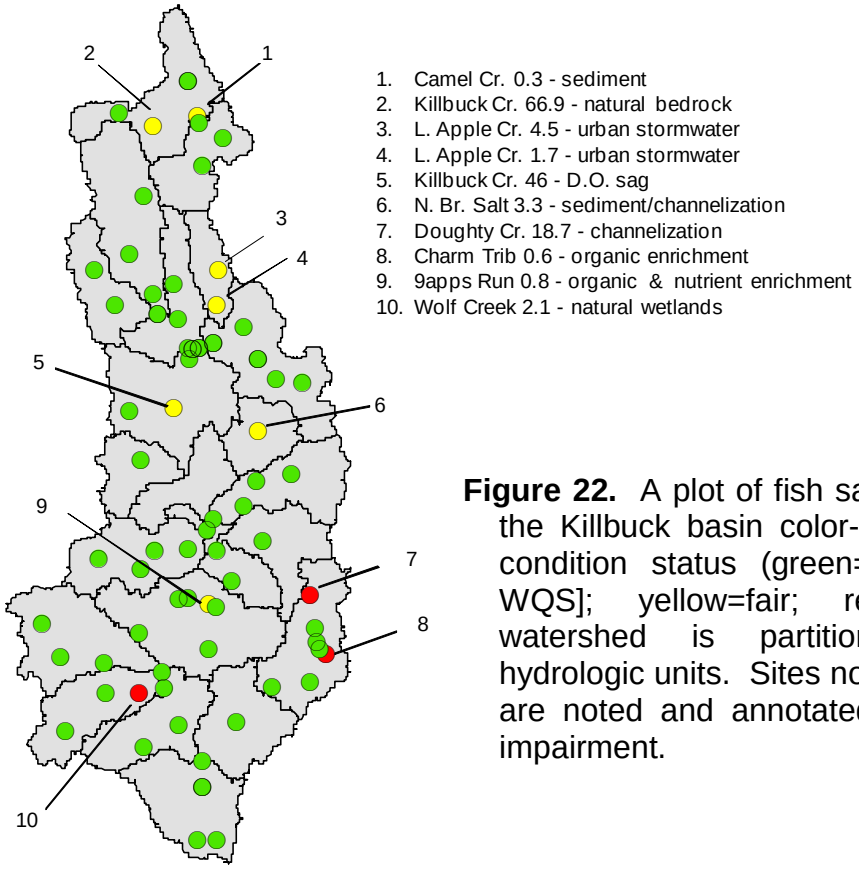


Figure 22. A plot of fish sampling locations in the Killbuck basin color-coded by narrative condition status (green=good [i.e., meets WQS]; yellow=fair; red=poor). The watershed is partitioned by 12-digit hydrologic units. Sites not meeting the WQS are noted and annotated for the cause of impairment.

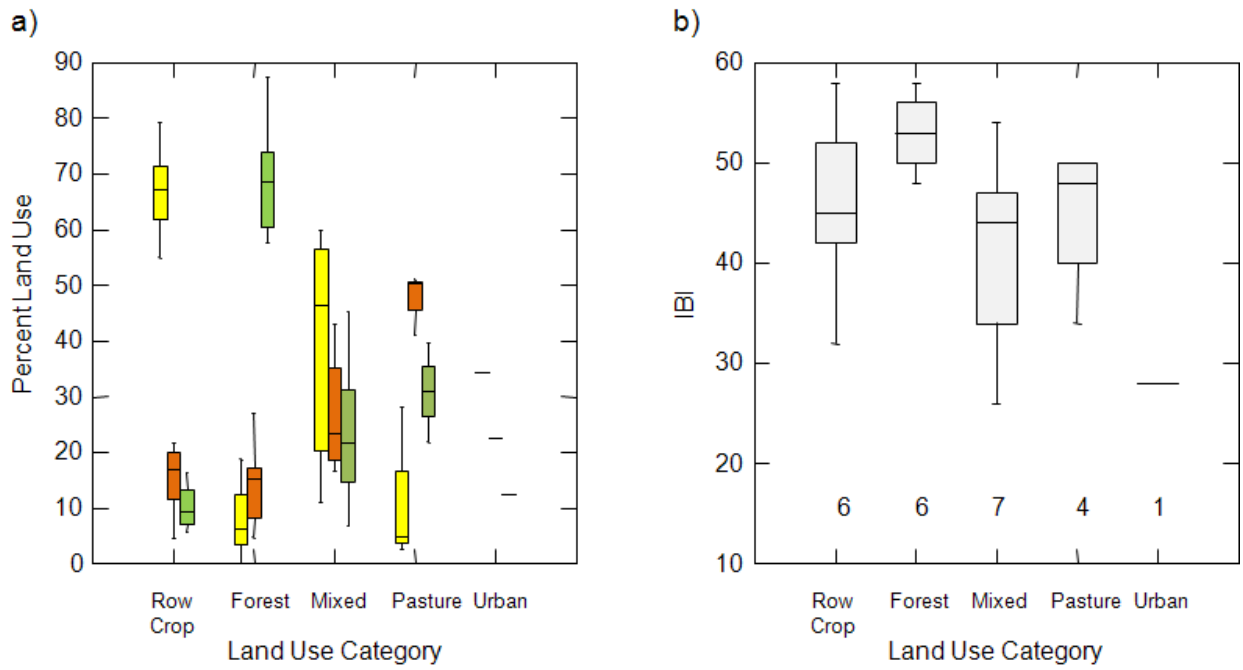


Figure 23. a) Distributions of land use within categorical strata (yellow=row crop, brown=pasture, green=forest). b) Distributions of IBI scores within strata. Sample sizes are noted above the x-axis.

Water quality indicators of nutrient and organic enrichment were elevated in the row crop, mixed and pasture categories relative to the forest stratum, especially for nitrate-nitrite nitrogen (Figure 27a-d). Ammonia nitrogen was highest in the pasture category, coincident with the highest relative composition of pioneering fishes. A multiple regression of IBI scores on QHEI scores, and water chemistry variables revealed that variation in IBI scores from the random sample was best explained (R^2 = 0.60) by a linear combination of QHEI scores and total Kjeldahl nitrogen (TKN) concentrations (Figure 28). This result suggests that, relative to nutrient enrichment, organic enrichment is a more proximate cause of impairment from diffuse sources at the watershed scale.

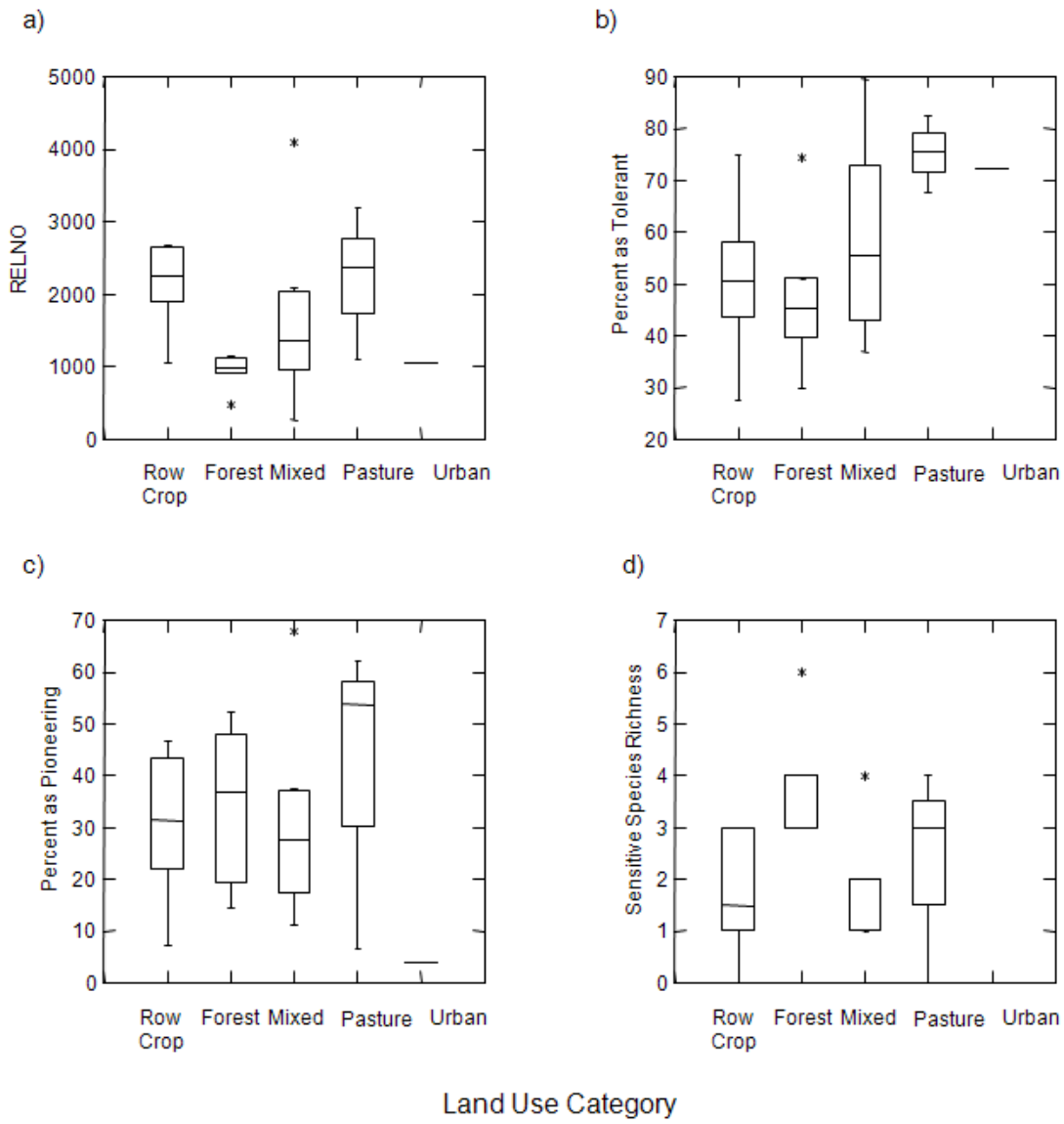


Figure 24. Distributions of fish community attributes by strata. a) Relative abundance of fish in electrofishing samples (standardized to number per 300 m), b) percent composition of species tolerant to pollution, c) percent composition of pioneering species, and d) the richness of species sensitive to pollution.

