



Biological and Water Quality Study of the Brandywine
Creek-Broken Sword Creek (Sandusky River) Study Area

2013

Hydrologic Unit Code (HUC)

04100011 03 01

Crawford County, Ohio



OHIO EPA Technical Report EAS/2015-03-02

Division of Surface Water
March 23, 2015

**Biological and Water Quality Study of the Brandywine Creek-
Broken Sword Creek (Sandusky River) Study Area
2013**

**Hydrologic Unit Code (HUC)
04100011 01 03**

Crawford County, Ohio

In support of:
U.S. Department of Agriculture
Natural Resource Conservation Service
National Water Quality Initiative

EA³ Project Name
Broken Sword Creek (Sandusky Basin)
NWQI Project, 2013

Ohio Environmental Protection Agency
Division of Surface Water
50 W. Town Street, Suite 700
Columbus, OH 43215

Ecological Assessment Section
4675 Homer Ohio Lane
Groveport, OH 43125

Northwest District Office
Division of Surface Water
347 North Dunbridge Road
Bowling Green, Ohio 43402

March 23, 2015

Table of Contents

Acknowledgements.....	3
INTRODUCTION.....	4
SUMMARY AND CONCLUSIONS	5
METHODS.....	10
RESULTS	12
Macroinvertebrate Community	12
Fish Community and Physical Habitat.....	14
Water Quality.....	17
Water Quality Sondes	21
REFERENCES.....	24
Appendix Tables (Available as a companion document).	

List of Tables

Table 1. Aquatic life use attainment status for sampling locations in the Broken Sword Creek (Sandusky Basin) HUC-12 watershed study area, 2013. The Index of Biotic Integrity (IBI), Modified Index of Well-being (MIwb), and Invertebrate Community Index (ICI) scores are based on the performance of the biological community. The Qualitative Habitat Evaluation Index (QHEI) is a measure of the ability of the physical habitat to support a biological community. Sampling locations were evaluated using Warmwater Habitat (WWH) aquatic life use biocriteria codified in the Ohio Administrative Code (OAC 3745-1-07, Table 7-15) for the Eastern Corn Belt Plains (ECBP) ecoregion of Ohio. If biological impairment has occurred, the cause(s) and source(s) of the impairment, based on the weight of evidence of data, are noted.	6
Table 2. Sampling locations in the Brandywine Creek-Broken Sword Creek (Sandusky River) watershed study area, 2013.	9
Table 3. Summary of macroinvertebrate data collected by Ohio EPA from artificial substrates (quantitative sampling) and natural substrates (qualitative sampling) in the Broken Sword Creek (Sandusky River) HUC-12 watershed study area, 2013. The applicable aquatic life use designation is Warmwater Habitat (WWH).	13
Table 4. Fish community summaries based on pulsed D.C. headwater and wading electrofishing sampling conducted by Ohio EPA in the Brandywine and Broken Sword Creek HUC-12 watershed study area, 2013. The applicable aquatic life use designation is Warmwater Habitat (WWH) for all sites.	15
Table 5. Qualitative Habitat Evaluation Index (QHEI) scores and physical attributes for sampling sites in the Lye Creek HUC-12 watershed study area, 2005-2013.	16
Table 6. Seasonal geometric mean values (mg/l) for nutrients calculated from grab samples collected in the Brandywine Creek-Broken Sword Creek WAU. Target levels for phosphorus are 0.08 mg/l (WWH) for headwaters and 0.10 mg/l (WWH) for wadeable streams. Target levels for nitrate-nitrite are 1.0 mg/l (WWH) for headwaters and 1.0 mg/l (WWH) for wadeable streams. Results highlighted are above statewide recommended targets (Ohio EPA, 1999).	18

List of Figures

Figure 1. Sampling locations (biological, physical habitat, and stream chemistry) and current land uses in the Brandywine Creek-Broken Sword Creek HUC-12 watershed study area, 2013.	8
Figure 2. The narrow and incised stream channel in Broken Sword Creek at Schwemley Road (RM 32.6) pictured above is designed for the quick transport of storm water. The increase in water transport exacerbates downstream flooding and also means increased sediment and nutrient transport from the adjacent tiled fields.	14

Figure 3. Geometric means for total phosphorus and nitrate+nitrite in the Brandywine Creek-Broken Sword Creek HUC-12 watershed study area, 2013-2014.....19

Figure 4. Plot of continuous field parameters collected with a submersible water quality sonde at Brokensword Creek (RM 25.48), August 13-15, 2013, with sensors taking hourly readings of temperature (Temp - °C), dissolved oxygen (LDO - mg/L), pH (S.U.), and specific conductivity (SpCond - µS/cm).....20

Figure 5. Plot of continuous field parameters collected with a submersible water quality sonde at Brokensword Creek (RM 23.0), August 13-15, 2013, with sensors taking hourly readings of temperature (Temp - °C), dissolved oxygen (LDO - mg/L), pH (S.U.), and specific conductivity (SpCond - µS/cm).....21

Figure 6. Plot of continuous field parameters collected with a submersible water quality sonde at Brokensword Creek (RM 19.7), August 13-15, 2013, with sensors taking hourly readings of temperature (Temp - °C), dissolved oxygen (LDO - mg/L), pH (S.U.), and specific conductivity (SpCond - µS/cm).....22

Figure 7. Plot of continuous field parameters collected with a submersible water quality sonde at Brandywine Creek (RM 0.2), August 13-15, 2013, with sensors taking hourly readings of temperature (Temp - °C), dissolved oxygen (LDO - mg/L), pH (S.U.), and specific conductivity (SpCond - µS/cm).....23

Acknowledgements

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

Report preparation and analysis	Jeff DeShon and Ben Rich
Fish community and physical habitat	Ben Rich
Macroinvertebrate community	Chuck McKnight
Water column chemistry	Ben Smith
Data support	Dennis Mishne
Reviewers	Jeff DeShon
	Joshua Griffin
Stream sampling	Chris Riddle and Ben Smith
	Chuck McKnight with college intern Samantha Spence
	Ben Rich with college interns: Cory Richmond, Nathaniel Williams, and Brad Noskowiak

The Ohio EPA appreciates the cooperation of the property owners who allowed Ohio EPA personnel access to the project area.

INTRODUCTION

Through the National Water Quality Initiative (NWQI) in 2013, the Natural Resources Conservation Service (NRCS) will work with farmers and ranchers in 165 small watersheds throughout the Nation to improve water quality where this is a critical concern. In 2013, NRCS will provide nearly \$35 million in financial assistance to help farmers and ranchers implement conservation systems to reduce nitrogen, phosphorous, sediment and pathogen contributions from agricultural land. This is the second year of the initiative, and NRCS provided \$34 million in 2012 to farmers and ranchers in the first year for the implementation of conservation systems. NRCS worked closely with partners, including federal and state agencies, and Soil and Water Conservation Districts, to refine the eligible priority watersheds for 2013. These partners assisted in selecting one to 12 priority watersheds in every state where on-farm conservation investments will deliver the greatest water quality improvement benefits. Eligible producers will receive assistance under the Environmental Quality Incentives Program for installing conservation systems that may include practices such as nutrient management, cover crops, conservation cropping systems, filter strips, terraces, and in some cases, edge-of-field water quality monitoring. In Ohio, three priority watersheds were selected including the headwaters of Broken Sword Creek, the focus of this study.

During the 2013 field season (July through October) chemical, physical, and biological sampling was conducted at 12 stations in the Brandywine Creek-Broken Sword Creek watershed (HUC12- 04100011 01 03) to assess and characterize baseline water quality conditions prior to full implementation of NWQI on-farm conservation investments. The watershed lies within the Sandusky River basin, a direct tributary to the western basin of Lake Erie. The Brandywine Creek-Broken Sword Creek watershed encompasses the headwaters of Broken Sword Creek downstream to and including Brandywine Creek. The watershed is located in north central Ohio in Crawford County and is comprised of approximately 35,392 acres (55 mi²) - of which 82.6% is in agricultural row crop production. Other land uses within the watershed include developed land (6.2%), forest (8.1%) and grass/pasture (2.5%) (Source: National Land Data Set, 2001).

The current aquatic life use designation of Broken Sword Creek and its primary tributaries in this HUC12, Brandywine Creek and Red Run, is Warmwater Habitat (WWH). Based on sampling in 2001, portions of Broken Sword Creek and Brandywine Creek were recommended for the Modified Warmwater Habitat (MWH) use due to extensive channel modifications; the headwaters of Brandywine Creek and Red Run were recommended for the Limited Resource Water (LRW) designation (Table 1). However, these recommended designations have not yet been promulgated in the Ohio Water Quality Standards via a rulemaking; assessments for this study are based on the current, existing use. Based on the 2001 sampling survey results, principal causes of impairment in the Brandywine Creek-Broken Sword Creek watershed were identified as nutrients, direct habitat alterations, flow alterations, and excessive sedimentation/siltation. Primary impairment sources identified were nonirrigated crop production, channelization, flow regulation/modification, and spills.

Specific objectives of the evaluation were to:

- Establish the present biological conditions in the Brandywine Creek-Broken Sword Creek watershed by evaluating fish and macroinvertebrate communities;
- Identify the relative concentrations and loadings of nutrients and other selected parameters in surface water;
- Assess physical habitat influences on stream biotic integrity;
- Determine beneficial use attainment status and recommend changes if appropriate; and
- Confirm or revise causes and sources of beneficial use impairment as determined by earlier studies.

The entire watershed is located within the Eastern Corn Belt Plains (ECBP) ecoregion and there are no permitted point source dischargers present. Aquatic life use attainment conditions are presented in Table 1, and sampling locations are detailed in Table 2 and graphically presented in Figure 1. Stream samples, including sample type, drainage area and location information are listed in Table 2 and represented graphically in Figure 1.

SUMMARY AND CONCLUSIONS

Ohio EPA completed two passes of fish community sampling and artificial and natural substrate collections of macroinvertebrate communities at three Broken Sword Creek sites in 2013. One-pass fish sampling and qualitative, natural substrate macroinvertebrate sampling were completed at seven additional sites from Broken Sword Creek, Brandywine Creek, Red Run, and an unnamed tributary to Broken Sword Creek (RM 28.04) in 2013 (Figure 1 and Table 2). All sites received a Qualitative Habitat Evaluation Index (QHEI) assessment in 2013 and at least four grab samples for stream chemistry analyses during summer/fall, 2013 and spring, 2014. Sampling locations are detailed in Table 2 and graphically presented in Figure 1 and aquatic life use attainment status is presented in Table 1. Summarized sample attributes from all biological, physical habitat, and chemical water quality sites are included as Tables 3-6. Other relevant data, including raw data, are tabulated in the Appendices.

All biological, physical habitat, and chemical sampling results indicate the Brandywine-Broken Sword Creek study area is impaired due to direct habitat alterations, silt/sedimentation, and nutrient enrichment (Table 1). Nutrients were elevated above statewide target levels at all of the sample sites (Appendix G, Table 6 and Figure 3). A spill/fish kill affected approximately seven stream miles encompassing the unnamed tributary (RM 28.04) and Broken Sword Creek during the sampling season (Appendix H). It is recommended that altered stream sections in the assessed streams be restored or allowed to recover to a more natural condition in order to reduce nutrient runoff and increase the nutrient assimilative capacities of these streams.

Table 1. Aquatic life use attainment status for sampling locations in the Brandywine Creek-Broken Sword Creek HUC-12 watershed study area, 2013. The Index of Biotic Integrity (IBI), Modified Index of Well-being (MIwb), and Invertebrate Community Index (ICI) scores are based on the performance of the biological community. The Qualitative Habitat Evaluation Index (QHEI) is a measure of the ability of the physical habitat to support a biological community. Sampling locations were evaluated using Warmwater Habitat (WWH) aquatic life use biocriteria codified in the Ohio Administrative Code (OAC 3745-1-07, Table 7-15) for the Eastern Corn Belt Plains (ECBP) ecoregion of Ohio. If biological impairment has occurred, the cause(s) and source(s) of the impairment, based on the weight of evidence of data, are noted.

Point of Record River Mile	Aquatic Life Use Attainment Status	IBI	MIwb ^b	ICI ^a	QHEI	Aquatic Life Use Impairment Cause(s) Source(s)
Broken Sword Creek (05-035-000) WWH Existing						
32.60 ^H	Partial	50	b	F*	42.0	<u>Direct Habitat Alteration, Sedimentation/Siltation</u> Agriculture, Channelization
30.31 ^H	Partial	46	b	F*	56.5	<u>Direct Habitat Alteration, Sedimentation/Siltation</u> Agriculture, Channelization
27.96 ^W	Partial	34*	8.16 ^{ns}	28*	60.5	Direct Habitat Alteration, Sedimentation/Siltation, <u>Fish Kill</u> Agriculture, Channelization, Unknown
25.48 ^W	NON	31*	6.72*	18*	49.3	Direct Habitat Alteration, Sedimentation/Siltation, <u>Fish Kill</u> Agriculture, Channelization, Unknown
19.70 ^W	NON	<u>26*</u>	6.45*	16*	66.3	<u>Direct Habitat Alteration, Sedimentation/Siltation</u> Agriculture, Channelization
Trib. to Broken Sword Creek (28.04) (05-035-003) WWH Recommended						
0.77 ^H	Partial	36 ^{ns}	b	F*	59.5	Direct Habitat Alteration, Sedimentation/Siltation, <u>Fish Kill</u> Agriculture, Channelization, Unknown
Brandywine Creek (05-037-000) WWH Existing						
3.30 ^H	NON	38 ^{ns}	b	<u>p*</u>	66.0	Direct Habitat Alteration, Sedimentation/Siltation, <u>Nutrient Enrichment/Biological Indicators</u> Agriculture, Channelization
0.45 ^H	NON	30*	b	<u>p*</u>	44.0	<u>Direct Habitat Alteration, Sedimentation/Siltation</u> Agriculture, Channelization
Red Run (05-038-000) WWH Existing						
2.65 ^H	NON	<u>24*</u>	b	<u>p*</u>	19.5	<u>Direct Habitat Alteration, Sedimentation/Siltation</u> Agriculture, Channelization
0.42 ^H	Partial	38 ^{ns}	b	F*	45.5	<u>Direct Habitat Alteration, Sedimentation/Siltation</u> Agriculture, Channelization

BIOCRITERIA (ECBP)			HABITAT		
INDEX - Site Type	WWH	EWH	QHEI Score (<20 mi ² sites)	QHEI Score (>20 mi ² sites)	Quality
IBI: Headwater	40	50	≥70	≥75	Excellent
IBI: Wading	40	50	55-69	60-74	Good
MIwb: Wading	8.3	9.4	43-54	45-59	Fair
ICI	36	46	<43/<30	<45/<30	Poor/Very Poor

- a Narrative assessment used in lieu of ICI score based on qualitative sampling data when no quantitative data collected (F-fair, LF-low fair, P-poor, VP-very poor).
- b MIwb not applicable to headwater streams.
- * Significant departure from ecoregion biocriterion; poor and very poor results are underlined.
- ns Nonsignificant departure from biocriterion (≤ 4 IBI or ICI units and ≤ 0.5 MIwb units).
- W Wading stream; >20 sq.mi. drainage area.
- H Headwater; <20 sq.mi. drainage area.

Figure 1. Sampling locations (biological, physical habitat, and stream chemistry) and current land uses in the Brandywine Creek-Broken Sword Creek HUC-12 watershed study area, 2013.