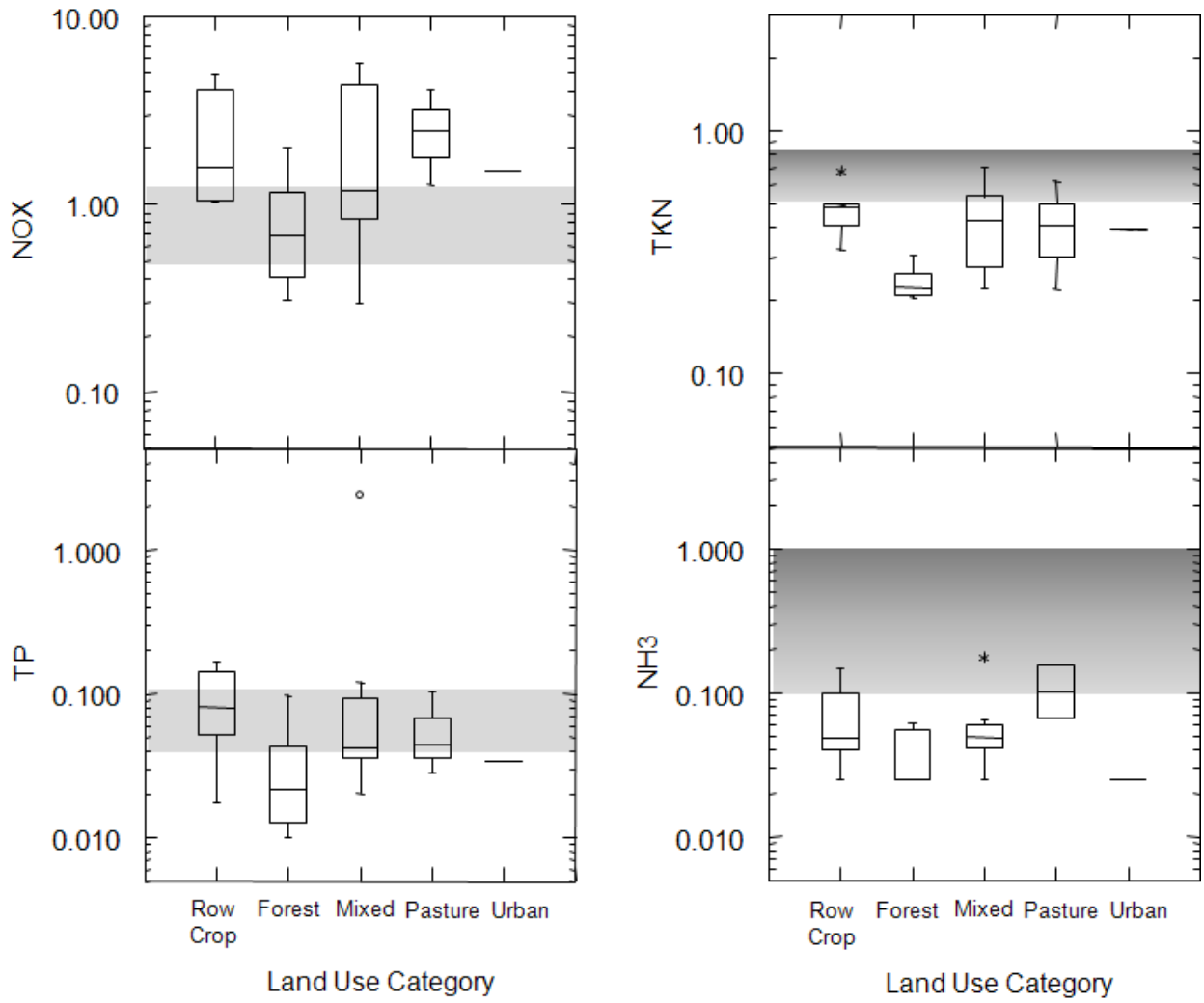


Figure 25. Distributions of water quality parameters (in mg/l) plotted by land use strata: a) nitrate-nitrite nitrogen (NOx), b) total kjeldahl nitrogen (TKN), c) total phosphorus (TP), and d) ammonia nitrogen (NH3). The shaded region in the NOx and TP plots represents the concentration range over which negative effects (e.g., persistent algal mats, wide dissolved oxygen swings) from nutrient enrichment become increasingly likely. The shaded region in the TKN and NH3 plots represents the concentration range over which deleterious effects to fish and macroinvertebrate communities are likely to be observed. For the NOx and TP plots, its best to compare both the shape of the distribution and the location of the central tendency relative to the respective shaded regions. For the TKN and NH3 plots, one should consider the frequency of values occurring in or above the respective shaded regions.

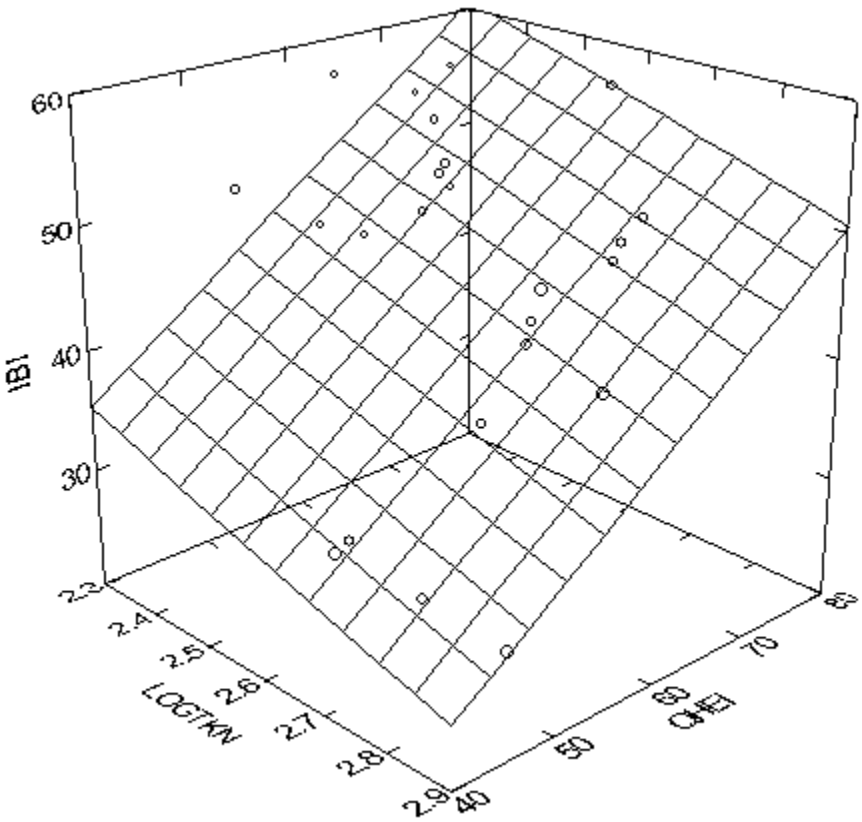


Figure 26. Scatter plot of IBI scores over QHEI scores and Log_{10}(TKN) concentrations. The response surface is based on a linear regression. The standardized slope coefficients for QHEI and TKN are 0.62 and -0.31, respectively, indicating that for each 1 point increase in QHEI score, the IBI score increases by ~0.6 points, and for each 0.1 mg/l increase in TKN, IBI scores decrease by ~2 points.

Killbuck Creek

Fish communities in the Killbuck mainstem met expectations for WWH at every site sampled except for one site sampled downstream from Wooster at Valley Road, and one site sampled in Burbank (Figure 29). The Burbank sample was located in a bedrock reach, and therefore lacked sufficient depth for large fishes. Consequently, the Modified Index of well-being (MIwb), an index that rewards biomass, narrowly missed the criterion. Index scores for samples collected at the Valley Road site have historically failed to meet the biocriteria due to industrial and municipal wastewater loadings from Wooster, and the influence of adjacent wetlands on dissolved oxygen. However, compared to 1983 and 1993, the scores in 2009 improved, especially with respect to the MIwb, and especially compared to 1983, when the MIwb and IBI scored in the poor range. MIwb scores in 2009 met the criterion for WWH, suggesting that acute toxicity, or exacerbations of critically low dissolved oxygen caused by loadings of oxygen demanding substances, are no longer a limiting factor. However, compared to similar reaches sampled further downstream, the fish community at Valley Road underperformed the available habitat, and was skewed compositionally toward tolerant and omnivorous fishes.

Better wastewater treatment and, presumably, management of nonpoint sources, resulted in improved condition of fish communities throughout the mainstem in 2009 relative to 1983 and 1993 (Figure 29). The improvement was manifest, most importantly, in the re-invasion or range expansion of pollution sensitive species, especially in the lower 40 mile reach of the mainstem (Figure 30). Species that appear to have re-invaded the system include bigeye chub and dusky darter.

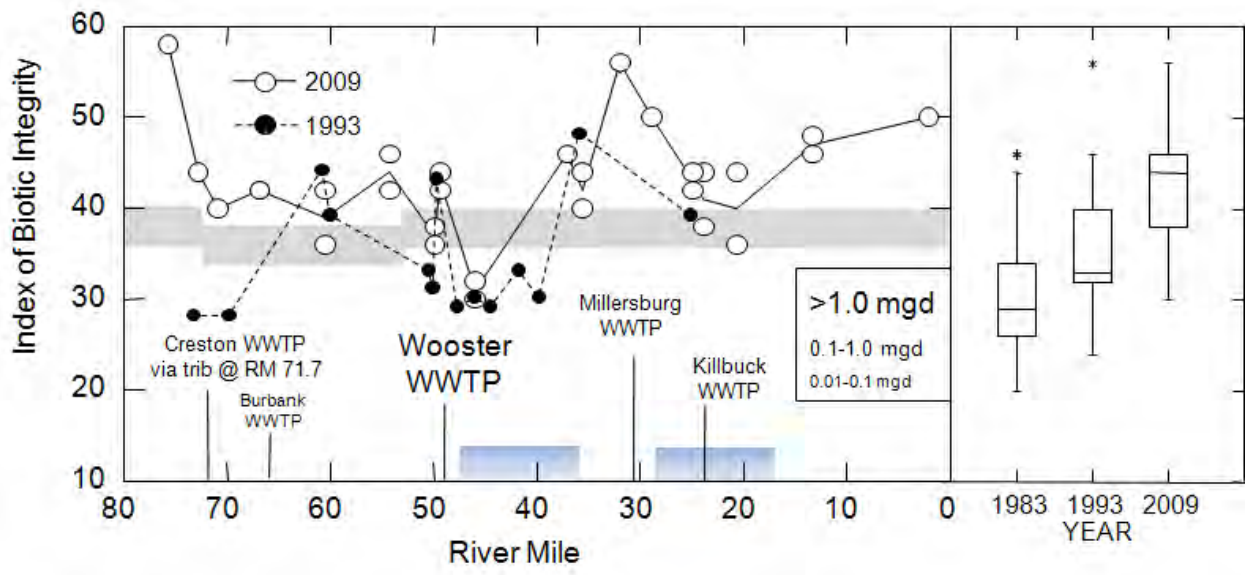


Figure 27. Index of Biotic Integrity scores for fish communities sampled in Killbuck Creek, 1993 and 2009, plotted by river mile, and in relation to municipal wastewater plants. The box and whisker plots in the right panel show distributions of IBI scores for sites sampled in common for the given years.

Species that have expanded their range from refugia in the lower several miles of the mainstem or the lower reaches of tributaries include the river redhorse, black redhorse, hornyhead chub, rosyface shiner, silver shiner, and eastern sand darter.

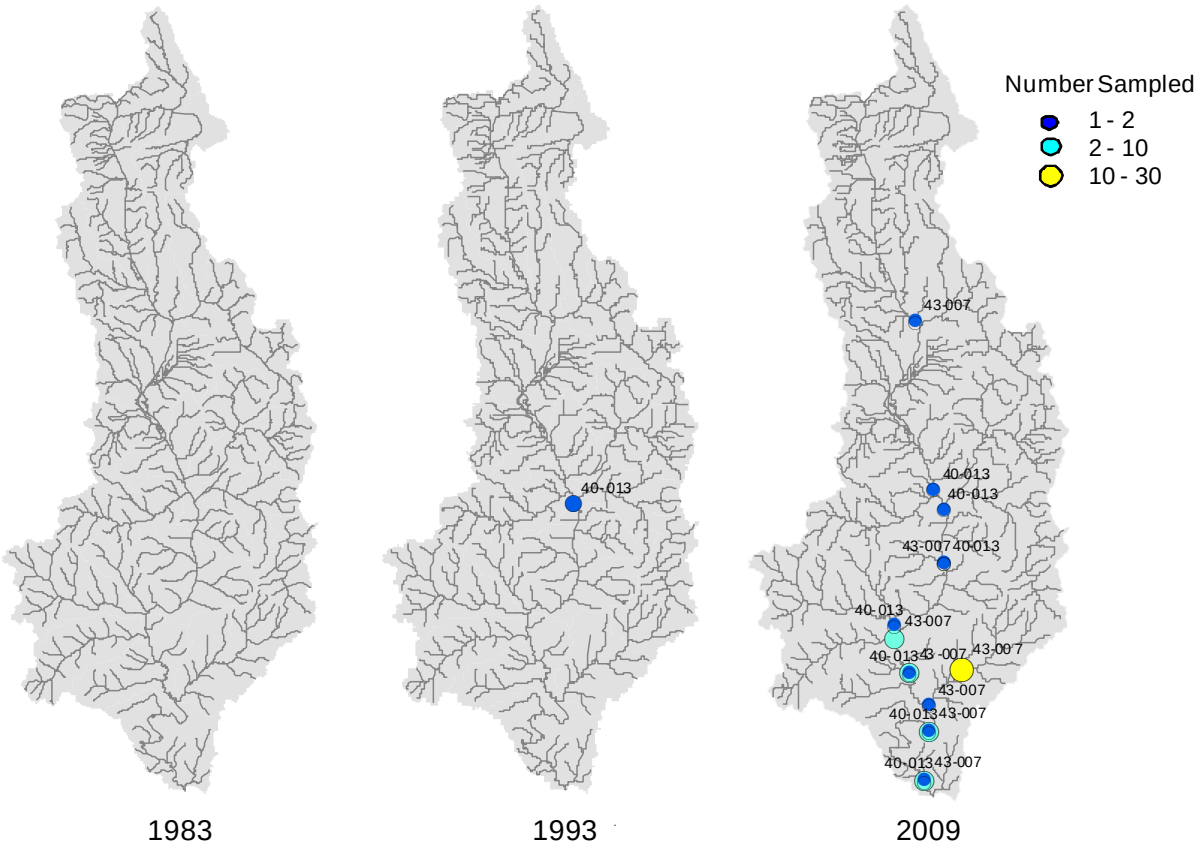


Figure 28. An example of range expansion and re-invasion for two pollution sensitive species, the river redhorse (40-013) and bigeye chub (43-007), in the Killbuck basin between the years 1983 - 2009. The absolute abundance in electrofishing samples for either species is plotted.