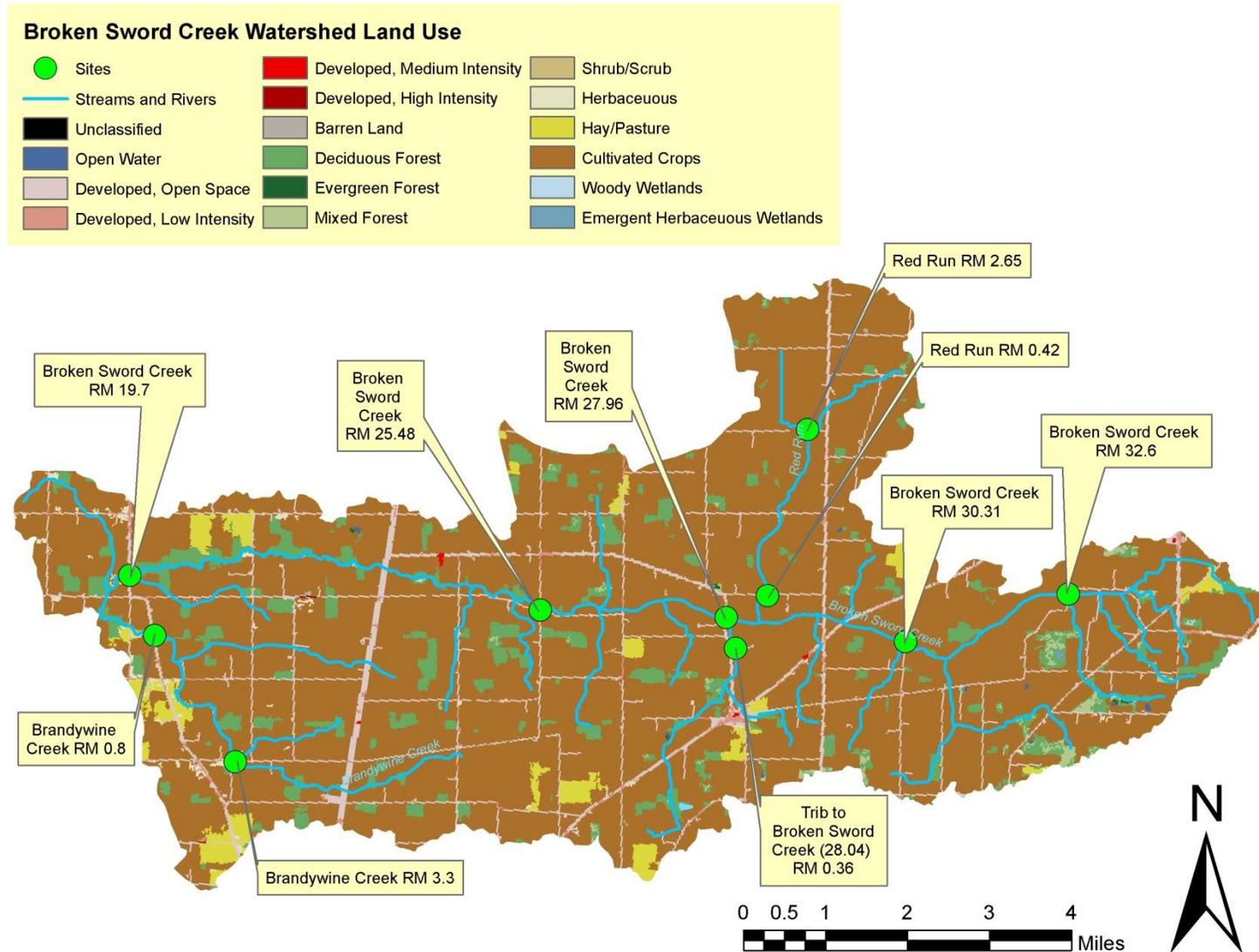


Table 2. Sampling locations in the Brandywine Creek-Broken Sword Creek HUC-12 watershed study area, 2013.

HUC12								
04100011 03 01 Brandywine Creek-Broken Sword Creek								
	Stream Code	Station	Latitude	Longitude	Sample Type	River Mile	Drainage Area	Location
Broken Sword Creek	05-035-000	201367	40.893357	-82.798203	F1x, Mql	32.60	4.4	Dickson Rd.
		U02G09	40.884857	-82.836005	F1x, Mql, C	30.31	9.4	Beck Rd.
		U02G08	40.888957	-82.877706	F2x, Mqt, C	27.96	26.6	Ridgeton-Annapolis Rd. (Co. Rd. 78)
		U02G07	40.890157	-82.921008	F2x, Mqt, C, Cl, D	25.48	32.6	Schwemley Rd.
		201366	40.895857	-83.016611	F2x, Mqt, C, Cl, D	19.70	42.0	St. Rts. 19/100
Brandywine Creek	05-037-000	201371	40.863157	-82.991810	F1x, Mql	3.30	5.3	Spore Brandywine Rd.
		302323	40.887180	-83.016760	F1x, Mql, C, Cl, D	0.45	11.1	Holmes Center Rd. (sample dst.)
Red Run	05-038-000	302280	40.922138	-82.858995	F1x, Mql	2.65	4.3	upst. Heetrich Rd.
		201372	40.892857	-82.868206	F1x, Mql, C	0.42	8.0	Henry Cooper Rd.
Trib. to Broken Sword Creek @ RM 28.04	05-035-003 (05-095)	U02G10	40.883585	-82.875514	F1x, Mql, C	0.36	4.8	Drive off Ridgeton-Annapolis Rd.

F1x - Fish one-pass site; F2x – Fish two-pass site.

Mqt - Macroinvertebrate quantitative site; Mql – Macroinvertebrate qualitative site.

C - Chemical water quality site.

Cl - Chlorophyll analysis site.

D - DataSonde[®] automated data logger monitoring site.

METHODS

All chemical, physical, and biological field, EPA laboratory, data processing, and data analysis methods and procedures adhere to those specified in the Surface Water Field Sampling Manual for Water Column Chemistry, Bacteria and Flows (Ohio Environmental Protection Agency 2013), Biological Criteria for the Protection of Aquatic Life, Volumes II - III (Ohio Environmental Protection Agency 1987b, 1989a, 1989b, 2014a, 2014b), The Qualitative Habitat Evaluation Index (QHEI); Rationale, Methods, and Application (Rankin 1989), and Methods for Assessing Habitat in Flowing Waters: Using the Qualitative Habitat Evaluation Index (Ohio Environmental Protection Agency 2006).

Determining Use Attainment

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 Index of Biotic Integrity (IBI) and modified Index of Well-Being (MIwb), indices measuring the response of the fish community, and the Invertebrate Community Index (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-attainment), the Qualitative Habitat Evaluation Index (QHEI), and causes and sources if impairment is indicated. Biological results for sites in the Broken Sword Creek (Sandusky River) HUC-12 watershed study area were compared to Warmwater Habitat (WWH) biocriteria established for the Eastern Corn Belt Plains ecoregion of Ohio.

Macroinvertebrate Community Assessment

Macroinvertebrates were collected from artificial substrates and from natural habitats at the three 2013 Broken Sword Creek wading sites (RMs 27.96, 25.48, and 19.70) and from natural habitats only at the other Broken Sword Creek, Brandywine Creek, Red Run, and unnamed tributary to Broken Sword Creek (RM 28.04) sites sampled in 2013 (Figure 1 and Table 2). 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. The natural habitat sampling effort provided presence/absence data and consisted of an inventory of all observed macroinvertebrate taxa from 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, and margin). Detailed discussion of macroinvertebrate field and laboratory procedures is detailed 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 Environmental Protection Agency 1989a, 2014b).

Fish Community Assessment

Fish were sampled with one pass each in 2013 at seven headwater and two passes each at three wading sites in the Broken Sword Creek study area using pulsed DC headwater or wading electrofishing methods depending on

watershed size at each sampling zone (Figure 1 and Table 2). Fish were processed in the field which included identifying each individual to species, counting individuals at all sites, weighing individuals at wading sites, and recording any external abnormalities. Discussion of the fish community assessment methodology used in this report is detailed 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 Environmental Protection Agency 1989a, 2014b).

Physical Habitat Assessment

Aquatic habitat at sites in the Broken Sword Creek watershed study area was evaluated using the Qualitative Habitat Evaluation Index (QHEI) developed by the Ohio EPA for streams and rivers in Ohio (Rankin 1989; Ohio Environmental Protection Agency 2006). Various attributes of the available habitat are scored based on their overall importance to the establishment of viable, diverse aquatic faunas. Evaluations of type and quality of substrate, amount of instream cover, channel morphology, extent of riparian canopy, pool and riffle development and quality, and stream gradient are among the metrics used to evaluate the characteristics of a stream segment, not just the characteristics of a single sampling site. As such, individual sites may have much 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 higher than 60 are generally conducive to the establishment of warm water faunas while those which score in excess of 75 often typify habitat conditions which have the ability to support exceptional faunas. Habitat assessments using QHEI protocols were completed at each fish sampling reach in the Broken Sword Creek watershed study area (Figure 1).

Chemical Water Quality

A minimum of four surface water chemistry grab samples were collected from each of seven Broken Sword Creek watershed sampling locations between July 10, 2013 and June 23, 2014 (Figure 1 and Table 2). Stations were established in free-flowing sections of the streams and were primarily collected from bridge crossings. Surface water samples were collected directly into appropriate containers, preserved and delivered to Ohio EPA's Environmental Services laboratory. Collected water was preserved using appropriate methods, as outlined in the Surface Water Field Sampling Manual for Water Column Chemistry, Bacteria and Flows (Ohio Environmental Protection Agency 2013).

RESULTS

Macroinvertebrate Community

Macroinvertebrate community sampling was conducted at ten sites in the Broken Sword Creek watershed during 2013. Quantitative artificial substrate data were collected and an Invertebrate Community Index (ICI) score was determined for three Broken Sword Creek sites with drainage areas in excess of 20 mi². Qualitative, natural substrate collections were made and relevant data attributes were calculated for remaining sites. Results are summarized in Table 3. ICI metrics and scores are presented in Appendix Tables D and relative numbers and species collected per location are presented in Appendix Table E. Sampling locations were evaluated using the Warmwater Habitat (WWH) aquatic life use narrative or the WWH biocriterion codified in the Ohio Administrative Code (OAC 3745-1-07, Table 7-15).

None of the macroinvertebrate communities at ten sites sampled in the Broken Sword Creek watershed study area met WWH aquatic life use expectations (Table 1). The entire area was impacted by channelization and sedimentation. In addition, low diversities of EPT and sensitive taxa and a predominance of facultative and tolerant taxa in Brandywine Creek, Red Run and the unnamed tributary to Broken Sword Creek (RM 28.04) were reflective of excessive nutrients and or/ organic loading. Narrative evaluations at these headwater sites were rated fair to poor. The three upper sites on Broken Sword Creek (RMs 32.60, 30.31 and 27.96) were similarly affected. The effects of a toxic spill reported two weeks earlier at Connely Road was evident in the benthos at Schwemley Road (25.48) and State Routes 19/100 (RM 19.70) Midges predominated at both sites and low numbers of most other taxa were noted, reflecting the partial recovery of the community in response to the spill. Particularly apparent was a paucity of hydroptychid caddisflies on the artificial substrates despite adequate physical conditions at both sites. The three most downstream Broken Sword Creek sites produced ICI scores in the fair range.

Table 3. Summary of macroinvertebrate data collected by Ohio EPA from artificial substrates (quantitative sampling) and natural substrates (qualitative sampling) in the Brandywine Creek-Broken Sword Creek HUC-12 watershed study area, 2013. The applicable aquatic life use designation is Warmwater Habitat (WWH).

River Mile	Drainage (sq mi)	Total Taxa	Quant Taxa	Qual Taxa	Qual EPT ^a	Qual Sens.	Qual Tolrnt	Density #/sq ft	Narr./ ICI ^b	Predominant Organisms on the Natural Substrates With Tolerance Category(ies) ^c
05-035-000 Broken Sword Creek										
32.60	4.40	40		40	3	4	13		Fair*	Midges(F,T)
30.31	9.40	34		34	3	3	10		Fair*	Midges(F,T)
27.96	26.60	58	28	48	5	3	19	1151	28*	Midges(F), Bryozoan(F), Damselflies(F)
25.48	32.60	50	32	34	3	4	14	1015	18*	Midges(F)
19.70	42.00	51	28	31	3	0	12	589	16*	Midges(F,T)
05-035-003 Trib. to Broken Sword Creek (RM 28.04)										
0.77	4.40	34		34	3	1	17		Fair*	Midges(F,T), Blackflies(F)
05-037-000 Brandywine Creek										
3.30	5.30	25		25	1	0	16		<u>Poor</u> *	Blackflies(F), Midges(F,T)
0.80	10.90	35		35	2	0	16		<u>Poor</u> *	Midges(F,T), Snails Snails(T)
0.45	11.10	24		24	1	1	14		<u>Poor</u> *	Midges(F,T)
05-038-000 Red Run										
2.65	4.30	25		25	0	0	18		<u>Poor</u> *	Snails(T)
0.42	8.00	35		35	4	2	17		<u>Poor</u> *	Midges(F,T)

Ecoregion Biocriterion: Eastern Corn Belt Plains (ECBP)		
INDEX	WWH	EWB
ICI	36	46

a Qual. EPT=Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies) taxa richness.

b Narrative assessment used in lieu of ICI score based on qualitative sampling data when no quantitative data are collected.

c Tolerance Categories: VT=Very Tolerant, T=Tolerant, MT=Moderately Tolerant, F=Facultative, MI=Moderately Intolerant, I=Intolerant

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

ns Nonsignificant departure from biocriterion (≤ 4 ICI units).

Fish Community and Physical Habitat

A total of 11,815 fish representing 28 species and 1 hybrid were collected from the ten sites in the Broken Sword Creek watershed study area during 2013. Results are summarized in Table 4; attributes of physical habitat, as scored by the QHEI for each fish zone, are tabulated in Table 5. IBI metrics and scores are presented in Appendix Tables 3a and 3b and relative numbers and species collected per location are presented in Appendix Table 4. Sampling locations were evaluated using Warmwater Habitat (WWH) biocriteria codified in the Ohio Administrative Code (OAC 3745-1-07, Table 7-15).

Physical habitat in the Broken Sword Creek watershed study area ranged from good to very poor quality due to the extensive amount of channel modification throughout (Figure 2). It is recommended that drainage maintenance activities in these streams be as minimal as practical which should allow more natural stream habitat to recover, increasing the pollutant assimilative capacity and lessening downstream erosion and flooding in the watershed.



Figure 2. The narrow and incised stream channel in Broken Sword Creek at Schwemley Road (RM 32.6) pictured above is designed for the quick transport of storm water. The increase in water transport exacerbates downstream flooding and also means increased sediment and nutrient transport from the adjacent tiled fields.

Five out of ten sites sampled in the Broken Sword Creek watershed study area fully met the recommended WWH aquatic life use target criteria for fish (Table 4). Partial criteria achievement was scored at two Broken Sword Creek sampling locations (RMs 27.96 and 25.48) due to low MIwb scores in both samples. The site at Ridgeton–Annapolis Road (RM 27.96) had the highest number of fish species among all of the sites with 25; however, 9 of the species or 70% by number were found to be tolerant of pollution. Similarly, 9 of the 19 (61% by number) fish species were found to be tolerant of pollution at Schwemley Road (RM 25.48) (Appendix C and Table 4). Schwemley Road is the next bridge downstream from Connely Road where a likely manure spill and resulting fish kill was reported on July 20th, 2013. The fish kill affected approximately 7 miles of stream with

5,853 dead fish counted by Ohio Department of Natural Resources officers (Appendix H). Dead fish were found during the Ohio EPA fish sampling event at Schwemley Road on July 24, 2013 with a total of 242 live fish collected. Results of the second sampling pass on August 13, 2013 yielded a catch of 478 fish at Schwemley Road indicating improved conditions (Appendix C).