Doughty Creek and Tributaries

Biological index scores for fish communities sampled in Doughty Creek and two of its tributaries generally met the biocriteria for WWH streams (Figure 31). Exceptions included the headwater site on Doughty Creek located at T-359 (RM 18.7), where poor habitat from channelization limited the fish community, and an unnamed tributary that drains the Village of Charm (aka Charm tributary). Fish communities in the Charm tributary were limited by a combination of poor habitat and organic enrichment. Mean IBI scores from samples collected at similar locations in 2009 and 1993 did not differ significantly. Qualitatively, however, a decrease in IBI scores associated with Guggisberg Cheese appears to have shifted further downstream.

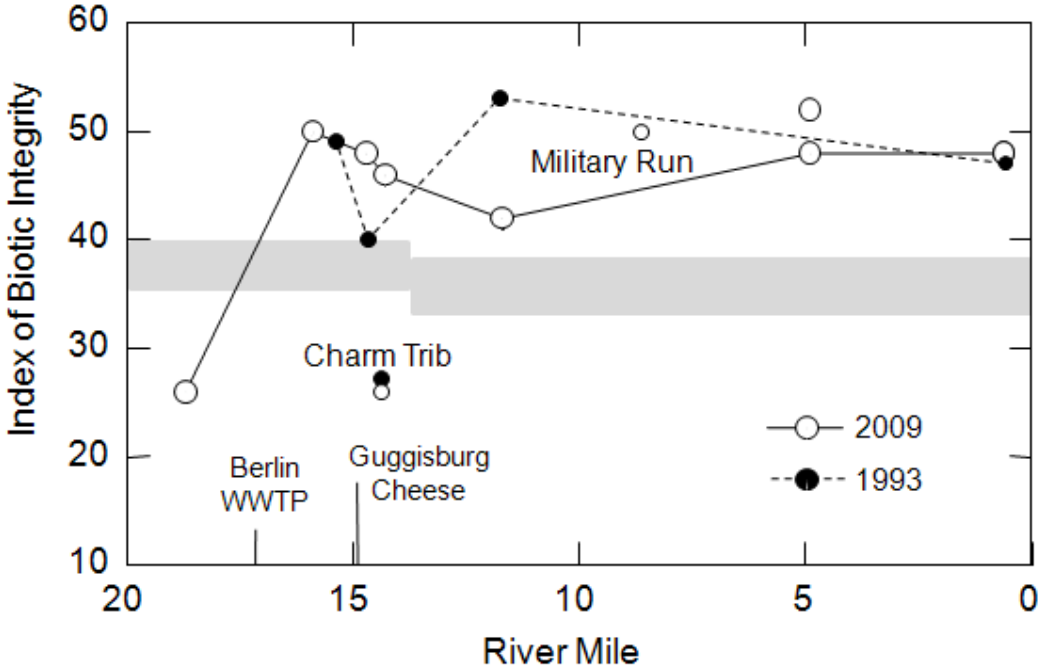


Figure 29. Fish Index of Biotic Integrity scores for sites sampled in Doughty Creek and its tributaries plotted by river mile, 1993 and 2009. The gray-shaded region depicts the region of non-significant departure from the WWH biocriterion.

Salt Creek

Although IBI scores for fish communities sampled in Salt Creek met the biocriterion for WWH streams, scores at two sites sampled downstream from the Fredricksburg WWTP under-performed relative to available habitat (Figure 32). Coincidentally, wide swings in dissolved oxygen were observed at RM 3.0, suggesting that the stream at that location is over-enriched with nutrients. The fish community sampled from the North Branch of Salt Creek at Moreland Road did not meet the WWH biocriterion due to poor habitat from channelization.

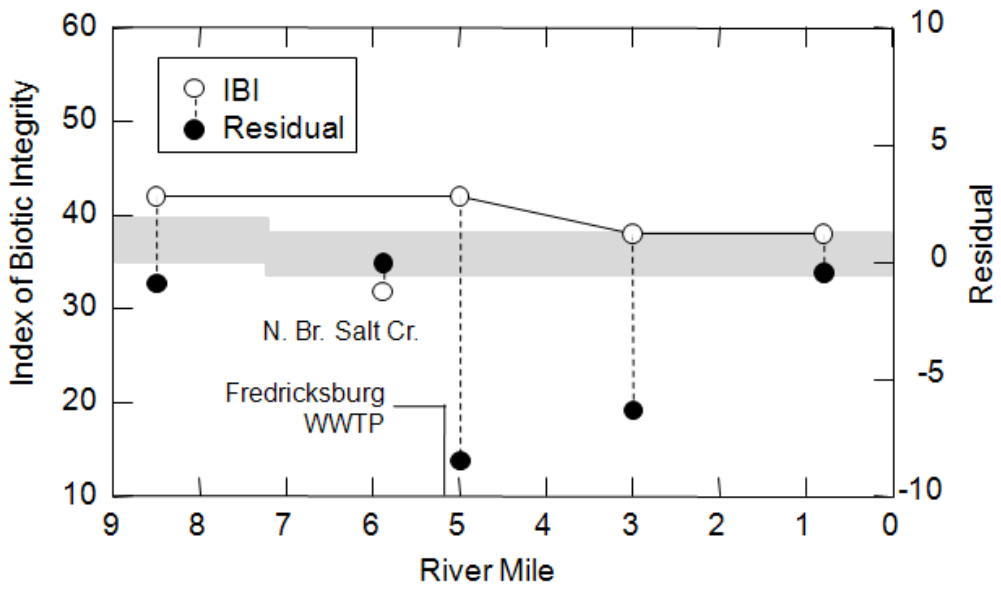


Figure 30. Index of Biotic Integrity scores (open points) for fish communities sampled in Salt Creek and the North Branch of Salt Creek plotted by river mile. Residuals (solid points) are from a regression of IBI scores on QHEI scores for small streams sampled in the Killbuck basin, 2009. A residual with a value approaching zero indicates that the associated IBI score is near what is predicted based on available habitat. Conversely, residuals departing strongly below zero indicate that the associated IBI score was less than what could be expected based on habitat quality.

Apple Creek and Little Apple Creek

All sites sampled in Apple Creek in 2009 had IBI scores meeting the WWH biocriteria. Additional sites sampled in common between 1993 and 2009 received nearly identical index scores (Figure 33). The site sampled downstream from the Apple Creek WWTP (RM 8.3), however, was in the range of nonsignificant departure of the IBI criterion, and under-performed relative to available habitat.

Little Apple Creek is a suburbanized watershed. The fish communities sampled at two locations (RMs 1.7 and 4.5) did not meet the WWH biocriterion. Percent impervious cover for the two sites is 12.9 and 7.4 percent, respectively. The 2009 IBI score of 28 at RM 4.5 was 10 points lower than the score obtained in 1987.

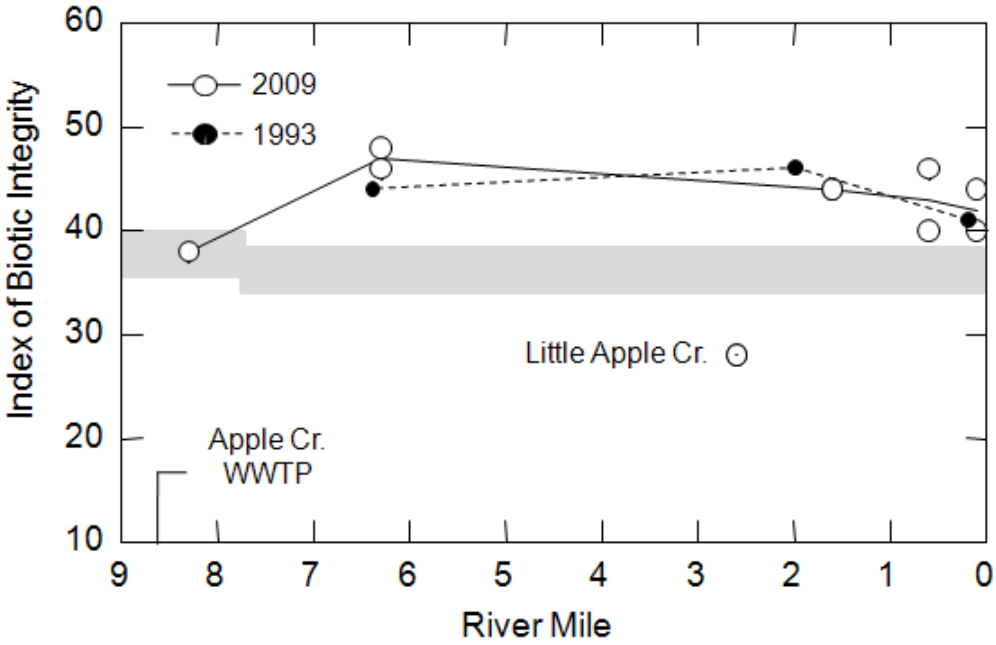


Figure 31. Index of Biotic Integrity scores for fish communities sampled in Apple Creek, 2009 and 1993. The gray-shaded region is the range of nonsignificant departure from the biocriterion. Note that Little Apple Creek was not sampled in 1993.

Table 21. Fish community attributes and biotic index scores for sites sampled in the Killbuck Creek basin, 2009, organized by 12-digit USGS hydrologic unit code. Condition status of the hydrologic unit relative to the fish community is noted. Index scores less than the applicable biocriteria are noted with an asterisk. Appropriate or verified aquatic life use designations are noted next to the stream name; recommended changes to existing uses are noted to the right of the forward slash. Criteria for the Erie-Ontario Lake Plain ecoregion apply unless otherwise noted.

River Mile	Cumulative Species	Relative Number	QHEI	MIwb†	IBI	NARRATIVE	Drainage Area
050400030501 - Attaining							
Killbuck Creek (17-150-000) - WWH							
75.70	15	1898	75.5	NA	58	E	5.1
72.80	26	1028	59.0	NA	44	G	15.8
70.90	17	850	57.5	7.5	40	MG/G	20.4
050400030502 - sediment & natural causes							
Killbuck Creek (17-150-000) - WWH							
66.90	17	1146	59.0	7.0*	42	F/G	42.3
Repp Run (17-189-000) - WWH							
0.90	13	1119	71.0	NA	46	VG	3.4
Camel Creek (17-190-000) - WWH							
3.80	22	778	72.5	NA	48	G	8.7
0.50	19	984	58.0	NA	34*	F	12.5
050400030503 - Attaining							
L. Killbuck Creek (17-184-000) - WWH/CWH Recommended							
6.50	12	2684	70.5	NA	48	VG	7.0
0.50	22	2353	54.5	8.4	43	G	20.8
Rathburn Run (17-185-000) - WWH/CWH Recommended							
2.50	12	2644	63.5	NA	54	E	5.1
050400030504 - Attaining							
Killbuck Creek (17-150-000) - WWH							
60.50	22	1378	71.5	8.9	39	VG/MG	55.8
54.30	27	477	62.0	8.7	44	G	115.0
Cedar Run (17-186-000) – WWH/CWH Recommended							
1.50	10	1118	65.0	NA	44	G	5.9
050400030505 - Attaining							
Killbuck Creek (17-150-000) - WWH							
49.90	22	280	50.0	8.9	38	G/MG	136.0
Clear Creek (17-183-000) - WWH/EWH&CWH Recommended							
3.70	10	2082	68.5	NA	50	E	4.4
1.10	18	2052	71.5	NA	58	E	11.4

Table 21. Continued.

River Mile	Cumulative Species	Relative Number	QHEI	MIwb†	IBI	NARRATIVE	Drainage Area
050400030601 - urban/suburban stormwater							
Little Apple Creek (17-182-000) - WWH							
5.0[a]	12	806	75.0	NA	30*	F	4.7
4.50	9	958	67.5	NA	28*	F	5.7
1.70	5	1056	49.0	NA	28*	F	11.1
0.2[a]	9	1149	67.0	NA	34*	F	12.9
050400030602 - Attaining							
L. Apple Creek 9.79 (17-181-003) - undesignated/WWH Recommended							
1.10	12	2522	59.0	NA	42	G	3.8
Apple Creek (17-181-000) - WWH							
8.30	14	1098	74.0	NA	38	MG	13.9
6.30	24	1320	75.5	8.6	47	G/VG	23.0
1.60	25	752	77.5	8.3	45	G	50.0
0.60	26	1673	65.5	8.5	43	G	51.4
0.10	26	641	62.5	8.4	43	G	51.6
Spring Run (17-198-000) – undesignated/CWH Recommended							
0.40	14	4101	64.5	NA	48	VG	5.1
050400030603 - Attaining							
Shreve Creek (17-180-000) - WWH							
3.10	14	1054	53.0	NA	36	MG	10.0
050400030604 - oxygen sag?							
Millbrook trib. (17-150-011) - undesignated/CWH Recommended							
3.30	7	1104	61.5	NA	32*	F	5.0
Killbuck Creek (17-150-000) - WWH							
49.40	32	601	59.0	9.0	43	G	139.0
46.00	24	319	54.5	8.2	31*	F	194.0
050400030605 - poor habitat and sediment							
N. Br. Salt Creek (17-176-000) - WWH							
3.30	10	1056	42.0	NA	32*	F	6.9
3.30[a]	19	2854	33.5	NA	42	G	6.9
050400030606 - (reasonable potential: nutrient enrichment)							
Salt Creek (17-175-000) - WWH							
8.50	14	1969	61.5	NA	42	G	13.2
5.00	18	1404	75.0	8.6	42	G	34.5
3.00	16	5194	64.0	8.8	38	G/MG	39.3
0.80	20	1608	53.5	8.0	38	G/MG	42.6

Table 21. Continued.

River Mile	Cumulative Species	Relative Number	QHEI	MIwb†	IBI	NARRATIVE	Drainage Area
050400030701 - Attaining							
Paint Cr. trib 3.01 (17-173-001) - undesignated/EWH&CWH Recommended							
1.50	12	2020	71.5	NA	50	E	4.2
Paint Creek (17-173-000) - EWH/CWH Recommended							
8.70	9	1605	68.5	NA	40	G	4.8
5.30	14	1694	67.0	NA	48	VG	12.3
1.60	17	3224	70.5	8.8	40	VG/G	25.6
050400030702 - Attaining							
Martins Creek (17-172-000) - WWH							
3.50	12	872	59.5	NA	40	G	12.5
050400030703 - Attaining							
Killbuck Creek (17-150-000) - WWH							
37.10	15	214	62.5	8.7	46	G/VG	313.0
35.60	18	292	67.0	8.6	42	MG/G	367.0
Honey Creek (17-170-000) – WWH/CWH Recommended							
1.00	13	3186	60.5	NA	46	VG	6.2
050400030704 - Attaining							
Black Cr. trib 7.35 (17-161-001) - undesignated/CWH Recommended							
0.70	16	978	70.5	NA	48	VG	4.6
Black Creek (17-161-000) WAP - undesignated/CWH Recommended							
9.80	14	1152	73.0	NA	54	E	3.8
4.60	19	560	69.0	7.7	40	F/G	26.5
050400030705 - organic & nutrient enrichment							
Killbuck Creek (17-150-000) - WWH							
32.00	30	544	65.0	10.1	56	E	380.0
28.90	23	420	65.0	9.5	50	VG/E	397.0
Shrimplin Creek (17-162-000) - WWH/CWH Recommended							
2.90	16	914	76.0	NA	54	E	5.7
Sapps Run (17-166-000) - WWH							
0.80	9	265	47.0	NA	28*	F	8.5
Bear Run (17-168-000) – WWH/CWH Recommended							
0.80	9	575	55.5	NA	36	MG	2.6
Corns Run (17-169-000) - WWH							
0.60	12	1476	61.0	NA	46	VG	1.7

Table 21. Continued.

River Mile	Cumulative Species	Relative Number	QHEI	MIwb†	IBI	NARRATIVE	Drainage Area
050400030801 - Attaining							
Wolf Creek trib 6.49 (17-160-001) WAP - undesignated/EWH&CWH Recommended							
1.40	14	996	62.0	NA	58	E	4.7
Wolf Creek (17-160-000) WAP - WWH/CWH Recommended for upstream part							
4.10	20	1178	61.5	NA	52	E	18.1
2.50	15	218	62.0	-	44	G	23.1
050400030802 - organic enrichment & poor habitat							
Doughty trib 14.34 (17-153-001) WAP – undesignated/WWH Recommended							
0.60	5	993	51.5	NA	26*	P	2.5
Doughty Creek (17-153-000) - WWH							
18.70	9	804	48.5	NA	26*	P	5.5
15.90	17	3032	68.0	NA	50	E	13.0
14.7	20	2468	63.0	NA	48	VG	15.1
14.30	19	1850	55.5	NA	46	VG	18.4
11.70	12	191	53.5	NA	42	G	19.7
Military Run (17-155-000) WAP - WWH							
0.80	18	2364	55.5	NA	50	E	4.9
050400030803 - Attaining							
Doughty Creek (17-153-000) - WWH							
4.90	31	1998	63.0	9.4	50	E	42.1
0.60	35	547	58.0	9.3	48	VG	60.7
050400030804 - Attaining							
Killbuck Creek (17-150-000) - WWH							
24.90	22	261	59.0	9.1	44	G	462.0
23.90	25	250	60.0	8.7	41	G	464.0
20.70	22	236	58.0	8.4	41	MG/G	501.0
Big Run (17-157-000) WAP - EWH							
3.60	14	1126	53.5	NA	50	E	8.3
050400030805 - Attaining							
Killbuck Creek (17-150-000) - WWH							
13.30	29	381	67.0	9.2	47	VG	581.0
2.10	27	440	75.0	9.6	50	E	599.0
Bucklew Run (17-151-000) WAP – EWH/WWH Recommended							
1.50	13	483	65.5	NA	48	E	4.3

Table 21. Continued.

Ecoregion Biocriteria: Erie-Ontario Lake Plain

Site Type	IBI WWH	IBI EWH	IBI MWH	MIwb WWH	MIwb EWH	MIwb MWH
Headwaters	40	50	24	NA	NA	NA
Wading	38	50	24	7.9	9.4	5.6
Boat	40	48	24	8.7	9.6	5.7

Ecoregion Biocriteria: Western Allegheny Plateau

Site Type	IBI WWH	IBI EWH	IBI MWH	MIwb WWH	MIwb EWH	MIwb MWH
Headwaters	44	50	24	NA	NA	NA
Wading	44	50	24	8.4	9.4	5.6
Boat	40	48	24	8.6	9.6	5.7

† - MIwb is not applicable (NA) to headwater streams with drainage areas $\leq$ 20 mi^2.
* - Indicates significant departure from applicable biocriteria (>4 IBI units or >0.5 MIwb units).
a - Sample collected in 2010.

Macroinvertebrate Communities

Macroinvertebrate communities were evaluated at 76 stations in the Killbuck Creek study area (Table 22, Appendix Tables 7 and 8). The community performance was evaluated as exceptional at 36 stations, very good at 10, good at 21, marginally good at three, and fair at six stations. The station with the highest total mayfly (Ephemeroptera), stonefly (Plecoptera), and caddisfly (Trichoptera) taxa richness (EPT) was on Killbuck Creek at McAfee Road (RM 55.4) with 37 taxa. The station with the highest number of total sensitive taxa was on Killbuck Creek at McAfee Road (RM 55.4) with 59 taxa. Twenty-five uncommonly collected sensitive taxa were found in this study area including the state listed caddisfly *Brachycentrus numerosus* (Endangered) and the freshwater mussels *Cyclonaias tuberculata* (purple wartyback-Species of Concern) and *Ligumia recta* (black sandshell-Threatened) (Tables 23 and 24). Hoggarth et al. (1995) and Hoggarth (1997) found 25 species of freshwater mussels to be extant in Killbuck Creek (Table 24) while investigating the recently discovered population of the federally endangered mussel *Epioblasma obliquata obliquata* (purple catspaw). These investigations included nine state listed species: three endangered, one threatened, and five species of concern. This study area had an unusually high number of uncommonly collected sensitive taxa and state listed species which are indications of the exceptional resource quality in the Killbuck Creek basin.

Killbuck Creek

The macroinvertebrate communities sampled upstream from the Wooster WWTP (RM 49.88) were performing at a good to exceptional level with moderate to high diversity of the qualitative EPT (15-31) and sensitive taxa (20-46) (Figure 34). Most of this section was historically channelized and much of it relocated in order to straighten the channel, however, the stream channel has recovered to the extent that riffle habitats were present at each of the collection sites and at least a modest woody riparian has been allowed to reestablish. This section of Killbuck Creek was benefiting from groundwater inputs as evidenced by three or more coldwater macroinvertebrate taxa found at five of the seven sampling stations. For example, the station at McAfee Road (RM 55.4) had the highest qualitative EPT (31) and sensitive taxa (46) diversity during this survey and included 10 cold water macroinvertebrate taxa.

The Wooster WWTP discharge (RM 49.88) and runoff from Wooster were not having an immediate impact on the macroinvertebrate community. The ICI (46) and qualitative EPT (23) and sensitive taxa (36) diversity continued to meet exceptional expectations about 0.4 mile downstream from the WWTP discharge. The community performance at the next two downstream stations (RMs 46.0, 37.1) declined, due in part to the stream being highly channelized and without riffle habitats. Other possible sources of impact were oxygen depleting inputs from the Wooster WWTP and from the wetlands that border and are separated from the stream by levees.

Macroinvertebrate community performance at Township Road 346 (RM 35.6) improved to near the condition present upstream from Wooster. The Millersburg WWTP (RM 30.5) and Killbuck WWTP (RM 24.4) discharges were not having a recognizable negative impact on the downstream macroinvertebrate communities. The downstream

13 miles of Killbuck Creek supported an unusually high number (9) of state listed freshwater mussels, of which one (purple catspaw mussel) is also on the federal endangered list, and one species of caddisfly (*Brachycentrus numerosus*) on the state endangered list (Tables 23, 24).

Killbuck Creek tributaries upstream from Apple Creek

The macroinvertebrate communities sampled at nine stations from Camel Creek, Repp Run, Cedar Run, Little Killbuck Creek, Rathburn Run, and Clear Creek were performing in the marginally good range at one, good at two, very good at one and exceptional at five stations. Eight out of the nine stations had two to 10 (average 5) coldwater macroinvertebrate taxa in this area, indicating a strong connectivity to the groundwater.

The only station that was marginally meeting the baseline biotic integrity expectation was in Rathburn Run adjacent to Lehr Road (RM 2.5). The EPT diversity of nine was just below the WWH expectation for that size stream. Observed heavy silt cover and algal growth were indications that siltation and nutrient enrichment may have caused the marginal biological integrity at this station.

Killbuck Creek tributaries above Apple Creek to below Salt Creek

The macroinvertebrate communities sampled at 19 stations from Apple Creek, Little Apple Creek (Trib. to Apple Cr. @RM 9.79), Spring Run, Little Apple Creek (Trib. to Apple Cr. @RM 2.60), Tributary to Killbuck Creek @RM 43.60, Shreve Creek, Salt Creek, and North Branch Salt Creek were performing in the fair range at two, good at nine, very good at one and exceptional at seven stations. All 19 stations had one to 11 (average 3.6) coldwater macroinvertebrate taxa in this area, indicating a strong connectivity to the groundwater.

Shreve Creek (RM 3.3) was evaluated as fair due to the EPT (6) and sensitive taxa (7) diversities being below WWH expectations and the riffle habitat was predominated by primarily facultative taxa including blackfly larvae. Observed heavy silt cover and algal growth were indications that siltation and nutrient enrichment may have caused the impairment at this station.

North Branch Salt Creek (RM 3.3) was sampled in 2009 in an area that was channelized and had thick silt deposits. The station was reevaluated in 2010 after streambed silt was removed from the highly channelized stream channel immediately downstream from Moreland Road. In 2010, the sampling station was moved a little downstream into a portion of the stream that was not channelized, after observing no improvement to in-stream habitat in the channelized portion. The stream was evaluated as fair both years. The 2010 sampling was evaluated as fair due to the sensitive taxa (8) diversity being below the WWH expectation and the riffle/run habitat was devoid of sensitive EPT taxa among the predominant and common taxa. Observed heavy silt deposits observed both years was an indication that siltation was a major contributing cause of the impairment at this station. The stream upstream from Moreland Road is pastured with unrestricted cattle access.

Killbuck Creek tributaries below Salt Creek to below Black Creek

The macroinvertebrate communities sampled at 15 stations from 11 streams in this area were performing in the low fair range at one, fair at one, good at three, very good at one and exceptional at nine stations. Fourteen out of the 15 stations had one to 11 (average 6) cold water macroinvertebrate taxa in this area, indicating a strong connectivity to the groundwater.

The Corns Run (RM 0.7) station located upstream from C-400, upstream from the confluence of Bear Run and downstream from the Holmes Cheese WWTP discharge was evaluated as low fair due to low EPT (3) and sensitive taxa (3) diversities and the riffle habitat was predominated by only facultative taxa without any EPT taxa. The macroinvertebrate community at this station was highly impacted by the Holmes Cheese WWTP discharge.