The only site sampled on Broken Sword Creek that was not channelized was at State Routes 19/100 (RM 19.70). However, it was also the only site on Broken Sword Creek which was found to have a poor quality fish community and also had the lowest macroinvertebrate ICI score. This could be attributed to all the miles of upstream pollutants starting to settle out and become assimilated through riffles, runs and pools where nutrient levels were found to be above statewide targets throughout the watershed (See Water Quality Section). Total phosphorus and nitrate+nitrite levels increased at this site compared to upstream (Table 6). Despite improved channel morphology and riparian habitat at this location, sedimentation/siltation covering the instream substrates was also problematic.

Habitat and fish community performance in Brandywine Creek at Holmes Center Road (RM 0.45) was narratively fair (Table 4). The stream is channelized with substrates dominated by silt in this reach and nutrients are above statewide target levels (Table 6). Only 143 fish were caught throughout the 150 meter sampling zone (Appendix C). The most upstream site on Red Run (RM 2.65) had poor quality habitat and fish community performance (Table 4). Very pollution tolerant common carp *Cyprinus carpio* dominated the small fish community with 131 individuals, 64.53% of the population (Appendix C). This section of Red Run was channelized and the instream substrates consisted of knee deep silt and muck (Appendix A).

Table 4. Fish community summaries based on pulsed D.C. headwater and wading electrofishing sampling conducted by Ohio EPA in the Brandywine Creek-Broken Sword Creek HUC-12 watershed study area, 2013. The applicable aquatic life use designation is Warmwater Habitat (WWH) for all sites.

River Mile	Site Type	Species (Total)	Species (Sensitive)	Relative Number ^a	QHEI	Index of Biotic Integrity	Modified Index of Well-being ^b	Narrative Evaluation
Broken Sword Creek 05-035-000								
32.60 ^H	Headwater	13	1	7230	42.0	50	b	Exceptional
30.31 ^H	Headwater	17	3	596	56.5	46	b	Very Good
27.96 ^W	Wading	25	3	2324	60.5	34*	8.16	Fair
25.48 ^W	Wading	19	1	1080	49.3	31*	6.72	Fair
19.70 ^W	Wading	19	1	946	66.3	26*	6.44	Poor/Fair
Tributary to Broken Sword Creek (RM 28.04) 05-035-003								
0.77 ^H	Headwater	15	0	594	59.5	36 ^{ns}	b	Marginally Good
Brandywine Creek (05-037-000) - WWH								
3.30 ^H	Headwater	13	1	1458	66.0	38 ^{ns}	b	Marginally Good
0.45 ^H	Headwater	12	0	215	44.0	30*	b	Fair
Red Run 05-038-000								
2.65 ^H	Headwater	9	0	406	19.5	24*	b	Poor
0.42 ^H	Headwater	18	0	3532	45.5	38 ^{ns}	b	Marginally Good

Ecoregion Biocriteria: Eastern Corn Belt Plains (ECBP)		
INDEX – Site Type	WWH	EWH
IBI: Headwater	40	50

IBI: Wading	40	50
MIwb: Wading	8.3	9.4

- * Significant departure from ecoregion biocriterion; poor and very poor results are underlined.
- ns Non-significant departure from ecoregion biocriterion (≤ 4 IBI units or 0.5 MIwb units).
- a Relative numbers are per 300 meters (headwater and wading methods).
- b MIwb not applicable at sites with $< 20 \text{ mi}^2$ drainage areas.
- W Wading stream; $>20 \text{ sq. mi.}$ drainage area.
- H Headwater; $<20 \text{ sq. mi.}$ drainage area.

Table 5. Qualitative Habitat Evaluation Index (QHEI) scores and physical attributes for sampling sites in the Brandywine Creek-Broken Sword Creek HUC-12 watershed study area, 2013.

River Mile	QHEI	Habitat Rating	MWH Attributes																															
			WWH Attributes										MWH Attributes																					
													High Influence					Moderate Influence																
Key QHEI Components			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 $>40 \text{ cm}$	Low-Normal Riffle Embeddedness	Total WWH Attributes	Channelized or No Recovery	Silt/Muck Substrates	No Sinuosity	Sparse/ No Cover	Max. Depth $<40 \text{ cm}$ (WD,HW sites)	Total High Influence Attributes	Recovering Channel	Heavy/Moderate Silt Cover	Sand Substrates (Boat)	Hardpan Substrate Origin	Fair/Poor Development	Low Sinuosity	Only 1-2 Cover Types	Intermittent & Poor Pools	No Fast Current	High/Mod. Overall Embeddedness	High/Mod. Riffle Embeddedness	No Riffle	Total Moderate Influence Attributes	(MWH H.I.+1)/ (WWH+1) Ratio	(MWH M.I.+1)/ (WWH+1) Ratio	
Broken Sword Creek (05-035-000)																																		
Year: 2013																																		
32.6	42.0	Poor	■								1	◆	◆	◆	◆	4		●														5	2.50	5.50
30.3	56.5	Good	■							■	2	◆		◆	◆	3		●														5	1.33	3.00
27.9	60.5	Good	■				■	■		■	4	◆				1		●						●								5	0.40	1.40
25.5	49.3	Fair	■				■	■		■	4	◆				1		●						●								5	0.40	1.40
19.7	66.3	Good	■	■			■	■		■	5					0		●						●								5	0.17	1.00
Brandywine Creek (05-037-000)																																		
Year: 2013																																		
3.3	66.0	Good	■	■		■	■	■	■	■	7					0		●														4	0.13	0.63
0.5	44.0	Fair								■	1		◆	◆	◆	3		●	●													6	2.00	5.00
Red Run (05-038-000)																																		
Year: 2013																																		
2.7	19.5	Very Poor								■	1		◆	◆	◆	◆	4		●						●							6	2.50	5.50
0.4	45.5	Fair		■							1		◆	◆	◆	◆	4		●	●					●							6	2.50	5.50
Trib. to Broken Sword Creek at RM 28.04 (05-095-000)																																		
Year: 2013																																		
0.40	59.50	Good		■				■	■	■	5		◆	◆	◆	3		●	●													5	0.67	1.50

Water Quality

Surface water grab samples were collected from the Broken Sword Creek watershed at seven locations on four to five occasions between July 10, 2013 and June 23, 2014. Surface water samples were analyzed for nutrients including nitrate+nitrite, ammonia, TKN, total phosphorus, and orthophosphate. Nutrient measurements that exceeded statewide targets are reported in Table 6; the full data set is compiled in Appendix G. Additional parameter coverage included suspended and dissolved solids, alkalinity, chloride, sulfate, and field meter measurements including dissolved oxygen, pH, conductivity, and temperature.

A dissolved oxygen measurement below the WWH outside mixing zone average WQS criterion occurred in Brandywine Creek at RM 0.45 on September 18, 2013, the only time at any site on the dates water quality field data were collected. Biological activity, water flow/turbulence, pollution, and stream temperature can influence the dissolved oxygen in streams. During summer months, flow is often decreased, pollutant sources are less diluted, water temperatures are higher, and biological activities are increased.

The Brandywine Creek watershed is predominantly surrounded by agricultural land use. Elevated total phosphorus levels above statewide targets were observed at all seven locations sampled. The unnamed tributary that enters Broken Sword Creek at RM 28.04 had consistently higher concentrations of total phosphorus (geomean 0.25 mg/L), and was the greatest contributor to the increasing geometric mean concentrations in Broken Sword Creek. In addition to agricultural runoff, the village of Sulphur Springs is an unsewered community that potentially provided additional nutrients to this unnamed tributary. Nitrate+nitrite geometric means in all seven sampling locations in the watershed were above statewide targets (Table 6 and Figure 3). Red Run had the highest geometric mean concentrations of nitrate+nitrite flowing to Broken Sword Creek at RM 28.37. However, all of the samples at all of the sites collected in May and June exceeded the nitrate+nitrite target, ranging from 6.04 mg/l to 14.30 mg/l. Total phosphorus and nitrate+nitrite levels in Broken Sword Creek at RM 19.13 (0.16 mg/l and 4.05 mg/l, respectively) was comparable to the contribution at RM 18.90 delivered by Brandywine Creek (0.18 mg/l and 3.97 mg/l, respectively, sampled at RM 0.45). Ammonia levels throughout the entire watershed did not exceed the Ohio WQS criteria at any of the locations sampled.