The Sapps Run (RM 0.8) station located at C-349 had interstitial flow on 27 July when the macroinvertebrate community was sampled. As a result, only pooled habitats were available for sampling. The community present was evaluated as fair due to the EPT (7) and sensitive taxa (9) diversities being below WWH expectations and the available habitats were primarily predominated by facultative and tolerant taxa. Observed abundant algal growth was an indication that nutrient enrichment may have contributed to the impairment at this station.

Killbuck Creek tributaries below Black Creek to Walhonding River

The macroinvertebrate communities sampled at 15 stations from seven streams in this area were performing in the fair range at one, marginally good at three, good at four, very good at one and exceptional at six stations. Nine out of the 15 stations had one to seven (average 3.5) cold water macroinvertebrate taxa in this area, indicating a strong connectivity to the groundwater in most of these streams, with Doughty Creek being the exception with only the two downstream stations having any cold water taxa.

The macroinvertebrate community sampled from the Tributary to Doughty Creek @RM 14.34 (RM 1.4) upstream from the unsewered community of Charm was evaluated as fair due to the EPT (7) diversity being below the WWH expectation. In particular, the mayfly diversity and abundance was very low with only two taxa present. Elevated manganese (1450-2490, med. 1955 µg/l) and TDS (530-656, med. 580 mg/l) were likely contributing causes of the impacted community. The macroinvertebrate community sampled from the Tributary to Doughty Creek @RM 14.34 (RM 0.6) downstream from the unsewered community of Charm was evaluated as marginally good due to the EPT (9) and sensitive taxa (11) diversities being at the minimum of the WWH expectations and the sparsity of sensitive EPT taxa at the site (1 mayfly and 1 caddisfly taxa). The stream in this area flowed through a pasture where cows had unrestricted access to the stream and the riparian forest was completely absent. Observed heavy silt cover and algal growth were indications that siltation and nutrient and/or organic enrichment in conjunction with the loss of the forested riparian were likely limiting the biotic integrity at this station.

The macroinvertebrate communities at two stations on Doughty Creek (RMs 18.7, 14.3) were marginally meeting WWH expectations (Figure 37). The upstream station (T-359, RM 18.7) was likely limited by siltation and enrichment from channelization and open pastures. The downstream station (T-123, RM 14.3) may have been limited by the eutrophication effects caused by nutrient inputs from the Guggisberg Cheese WWTP (RM 14.86) and Berlin WWTP (RM 16.4).

Macroinvertebrate Trends

Macroinvertebrate community performance in Killbuck Creek during this study demonstrated improvement compared to sampling in 1983 and 1993 (Figure 34). The ICI scores were similar at several corresponding sites between the years, however, the general trend of the ICI scores in 2009 was higher, with all ICIs above the biocriterion. The qualitative EPT and sensitive taxa diversities in 2009 were consistently higher throughout the stream length than previous years, except for the station at C 320 (RM 37.1) which was highly channelized and located just downstream of the adjacent wetland areas downstream from Wooster.

Macroinvertebrate community performance in Apple Creek during this study demonstrated improvement compared to sampling in 1983 and 1993 (Figure 35). The ICI scores were similar to those from 1993 and greatly improved compared to the one ICI score from 1983 near the mouth. The qualitative EPT and sensitive taxa diversities in 2009 were consistently higher throughout the stream length than previous years.

Macroinvertebrate community performance in Little Apple Creek during this study demonstrated improvement compared to sampling in 1983 and 1987 (Figure 36). The qualitative EPT and sensitive taxa diversities in 2009 were consistently higher throughout the stream length than previous years.

Macroinvertebrate community performance in Doughty Creek during this study was similar to sampling in 1983 and 1993 (Figure 37). The Guggisberg Cheese WWTP did not have an observed impact on macroinvertebrate communities sampled immediately downstream from the discharge during the sampled years.

Table 22. Summary of macroinvertebrate data collected from artificial substrates (quantitative sampling) and natural substrates (qualitative sampling) in the Killbuck Creek study area, July to October, 2009.

Stream RM	Dr. Ar. (sq. mi.)	Data Codes	Qual. Taxa	EPT Ql. / Total	Sensitive Taxa Ql. / Total	Density Ql. / Qt.	CW Taxa	Predominant Organisms on the Natural Substrates With Tolerance Category(ies)	ICI[a]	Narrative Evaluation
Killbuck Creek (17-150)										
75.7	5.1	-	55	21	24	M-H	4	Caddisflies (MI,F), midges (F,MI)	-	Exceptional
72.8	15.8	-	79	24	30	M-H	3	Caddisflies (MI,F), baetid mayflies (F,I), midges (MI,F)	-	Exceptional
70.9	20.4	-	68	19	20	M-H	0	Midges (MI,F,T), baetid mayflies (F,I), hydropsychid caddisflies (F,MI)	-	Very Good
66.9	42.3	-	66	15	22	M	3	Caddisflies (F,MI), baetid mayflies (F,I), midges (MI,F)	-	Good
64.4	56	4,12	69	20 / 21	30 / 38	L / 576	0	*Helichopsyche* caddisflies (MI), baetid mayflies (F,I), midges (MI,F)	44	
55.4	92	5,12	87	31 / 37	46 / 59	L-m / 1993	10	Hydropsychid caddisflies (MI,F), baetid mayflies (F,I), midges (MI,F)	48	
50.3	136	-	81	29 / 30	34 / 43	L-M / 453	3	Hydropsychid caddisflies (F,MI), midges (F,MI), mites (F)	50	
49.4	190	-	79	23 / 26	36 / 50	M / 1099	6	Caddisflies (MI,F), baetid mayflies (F), midges (F)	46	
46.0	194	-	61	14 / 19	21 / 34	L-M / 994	3	Caddisflies (F,MI), mayflies (I,F,MI), midges (MI,F)	44	
37.1	313	-	42	6 / 12	9 / 18	M / 571	0	Midges (MI), hydropsychid caddisflies (F), riffle beetles (MI)	36	
35.6	367	-	73	22 / 28	31 / 40	L / 1341	2	Midges (MI,F), hydropsychid caddisflies (F,MI), baetid mayflies (F)	48	
31.9	380	-	53	14 / 19	19 / 26	L / 758	0	Hydropsychid caddisflies (F,MI), midges (F,MI), blackflies (F)	46	

Stream RM	Dr. Ar. (sq. mi.)	Data Codes	Qual. Taxa	EPT Ql. / Total	Sensitive Taxa Ql. / Total	Density Ql. / Qt.	CW Taxa	Predominant Organisms on the Natural Substrates With Tolerance Category(ies)	ICI[a]	Narrative Evaluation
28.9	407	-	54	15 / 20	18 / 24	L-M / 1406	0	Hydropsychid caddisflies (F,MI), midges (MI,F), mayflies (F,MI)	46	
24.9	462	-	47	14 / 18	15 / 21	L-M / 1555	0	Midges (MI,F), hydropsychid caddisflies (F), heptageniid mayflies MI)	42	
23.9	464	-	53	22 / 23	25 / 29	L-M / 1455	0	Midges (MI,F), blackflies (F), mayflies (F,MI)	44	
20.7	501	-	48	13 / 17	20 / 29	M / 2363	0	Caddisflies (F,MI), midges (MI,F), riffle beetles (MI)	38	
13.3	581	-	28	21 / 24	28 / 36	L / 1138	0	Caddisflies (MI), midges (MI,T), mayflies (F,MI)	44	
1.7	600	-	81	28 / 36	42 / 55	L-M / 1600	0	Caddisflies (F,MI), midges (F,MI), mayflies (F,MI)	52	
Camel Creek (17-190)										
3.8	8.7	15	67	19 / 20	26 / 38	L / 617	8	Hydropsychid caddisflies (F,MI), baetid mayflies (F,I), midges (MI,F)	50	
0.5	12.5	-	60	15	19	M	0	Midges (MI,F), hydropsychid caddisflies (F,MI), baetid mayflies (F)	-	Good
Repp Run (17-189)										
0.9	3.4	-	64	18	24	M	3	Hydropsychid caddisflies (F,MI), baetid mayflies (F,I), midges (MI,F)	-	Very Good
Cedar Run (17-186)										
1.5	5.9	-	66	19	32	L	10	Baetid mayflies, (MI,F), *Leuctra* stoneflies (I), hydropsychid caddisflies (MI)	-	Exceptional

Stream RM	Dr. Ar. (sq. mi.)	Data Codes	Qual. Taxa	EPT Ql. / Total	Sensitive Taxa Ql. / Total	Density Ql. / Qt.	CW Taxa	Predominant Organisms on the Natural Substrates With Tolerance Category(ies)	ICI[a]	Narrative Evaluation
Little Killbuck Creek (17-184)										
6.5	7.0	-	69	13	18	M-H	2	Baetid mayflies, (F), midges (MI,F), hydropsychid caddisflies (F,MI)	-	Good
0.5	20.8	6	66	20 / 23	28 / 42	L	5	Midges (MI,F), baetid mayflies (F), hydropsychid caddisflies (MI,F)	50	
Rathburn Run (17-185)										
2.5	5.1	-	43	9	14	M	3	Hydropsychid caddisflies (F,MI), midges (F,MI), baetid mayflies (F,MI)	-	Marg. Good
Clear Creek (17-183)										
3.7	7.2	-	69	25	34	M	4	Hydropsychid caddisflies (MI,F), baetid mayflies (F,MI), *Leuctra* stoneflies (I)	-	Exceptional
1.1	11.4	-	76	25	38	M	6	Hydropsychid caddisflies (MI,F), baetid mayflies (F,MI), midges (F,MI)	-	Exceptional
Apple Creek (17-181)										
10.5	4.6	-	65	18	23	M	2	Caddisflies (F,MI,I), baetid mayflies (F), midges (MI)	-	Good
8.3	15.0	-	67	15	24	M	3	Hydropsychid caddisflies (MI,F), baetid mayflies (F), midges (F)	-	Good
6.3	23.0	-	73	21 / 23	30 / 41	M / 580	3	Caddisflies (MI,F), baetid mayflies (F), midges (MI)	52	
2.0	49.0	-	58	19 / 22	21 / 36	L-M / 446	4	Hydropsychid caddisflies (MI,F), baetid mayflies (F), midges (MI)	42	
1.6	49.0	-	66	19 / 25	29 / 44	M / 659	6	Caddisflies (MI,F), baetid mayflies (F), midges (F,MI)	56	

Stream RM	Dr. Ar. (sq. mi.)	Data Codes	Qual. Taxa	EPT Ql. / Total	Sensitive Taxa Ql. / Total	Density Ql. / Qt.	CW Taxa	Predominant Organisms on the Natural Substrates With Tolerance Category(ies)	ICI[a]	Narrative Evaluation
0.6	51.4	-	50	15 / 18	17 / 36	L-M / 659	5	Hydropsychid caddisflies (F,MI), midges (MI), blackflies (F)	50	
0.1	51.6	5,12	50	14 / 18	21 / 38	L / 697	3	Hydropsychid caddisflies (F,MI), midges (MI), baetid mayflies (F)	50	
Little Apple Creek (Trib. to Apple Cr. @ RM 9.79) (17-149 / 17-181-003)										
1.1	3.8	-	53	15	19	M	3	Caddisflies (F,MI), baetid mayflies (F,I), midges (MI,F)	-	Good
Spring Run (17-198 / 17-181-001)										
0.4	5.1	-	49	16	20	M	5	Hydropsychid caddisflies (MI,F), baetid mayflies (F,MI), midges (MI,F)	-	Good
Little Apple Creek (17-182)										
4.5	5.7	-	55	15	17	L-M	3	Baetid mayflies (F), caddisflies (F,MI), water penny beetles (MI)	-	Good
1.7	11.1	-	71	14	24	L-M	6	Baetid mayflies (F,MI), midges (MI,F), hydropsychid caddisflies (MI,F)	-	Good
0.2	12.9	-	62	12	25	M	3	Baetid mayflies (F), hydropsychid caddisflies (MI,F), midges (MI,F) ,	-	Good
Trib. to Killbuck Cr. @ RM 43.60 ("Millbrook Trib.") (17-144 / 17-150-011)										
2.7	5.0	-	49	12	18	M-H	11	Hydropsychid caddisflies (MI), baetid mayflies (MI), *Leuctra* stoneflies (I)	-	Good
Shreve Creek (17-180)										
3.1	10.0	-	38	6	7	M	1	Midges (F,T,MI), baetid mayflies (F), blackflies (F)	-	Fair