Overall, nitrate+nitrite and total phosphorus levels increased as additional load entered Broken Sword Creek in excess of what could be assimilated by the biomass resulting in a nutrient enriched stream system.

Table 6. Seasonal geometric mean values (mg/l) for nutrients calculated from grab samples collected in the Brandywine Creek-Broken Sword Creek HUC-12 watershed study area. Target levels for phosphorus are 0.08 mg/l (WWH) for headwaters and 0.10 mg/l (WWH) for wadeable streams. Target levels for nitrate-nitrite are 1.0 mg/l (WWH) for headwaters and 1.0 mg/l (WWH) for wadeable streams. Results highlighted are above statewide recommended targets (Ohio EPA, 1999).

<u>River Mile</u>	<u>Stream</u>	<u>Nutrient</u>	<u>Mean Value (mg/l)</u>
<i>Headwaters (drainage area < 20 mi²)</i>			
04100011-03-01: Brandywine Creek – Broken Sword Creek			
30.31	(Broken Sword Creek) -	phosphorus	(0.07)
		nitrate-nitrite	(2.94)
0.77	(Trib. To Broken Sword Creek) -	phosphorus	(0.25)
		nitrate-nitrite	(3.79)
0.45	(Brandywine Creek) -	phosphorus	(0.18)
		nitrate-nitrite	(3.97)
0.42	(Red Run) -	phosphorus	(0.08)
		nitrate-nitrite	(13.42)
<i>Wadeable Stream (drainage area ≥20 mi² to < 200 mi²)</i>			
04100011-03-01: Brandywine Creek – Broken Sword Creek			
27.96	(Broken Sword Creek) –	phosphorus	(0.09)
		nitrate-nitrite	(3.62)
25.50	(Broken Sword Creek) –	phosphorus	(0.12)
		nitrate-nitrite	(3.18)
19.13	(Broken Sword Creek) –	phosphorus	(0.16)
		nitrate-nitrite	(4.05)

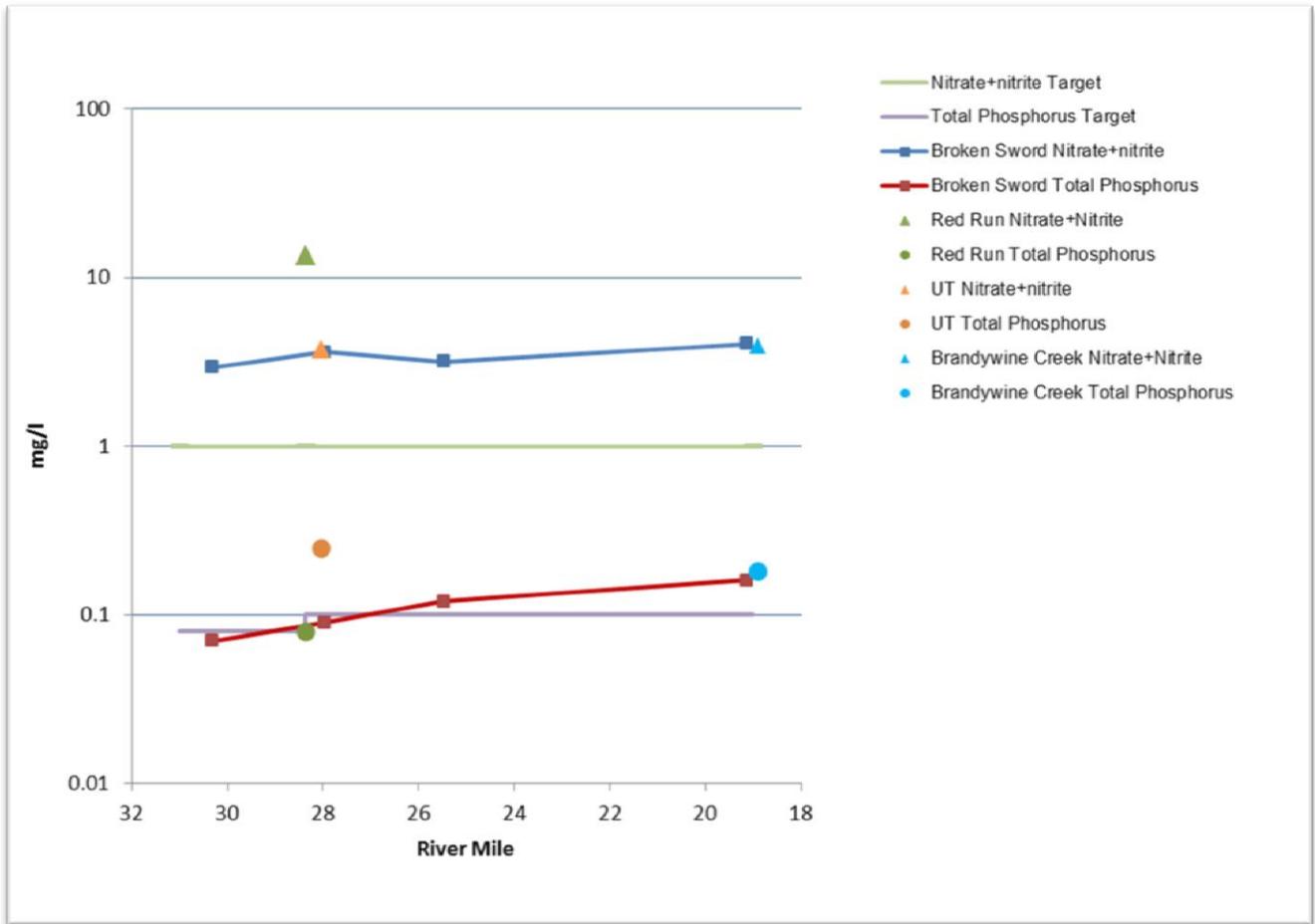


Figure 3. Geometric means for total phosphorus and nitrate+nitrite in the Brandywine Creek-Broken Sword Creek HUC-12 watershed study area, 2013-2014.

Water Quality Sondes

Water quality sondes were deployed to take hourly measurements of temperature, dissolved oxygen (DO), pH and specific conductivity. The sondes were deployed at four of the locations; Brokenword Creek at RM 25.48, Brokenword Creek at RM 23.0, Brokenword Creek at RM 19.7, and Brandywine Creek at RM 0.20. No exceedances of Ohio WQS criteria were captured during this time period. The measurement of DO throughout the 24-hour diel cycle is a strong indicator of primary production and therefore eutrophication. The sonde deployment generally represented low levels of primary production with the highest diel DO range being around 5 mg/L. Dissolved oxygen ranges decreased from upstream to downstream (Figures 4-7). The most likely reason for this phenomenon is decreased photosynthesis and the increasingly dense riparian canopy offered to the stream. However, the cool and cloudy conditions during the survey were not ideal for assessing the potential for eutrophication. There is some expectation that if temperatures were warmer and cloud cover reduced that eutrophic conditions would have been expressed at the most upstream Brokenword Creek site. The dominantly agricultural landscape serves as an ample supply of nutrients and the lack of a woody riparian in these upstream reaches do little to stymie eutrophication.