Stream RM	Dr. Ar. (sq. mi.)	Data Codes	Qual. Taxa	EPT Ql. / Total	Sensitive Taxa Ql. / Total	Density Ql. / Qt.	CW Taxa	Predominant Organisms on the Natural Substrates With Tolerance Category(ies)	ICI[a]	Narrative Evaluation
Salt Creek (17-175)										
8.5	13.2	-	53	14	12	M	3	Hydropsychid caddisflies (F,MI), mayflies (F), midges (F)	-	Good
5.0	34.5	-	63	20 / 22	24	L-M / 845	3	Caddisflies (F,MI), midges (MI), mites (F)	54	
3.0	39.3	-	69	25 / 26	29	L-M / 660	2	Caddisflies (F,MI), mayflies (MI,F), mites (F)	58	
0.7	42.6	-	64	19 / 23	25	L-M / 953	2	Midges (F), *Tricorythodes* mayflies (MI), mites (F)	54	
North Branch Salt Creek (17-176)										
3.3	6.9	-	44	7	8	M	0	Midges (T,F)	-	Fair
3.3[b]	6.9	-	58	10	8	L-M	1	Midges (F,MI,T), hydropsychid caddisflies (F), riffle beetles (MI)	-	Fair
Paint Creek (17-173)										
8.7	4.8	-	57	21	28	M	5	Hydropsychid caddisflies (MI), baetid mayflies (I,F,MI), midges (MI,I,F)	-	Exceptional
5.3	14.3	-	57	20	26	M-H	7	Mayflies (MI,F,I), hydropsychid caddisflies (MI), midges (MI,F)	-	Exceptional
1.6	25.6	-	53	26	27	M-H	3	Mayflies (MI,F,I), hydropsychid caddisflies (MI), midges (MI,F)	-	Exceptional
Tributary to Paint Creek @ RM 3.01 (17-148 / 17-173-001)										
1.5	4.2	-	61	23	36	M	6	Caddisflies (MI), mayflies (I,MI,F), *Leuctra* stoneflies (I)	-	Exceptional
Martins Creek (17-172)										
3.5	12.5	-	59	16	20	M-H	4	Hydropsychid caddisflies (MI,F), mayflies (MI,F), midges (F,MI)	-	Good

Stream RM	Dr. Ar. (sq. mi.)	Data Codes	Qual. Taxa	EPT Ql. / Total	Sensitive Taxa Ql. / Total	Density Ql. / Qt.	CW Taxa	Predominant Organisms on the Natural Substrates With Tolerance Category(ies)	ICI[a]	Narrative Evaluation
Honey Run (17-170)										
1.0	6.2	-	50	17	24	M-H	6	Baetid mayflies (F,MI), blackflies (F), midges (F,MI), hydropsychid caddisflies (MI)	-	Good
Sapps Run (17-166)										
0.8	8.5	9	46	7	9	M	0	Snails (T,F), midges (MI,F,T), beetles (F)	-	Fair
Corns Run (17-169)										
1.5	1.1	-	42	14	15	L-M	3	Caddisflies (MI,F), midges (F,MI)	-	Good
0.7	1.7	-	39	3	3	M-H	1	Midges (F), water mites (F)	-	Low Fair
Bear Run (17-168)										
0.8	2.6	-	42	18	22	M	7	Caddisflies (MI), baetid mayflies (I,MI,F), *Leuctra* stoneflies (I)	-	Very Good
Sand Run (17-164)										
0.4	8.5	-	62	20	31	L	8	Hydropsychid caddisflies (F,MI), baetid mayflies (F,MI), midges (MI,F)	-	Exceptional
Shrimplin Creek (17-162)										
2.9	5.7	-	59	23	35	M	11	Hydropsychid caddisflies (MI), *Tricorythodes* mayflies (MI), mites (F)	-	Exceptional
Black Creek (17-161)										
9.8	3.8	-	56	20	27	L	9	Caddisflies (MI), *Leuctra* stoneflies (I), baetid mayflies (I)	-	Exceptional
4.6	26.5	-	72	25	42	M	7	Hydropsychid caddisflies (MI), midges (MI,F), mites (F)	-	Exceptional

Stream RM	Dr. Ar. (sq. mi.)	Data Codes	Qual. Taxa	EPT Ql. / Total	Sensitive Taxa Ql. / Total	Density Ql. / Qt.	CW Taxa	Predominant Organisms on the Natural Substrates With Tolerance Category(ies)	ICI[a]	Narrative Evaluation
Tributary to Black Creek @ RM 7.35 (17-147 / 17-161-001)										
0.7	4.6	-	74	22	35	L	7	Caddisflies (MI), mayflies (MI,F), *Leuctra* stoneflies (I)	-	Exceptional
Wolf Creek (17-160)										
4.1	18.1	-	69	34	42	L-M	7	Hydropsychid caddisflies (MI,F), baetid mayflies (I,F), midges (MI,F)	-	Exceptional
2.1	22.9	-	72	20	24	L	2	Hydropsychid caddisflies (F,MI)	-	Very Good
Tributary to Wolf Creek @ RM 6.49 (17-146 / 17-160-001)										
1.4	4.7	-	60	21	31	L-M	7	Mites (F), hydropsychid caddisflies (MI), *Antocha* craneflies (MI)	-	Exceptional
Big Run (17-157)										
3.6	8.3	-	59	22	27	L	4	Mayflies (F,I,MI), midges (MI,F)	-	Exceptional
Doughty Creek (17-153)										
18.7	5.5	-	65	10	10	M-H	0	Hydropsychid caddisflies (F), baetid mayflies (F), midges (MI,F,MT)	-	Marg. Good
15.9	13.0	-	57	11 / 15	14 / 22	M / 2001	0	Caddisflies (F,MI), midges (F,MT,MI), baetid mayflies (F)	46	
14.7	15.1	-	54	13	18	M-H	0	Hydropsychid caddisflies (F,MI), baetid mayflies (F), midges (F,MI)	-	Good
14.3	18.4	-	52	12	10	M	0	Hydropsychid caddisflies (F,MI), baetid mayflies (F), midges (F,MI)	-	Marg. Good
11.7	19.7	-	55	16	20	M	0	Hydropsychid caddisflies (F,MI), baetid mayflies (F), midges (MI,F)	-	Good
4.9	42.1	-	67	16 / 17	21 / 34	L-M / 496	1	Hydropsychid caddisflies (MI,F), baetid mayflies (F), midges (T,MI,F)	52	
0.6	60.7	-	60	18 / 19	24 / 30	L / 461	1	Hydropsychid caddisflies (F,MI), midges (MI,F), *Isonychia* mayflies (MI)	48	

Stream RM	Dr. Ar. (sq. mi.)	Data Codes	Qual. Taxa	EPT Ql. / Total	Sensitive Taxa Ql. / Total	Density Ql. / Qt.	CW Taxa	Predominant Organisms on the Natural Substrates With Tolerance Category(ies)	ICI[a]	Narrative Evaluation
Tributary to Doughty Creek @ RM 14.34 (17-138 / 17-153-001)										
1.4	1.4	-	39	7	12	L	5	Hydropsychid caddisflies (F,MI), midges (F,MI)	-	Fair
0.6	2.5	-	48	9	11	M	0	Hydropsychid caddisflies (MI,F), baetid mayflies (F), midges (F,MI)	-	Marg. Good
Military Run (17-155)										
0.8	4.9	-	54	16	16	L	3	Hydropsychid caddisflies (F,MI), midges (MI,F) , baetid mayflies (F)	-	Good
Bucklew Run (17-151)										
1.5	6.0	-	55	13	24	L	2	Midges (MI,F)	-	Good

RM: River Mile.
Dr. Ar.: Drainage Area
Data Codes: 5=3 HD Only, 6=4 HD Only, 8=Non-Detectable Current, 9=Intermittent or Near-Intermittent Conditions, 13=Suspected Disturbance by Vandalism, 15=Current >0.0 fps but <0.3 fps, 21=Mixing Zone Sample.
Ql.: Qualitative sample collected from the natural substrates.
Sensitive Taxa: Taxa listed on the Ohio EPA Macroinvertebrate Taxa List as MI (moderately intolerant) or I (intolerant).
Qt.: Quantitative sample collected on Hester-Dendy artificial substrates, density is expressed in organisms per square foot.
Qualitative sample relative density: L=Low, M=Moderate, H=High.
CW: Cold Water.
Tolerance Categories: VT=Very Tolerant, T=Tolerant, MT=Moderately Tolerant, F=Facultative, MI=Moderately Intolerant, I=Intolerant
[a] ICI values in parentheses are invalidated due to insufficient current speed over the artificial substrates. The station evaluation is based on the qualitative sample narrative evaluation.
[b] Sample was collected in 2010.

Table 23. Uncommon sensitive macroinvertebrate taxa (excluding freshwater mussels) collected from locations in the Killbuck Creek basin, 2009. State listed species: **E**=Endangered.

Taxa	Collection Location by River Mile
Mayflies	
Acentrella parvula	Killbuck Cr. 23.9, 1.7; Big Run 3.6
Acentrella turbida	Killbuck Cr. 55.4; Clear Cr. 3.7, 1.1; Paint Cr. 1.6; Wolf Cr. 4.1; Trib. to Wolf Cr. 1.4
Acerpenna macdunnoughi	Killbuck Cr. 75.7, 72.8; Camel Cr. 3.8; Repp Run 0.9; Paint Cr. 8.7, 5.3, 1.6; Trib. to Paint Cr. 1.5; Corns Run 1.5; Bear Run 0.8; Shrimplin Cr. 2.9; Black Cr. 9.8
Paracloeodes fleeki	Doughty Cr. 0.6
Paracloeodes minutus	Killbuck Cr. 23.9
Plauditus cestus	Big Run 3.6
Serratella deficiens	Killbuck Cr. 35.6; Wolf Cr. 4.1; Trib. to Wolf Cr. 1.4; Doughty Cr. 4.9
Dragonflies	
Boyeria grafiana	Trib. to Black Cr. 0.7
Lanthus parvulus	Clear Cr. 1.1; Black Cr. 9.8, 4.6
Stoneflies	
Pteronarcys sp.	Killbuck Cr. 35.6, 1.7
Acroneuria carolinensis	Killbuck Cr. 55.4
Agnetina capitata	Killbuck Cr. 31.9, 13.3, 1.7; Doughty Cr. 4.9
Fishflies	
Nigronia fasciatus	Killbuck Cr. 55.4
Caddisflies	
Dolophilodes distinctus	Killbuck Cr. 55.4; Millbrook Trib. 2.7; Honey Cr. 1.0; Bear Run 0.8; Shrimplin Cr. 2.9; Black Cr. 9.8; Trib. to Black Cr. 0.7
Psychomyia flavida	Apple Cr. 8.3; Paint Cr. 8.7; Shrimplin Cr. 2.9
Glossosoma sp.	Killbuck Cr. 49.4; Cedar Run 1.5; Clear Cr. 3.7, 1.1; Apple Cr. 6.3; Millbrook Trib. 2.7; Paint Cr. 8.7, 5.3, 1.6; Trib. to Paint Cr. 1.5; Honey Cr. 1.0; Bear Run 0.8; Shrimplin Cr. 2.9; Black Cr. 9.8; Trib. to Black Cr. 0.7; Wolf Cr. 4.1; Trib. to Wolf Cr. 1.4
Brachycentrus numerosus (**E**)	Killbuck Cr. 23.9, 13.3, 1.7
Midges	
Eukiefferiella devonica group	Apple Cr. 2.0
Lipiniella sp.	Wolf Cr. 2.1
Cladotanytarsus vander. gr. 3	Killbuck Cr. 64.4
Sublettea coffmani	Killbuck Cr. 1.7; Salt Cr. 3.0, 0.7; Shrimplin Cr. 2.9; Black Cr. 4.6; Doughty Cr. 4.9

Table 24. Freshwater mussels (Unionidae) collected live or fresh-dead by Hoggarth et al. (1995) and Hoggarth (1997) and by the Ohio EPA (2009 by river mile) from Killbuck Creek. State listed species: **E**=Endangered, **T**=Threatened, **SC**=Species of Concern; ***=also federally endangered.

Species	Hoggarth	Killbuck Creek stations by river mile								
		72.8	70.9	64.4	55.4	28.9	20.7	13.3	11.5	1.7
Actinonaias ligamentina carinata	RMs 13.0-0.9							X	X	X
Amblema plicata	RMs 55.5-54.2, 13.0-5.8									X
Anodontoides ferussacianus	RMs 72.8-72.3	X								
Alasmidonta marginata (**SC**)	RMs 12.6-0.9									
Cyclonaias tuberculata (**SC**)	RMs 13.0-5.8									X
Elliptio dilatata	RMs 66.6, 13.0-7.8. 5.8									
Epioblasma obliquata obliquata (**E***)	RMs 13.0-7.8, 5.8									
Epioblasma triquetra (**E**)	RMs 13.0-0.9									
Fusconaia flava	RMs 72.3, 64.4, 61.7-52.3, 46.0, 13.0-0.9			X				X	X	
Lampsilis cardium	RMs 13.0-5.8									X
Lampsilis ovata (**E**)	RMs 11.9-11.5									
Lampsilis radiata luteola	RMs 75.7, 72.3, 61.7-52.3, 46.0, 13.3-0.9			X	X	X		X	X	
Lasmigona complanata	RMs 64.4, 61.7-52.3, 46.0, 13.3-0.9				X					
Lasmigona compressa (**SC**)	RMs 59.5-54.2, 13.0-12.6, 0.9									
Lasmigona costata	RMs 58.5-54.2, 13.0-0.9				X					

Species	Hoggarth	Killbuck Creek stations by river mile								
		72.8	70.9	64.4	55.4	28.9	20.7	13.3	11.5	1.7
Leptodea fragilis	RMs 13.3-0.9						X			
Ligumia recta (**T**)	RMs 12.6-0.9								X	X
Pleurobema sintoxia (**SC**)	RMs 13.0-11.5									
Ptychobranchus fasciolaris (**SC**)	RMs 13.0-0.9									
Pyganodon grandis	RMs 63.4, 61.7-52.3, 46.0, 13.0-7.8, 0.9		X							
Quadrula pustulosa	RMs 13.0-0.9						X		X	
Quadrula quadrula	RMs 12.6-11.9, 0.9									
Strophitus undulatus	RMs 59.5-54.2, 13.0-0.9									
Tritogonia verrucosa	RMs 13.0-0.9							X	X	X
Utterbackia imbecillis	RMs 59.5-58.5, 55.5-54.2									
Total species per station:		1	1	2	3	1	2	4	6	6

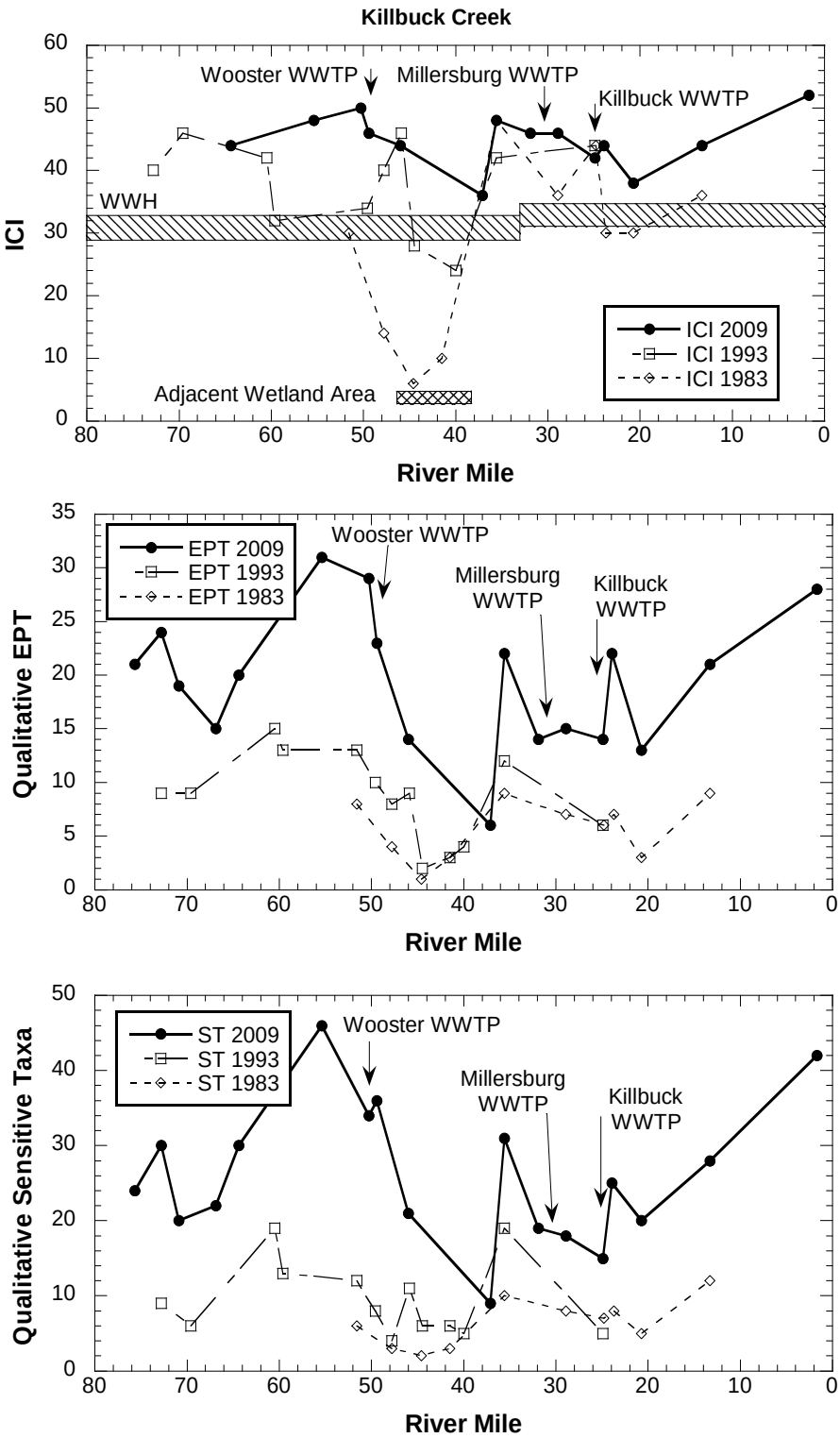


Figure 32. Longitudinal trend of the Invertebrate Community Index (ICI), number of EPT taxa (EPT) in the qualitative sample, and number of sensitive taxa (ST) in the qualitative sample in Killbuck Creek, 1983-2009.

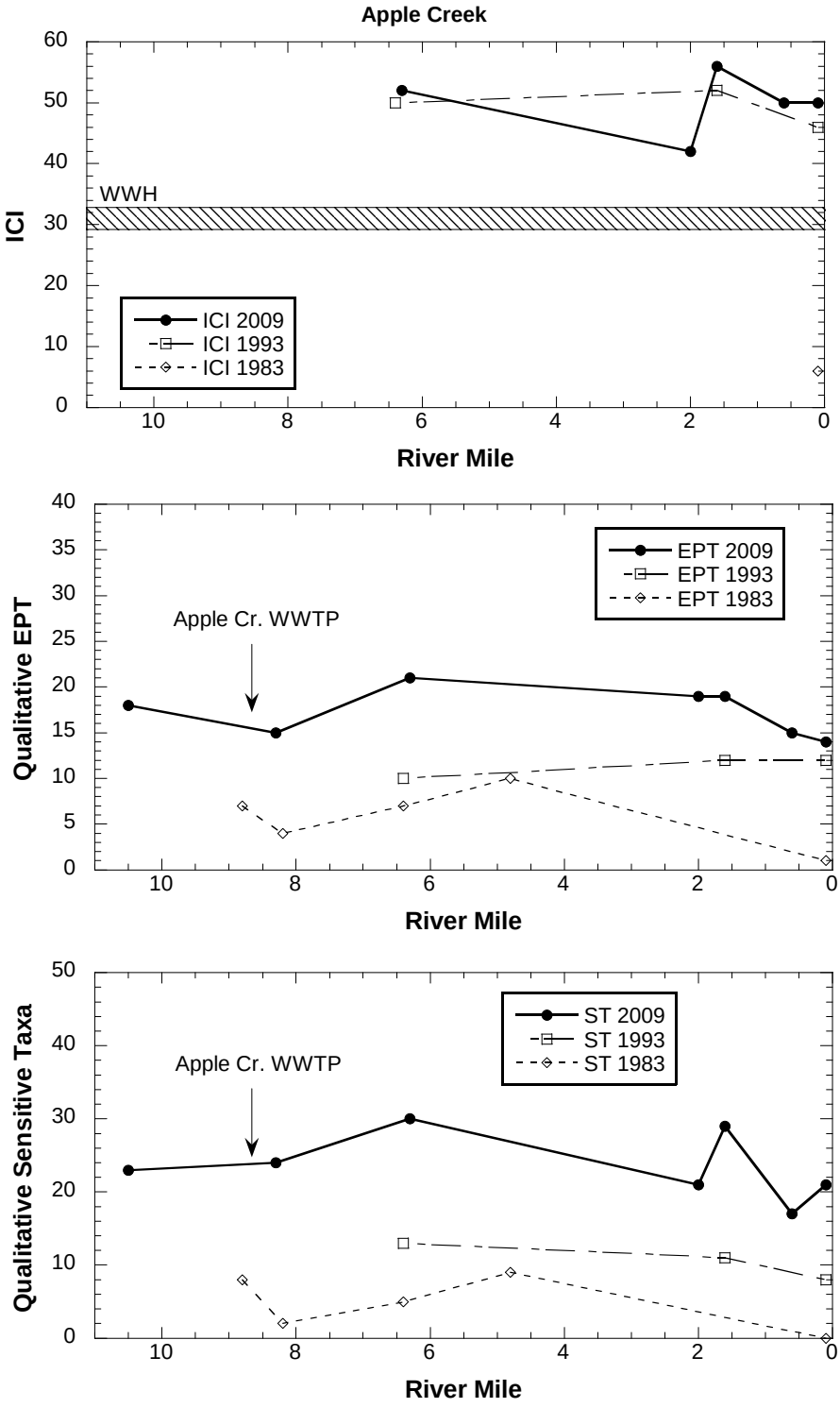


Figure 33. Longitudinal trend of the Invertebrate Community Index (ICI), number of EPT taxa (EPT) in the qualitative sample, and number of sensitive taxa (ST) in the qualitative sample in Apple Creek, 1983-2009.

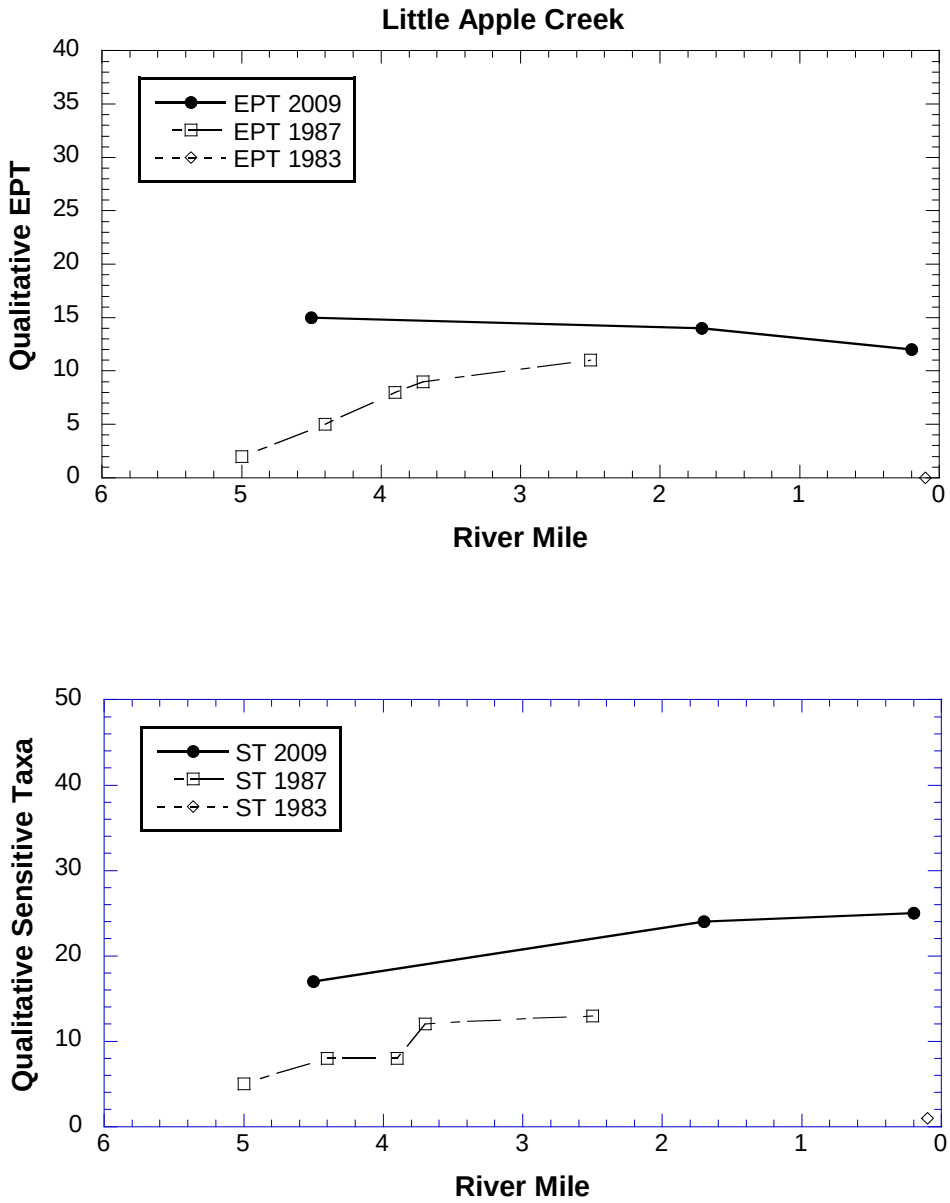


Figure 34. Longitudinal trend of the number of EPT taxa (EPT) in the qualitative sample and number of sensitive taxa (ST) in the qualitative sample in Little Apple Creek, 1983-2009.