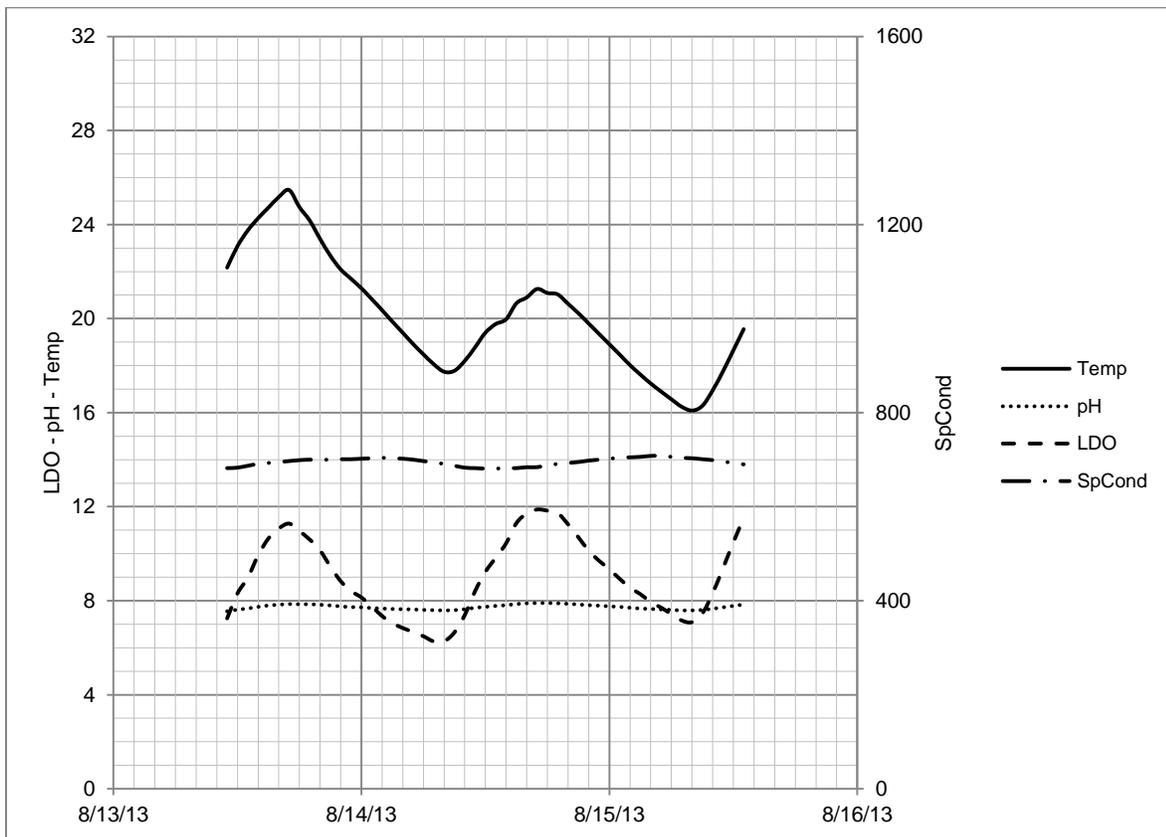


Figure 4. Plot of continuous field parameters collected with a submersible water quality sonde at Brokenword Creek (RM 25.48), August 13-15, 2013, with sensors taking hourly readings of temperature (Temp - °C), dissolved oxygen (LDO - mg/L), pH (S.U.), and specific conductivity (SpCond - µS/cm).

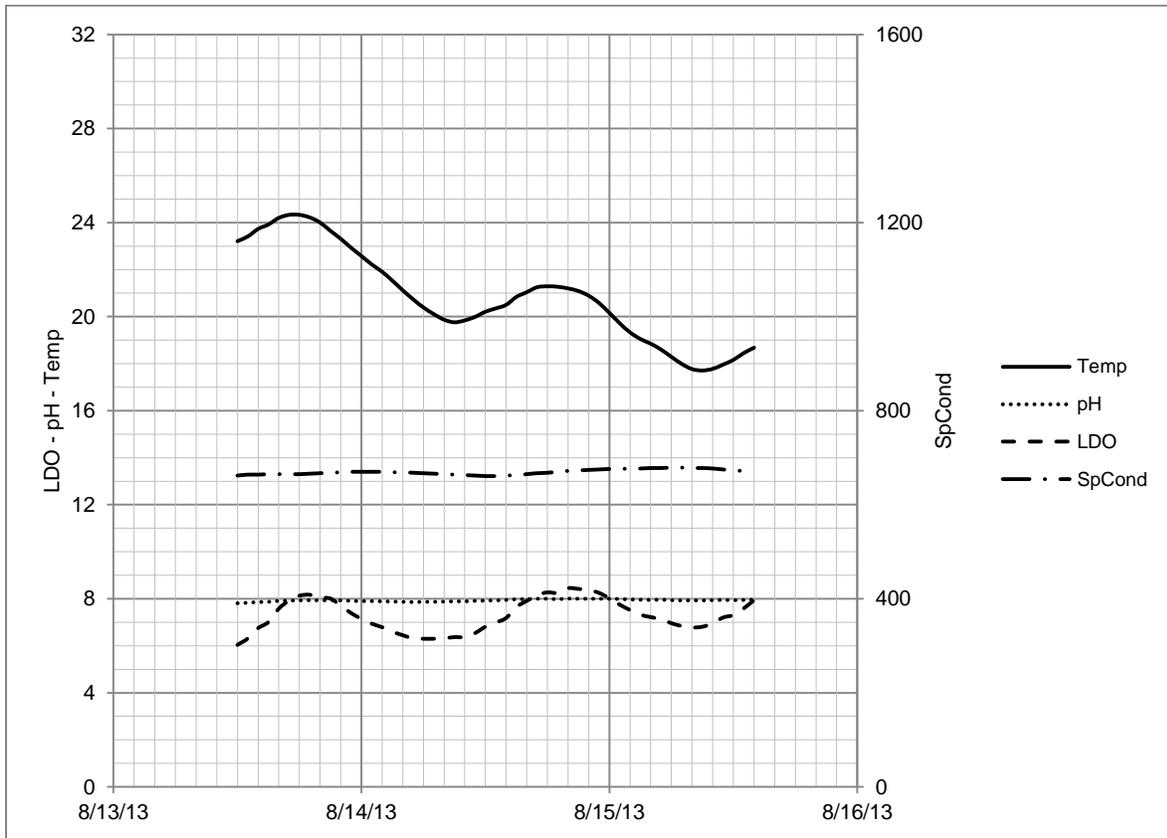


Figure 5. Plot of continuous field parameters collected with a submersible water quality sonde at Brokenword Creek (RM 23.0), August 13-15, 2013, with sensors taking hourly readings of temperature (Temp - °C), dissolved oxygen (LDO - mg/L), pH (S.U.), and specific conductivity (SpCond - µS/cm).