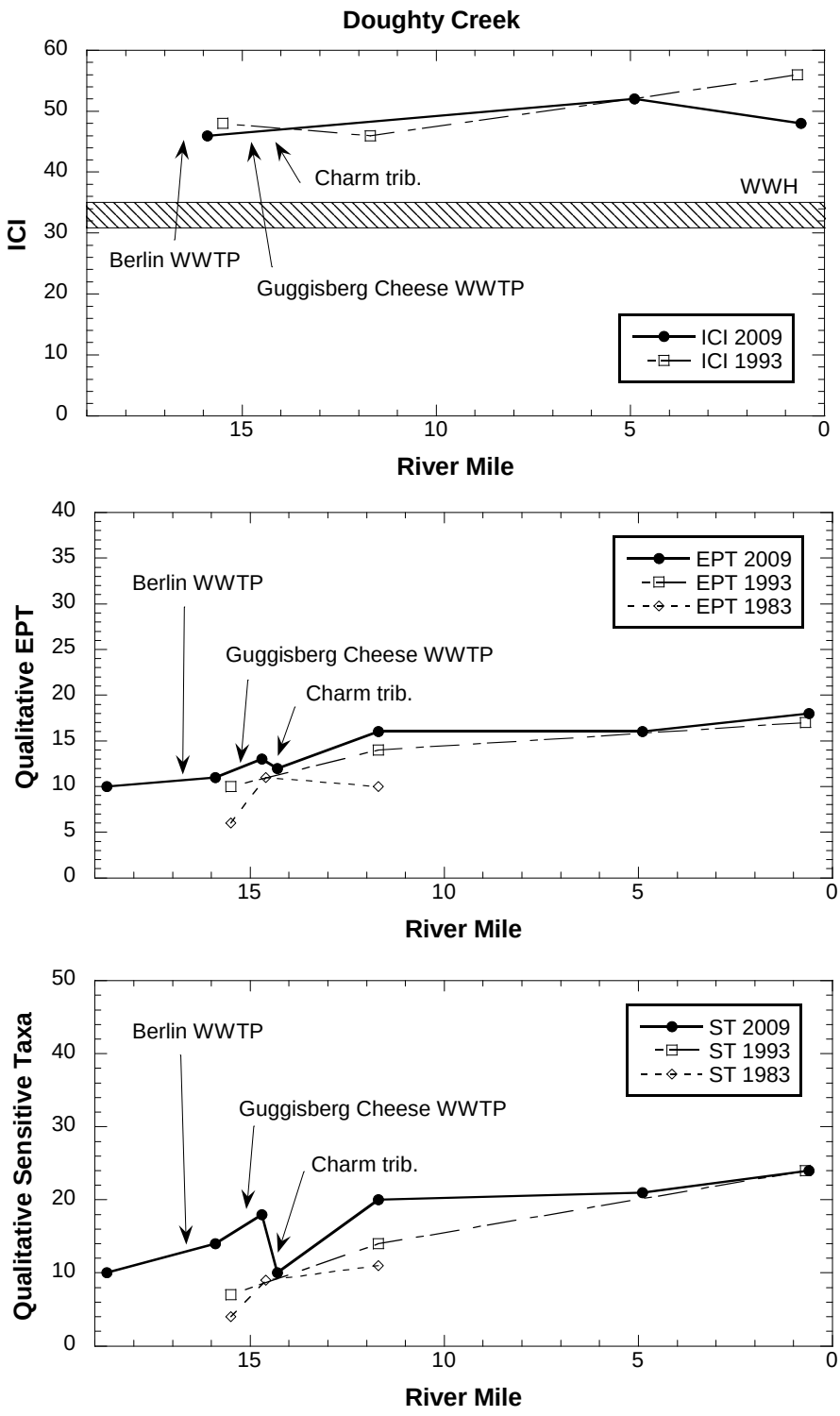


Figure 35. Longitudinal trend of the Invertebrate Community Index (ICI), number of EPT taxa (EPT) in the qualitative sample, and number of sensitive taxa (ST) in the qualitative sample in Doughty Creek, 1983-2009.

ACKNOWLEDGMENTS

The following Ohio EPA staff are acknowledged for their contribution to this report:

Study area – Bill Zawiski
Chemical water/sediment quality; Point sources – Bill Zawiski
Physical habitat – Bob Miltner
Biological assessment:
    Macroinvertebrate community –Mike Bolton
    Fish community – Bob Miltner
Data management - Dennis Mishne
TSD coordination – Mike Bolton
Reviewers – Jeff DeShon, Holly Tucker

This evaluation and report was possible only with the assistance of the study team, many full and part time field staff and interns, and the chemistry analysis provided by the Ohio EPA Division of Environmental Services. Property owners who permitted access for sampling are also gratefully acknowledged for their cooperation.

Copies of this report are located on the Ohio EPA internet web page (www.epa.state.oh.us/dsw/document_index/psdindx.html) or may be available on CD from:

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References

Anderson, P. and R.D. Davic. 2004. Use of transparency tubes for rapid assessment of total suspended solids and turbidity in streams. Lake and Reservoir Management 20(2):110-120.

Dufour, A.P. 1977. "*Escherichia coli*: The fecal coliform." *American Society for Testing and Materials* (Spec. Publ.), 635, 45-58.

Hoggarth, M.A. 1997. The Distribution of the Unionidae (Mollusca: Bivalvia) of the Walhonding River as a Function of the Physical Condition of the Stream, Including Studies of the Catspaw (*Epioblasma obliquata obliquata*) in the Walhonding River and Killbuck Creek. Ohio Department of Natural Resources, Division of Wildlife. 62 pages.

Hoggarth, M.A., D.L. Rice, and D.M. Lee. 1995. Discovery of the Federally Endangered Freshwater Mussel, *Epioblasma obliquata obliquata* (Rafinesque, 1820) (Unionidae), in Ohio. Ohio Journal of Science, 95(4):298-299.

Karr, J. R. 1991. Biological integrity: A long-neglected aspect of water resource management. Ecological Applications 1(1): 66-84.

Karr J. R. and E.W. Chu. 2000. Sustaining living rivers. Hydrobiologia 422/423: 1-14.

Karr, J.R., K.D. Fausch, P.L. Angermier, P.R. Yant, and I.J. Schlosser. 1986. Assessing biological integrity in running waters: a method and its rationale. Ill. Nat. Hist. Surv. Spec. Publ. 5. 28 pp.

MacDonald, D., C. Ingersoll, T. Berger. 2000. Development and evaluation of consensus-based sediment quality guidelines for freshwater ecosystems. Arch. Environ. Contam. Toxicol.: Vol.39, 20-31.

Miltner, R.J. and E.T. Rankin. 1998. Primary nutrients and the biotic integrity of rivers and streams. Freshwater Biology 40:145-158.

Miltner, R.J., D. White, and C.O. Yoder. 2004. The biotic integrity of streams in urban and suburbanizing landscapes. Landscape and Urban Planning 69 (2004) 87–100.

Miner R. and D. Borton. 1991. Considerations in the development and implementation of biocriteria, Water Quality Standards for the 21st Century, U.S. EPA, Offc. Science and Technology, Washington, D.C., 115.

Ohio Environmental Protection Agency. 1987a. Biological criteria for the protection of aquatic life: Volume I. The role of biological data in water quality assessment. Division of Water Quality Monitoring and Assessment, Surface Water Section, Columbus, Ohio.

Ohio Environmental Protection Agency. 1987b. Biological criteria for the protection of aquatic life: Volume II. Users manual for biological field assessment of Ohio surface waters. Division of Water Quality Monitoring and Assessment, Surface Water Section, Columbus, Ohio.

Ohio Environmental Protection Agency. 1989a. Addendum to biological criteria for the protection of aquatic life: Volume II. Users manual for biological field assessment of Ohio surface waters. Division of Water Quality Planning and Assessment, Surface Water Section, Columbus, Ohio.

Ohio Environmental Protection Agency. 1989b. Biological criteria for the protection of aquatic life: Volume III. Standardized biological field sampling and laboratory

methods for assessing fish and macroinvertebrate communities. Division of Water Quality Planning and Assessment, Columbus, Ohio.

Ohio Environmental Protection Agency. 1999. Association Between Nutrients, Habitat, and the Aquatic Biota in Ohio Rivers and Streams. Division of Surface Water, Columbus, Ohio.

Ohio Environmental Protection Agency. 2001. Ohio EPA Sediment Sampling Guide and Methodologies. Division of Emergency Remedial Response, Columbus, Ohio.

Ohio Environmental Protection Agency. 2006. Methods for assessing habitat in flowing waters: Using the Qualitative Habitat Evaluation Index (QHEI). Ohio EPA Tech. Bull. EAS/2006-06-1. Div. of Surface Water, Ecol. Assess. Sect., Columbus, Ohio.

Ohio Environmental Protection Agency. 2008a. 2008 updates to Biological Criteria for the Protection of Aquatic Life: Volume II and Volume II Addendum. Users manual for biological field assessment of Ohio surface waters. Div. of Surface Water, Ecol. Assess. Sect., Columbus, Ohio.

Ohio Environmental Protection Agency. 2008b. 2008 updates to Biological Criteria for the Protection of Aquatic Life: Volume III. Standardized biological field sampling and laboratory methods for assessing fish and macroinvertebrate communities. Div. of Surface Water, Ecol. Assess. Sect., Columbus, Ohio.

Ohio Environmental Protection Agency. 2008c. Sediment Reference Values. Division of Emergency and Remedial Response, Columbus, Ohio.

Ohio Environmental Protection Agency. 2009. Ohio EPA manual of surveillance methods and quality assurance practices, updated edition. Division of Environmental Services, Columbus, Ohio.

Omernik, J.M. and A.L. Gallant. 1988. Ecoregions of the Upper Midwest States. EPA/600/3-88/037. U. S. Environmental Protection Agency, Environmental Research Laboratory, Corvalis, Oregon. 56pp.

Rankin, E.T. 1989. The qualitative habitat evaluation index (QHEI): rationale, methods, and application. Div. Water Qual. Plan. & Assess., Ecol. Assess. Sect., Columbus, Ohio.

Rankin, E. T. 1995. The use of habitat assessments in water resource management programs, pp. 181-208. in W. Davis and T. Simon (eds.). Biological Assessment and Criteria: Tools for Water Resource Planning and Decision Making. Lewis Publishers, Boca Raton, FL.

Steedman, R. J. 1988. Modification and assessment of the Index of Biotic Integrity to quantify stream quality in southern Ontario. Canadian Journal of Fisheries and Aquatic Sciences 45: 492-501.

Suter, G.W., II. 1993. A critique of ecosystem health concepts and indexes. Environmental Toxicology and Chemistry 12: 1533-1539.

Ward, A. and S.W. Trimble. 2004. Environmental Hydrology. CRC-Lewis Press, Boca Raton,FL 475pp.

Yoder, C.O. 1989. The development and use of biological criteria for Ohio surface waters. U.S. EPA, Criteria and Standards Div., Water Quality Stds. 21st Century, 1989: 139-146.

Yoder, C. O. 1991. Answering some concerns about biological criteria based on experiences in Ohio, *in* G. H. Flock (ed.) Water quality standards for the 21st

century. Proceedings of a National Conference, U. S. EPA, Office of Water, Washington, D.C.

Yoder, C.O. 1995. Policy issues and management applications of biological criteria, *in* W.S. Davis and T. Simon (eds.). Biological Assessment and Criteria: Tools for Risk-based Planning and Decision Making. CRC Press/Lewis Publishers, Ann Arbor.

Yoder, C.O. and E.T. Rankin. 1995. Biological criteria program development and implementation in Ohio, pp. 109-144. in W. Davis and T. Simon (eds.). Biological Assessment and Criteria: Tools for Water Resource Planning and Decision Making. Lewis Publishers, Boca Raton, FL.