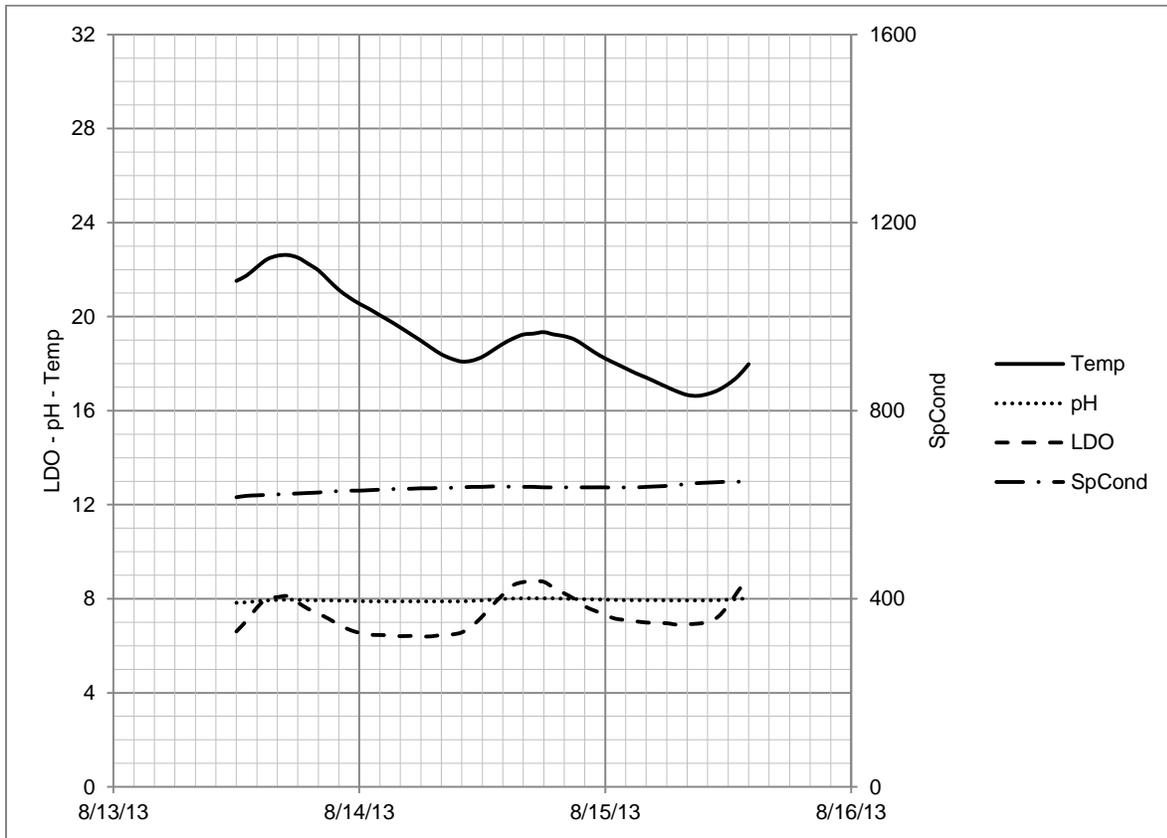


Figure 6. Plot of continuous field parameters collected with a submersible water quality sonde at Brokenword Creek (RM 19.7), August 13- 15, 2013, with sensors taking hourly readings of temperature (Temp - °C), dissolved oxygen (LDO - mg/L), pH (S.U.), and specific conductivity (SpCond - µS/cm).

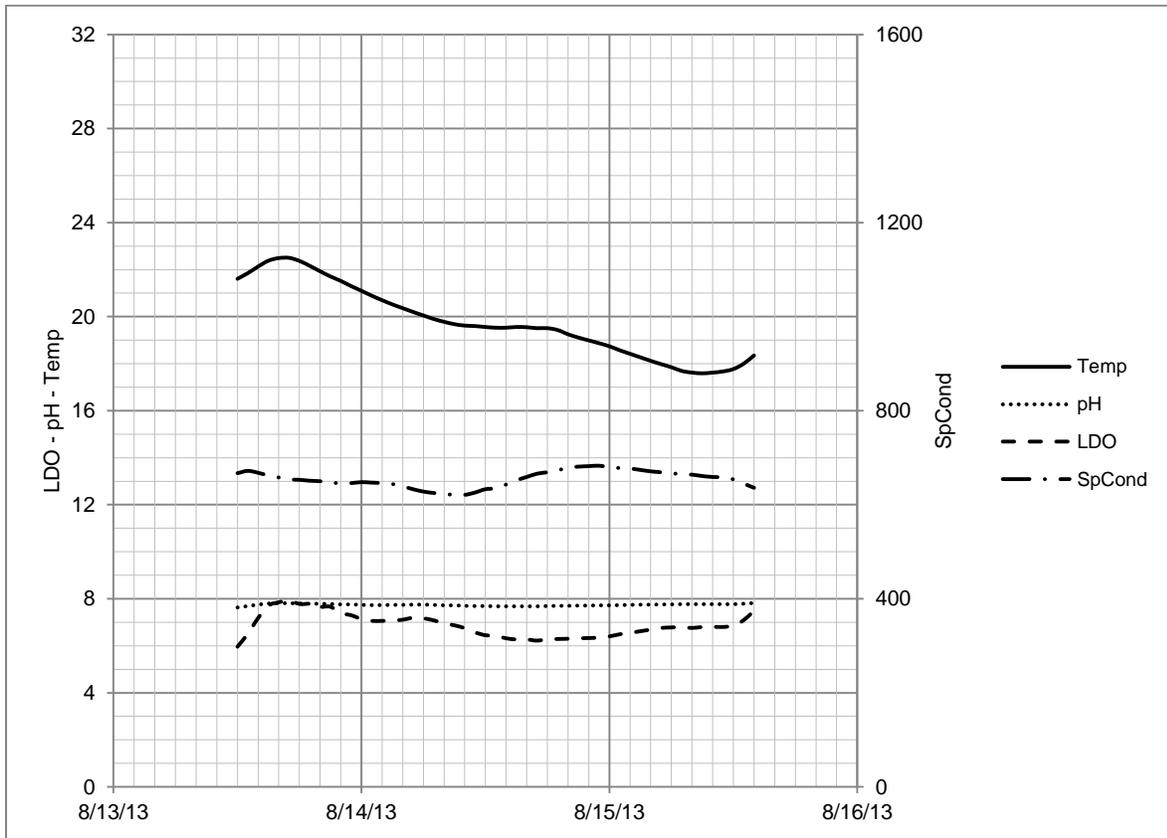


Figure 7. Plot of continuous field parameters collected with a submersible water quality sonde at Brandywine Creek (RM 0.2), August 13- 15, 2013, with sensors taking hourly readings of temperature (Temp - °C), dissolved oxygen (LDO - mg/L), pH (S.U.), and specific conductivity (SpCond - μS/cm).

REFERENCES

- Ohio Environmental Protection Agency. 2014a. 2014 updates to Biological Criteria for the Protection of Aquatic Life: Volume II and Volume II Addendum. User's manual for biological field assessment of Ohio surface waters. Division of Surface Water, Ecol. Assess. Sect., Columbus, Ohio.
http://epa.ohio.gov/Portals/35/documents/BioCrit88_Vol2Updates2014.pdf
- Ohio Environmental Protection Agency. 2014b. 2014 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. Division of Surface Water, Ecol. Assess. Sect., Columbus, Ohio.
http://epa.ohio.gov/Portals/35/documents/BioCrit88_Vol3Updates2014.pdf
- Ohio Environmental Protection Agency. 2013. Surface water field sampling manual for water column chemistry, bacteria and flows. Division of Surface Water, Columbus, Ohio.
http://epa.ohio.gov/Portals/35/documents/SW_SamplingManual.pdf
- Ohio Environmental Protection Agency. 2010. Ohio Lake Erie Phosphorus Task Force final report. Division of Surface Water, Columbus, Ohio.
http://www.epa.state.oh.us/portals/35/lakeerie/ptaskforce/Task_Force_Final_Report_April_2010.pdf
- 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. Division of Surface Water, Ecol. Assess. Sect., Columbus, Ohio.
<http://epa.ohio.gov/portals/35/documents/QHEIManualJune2006.pdf>
- Ohio Environmental Protection Agency. 1999. Association between nutrients, habitat, and the aquatic biota in Ohio rivers and streams. Technical Bulletin MAS/1999-1-1. Division of Surface Water, Columbus, Ohio.
http://www.epa.state.oh.us/portals/35/documents/assoc_load.pdf
- Ohio Environmental Protection Agency. 1989a. Addendum to Biological criteria for the protection of aquatic life: Volume II. User's manual for biological field assessment of Ohio surface waters. Division of Water Qual. Plan. & Assess., Ecol. Assess. Sect., Columbus, Ohio.
http://epa.ohio.gov/portals/35/documents/BioCrit88_Vol2Addendum.pdf
- 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 Plan. & Assess., Ecol. Assess. Sect., Columbus, Ohio.
<http://epa.ohio.gov/portals/35/documents/Vol3.pdf>
- 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 Qual. Monit. & Assess., Surface Water Section, Columbus, Ohio.
<http://epa.ohio.gov/Portals/35/documents/Vol1.pdf>
- 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 Qual. Monit. & Assess., Surface Water Section, Columbus, Ohio.
<http://epa.ohio.gov/Portals/35/documents/Vol2.pdf>
- Rankin, E.T. 1989. The qualitative habitat evaluation index (QHEI): rationale, methods, and application. Ohio Environmental Protection Agency, Division of Water Qual. Plan. & Assess., Ecol. Assess. Sect., Columbus, Ohio.
http://epa.ohio.gov/Portals/35/documents/QHEI_1989.pdf