West Branch Brandywine Ag-1 Watershed Assessment Report

RED Streams BLUE

Honey Brook Township and Honey Brook Borough, Chester County
Caernarvon Township, Lancaster County
Brandywine Creek Watershed, Pennsylvania

May 2018

Brandywine Red Clay Alliance

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1.0 INTRODUCTION

The Upper West Branch Brandywine Creek is considered a "Red" Stream by Brandywine Red Clay Alliance (BRC) "Red Streams Blue" program. Within the program, "Red" streams are those that are impaired to the point of being below the state designated threshold for their designated use. "Blue" streams are those that meet the state designated threshold to be considered un-impaired. Impairments to the Upper West Branch Brandywine Creek include agricultural siltation, pathogens, and nutrients. These pollutants not only degrade the water quality in the immediate area where they discharge into the stream, but also contribute to degraded water quality downstream. The City of Wilmington, Delaware Water Department is a key stakeholder in the health of the Brandywine Watershed. The Water Department has determined that turning "Red Streams Blue" will not only improve the quality of the water reaching their intake pipe, but also decrease treatment costs and reduce annual expenditures. With complementary interests in water quality, BRC and the City of Wilmington Water Department have collaborated with Clauser Environmental, LLC to develop this assessment report to document water quality changes related to restoration projects completed in the West Branch Brandywine Ag-1 Watershed.

2.0 BACKGROUND

The West Branch Brandywine Ag-1 Watershed begins at the drainage divide atop Welsh Mountain in Caernarvon Township, Lancaster County. Waters falling on the northern side of Welsh Mountain drain into the Conestoga River Valley and ultimately to the Susquehanna River and Chesapeake Bay. Waters falling on the southern side of the mountain are of primary interest in this study and drain into several unnamed tributaries to and the West Branch Brandywine Creek itself. Moving downhill to the south, off of Welsh Mountain, one enters Honey Brook Township, Chester County. This portion of the township is dominated by a pastoral farming community that is identified here as Ag Cluster 1. Ag Cluster 1 refers to the naming conventions of the City of Wilmington Water Department and is in contrast to two other Ag Clusters currently identified elsewhere in the Brandywine Watershed. The farming community within this area is comprised of a mix of Amish and English farms that focus primarily on dairy and field crops. Within the western portion of the watershed lies the quaint Honey Brook Borough. Honey Brook Borough lies on a ridge that serves as a watershed boundary for this study. Draining to the south, the stream receives some runoff from development along the Horseshoe Pike (US-322) corridor. The study area ends at a point approximately 2,000 feet downstream of Horseshoe Pike at the downstream end of Ag Cluster 1. This portion of the Upper West Branch Brandywine Creek including its unnamed tributaries is classified by the Pennsylvania Department of Environmental Protection (DEP) as High Quality-Trout Stocked Fishery/ Migratory Fishery. The 2008 Pennsylvania Integrated Water Quality Monitoring and Assessment Report specifically identifies nutrients and siltation as agricultural impairments to this watershed (DEP). Agricultural pathogens have also been identified as major pollutants within the watershed (Towne 2001). Here we look at the

current stream conditions in relation to stream restoration projects that have been completed since the 2010 baseline study.

3.0 METHODOLOGY

Clauser Environmental, LLC conducted in-stream sampling within the West Branch Brandywine Ag-1 Watershed.

3.1 Sample Locations

Eight (8) sample locations were identified within the West Branch Brandywine Ag-1 Watershed (Appendix A). Sample Points 1-7 were in the same locations as Sample Points 1-7 during the 2010 study (Clauser and Clauser, 2010). Sample Point 1 is located downstream of US-322, the Horseshoe Pike. Sample Point 1 is located near a small agricultural stream crossing within a pasture area where cattle and horses have direct access to the stream. Sample Point 2 is located within the pasture of a dairy farm where Chester County Conservation District and Brandywine Red Clay Alliance completed a stream restoration project that includes streambank fencing during the winter of 2015-2016. The sample point is located midway between the crossings of Pleasant View Road and Suplee Road. Sample Point 3 is located at the stream crossing of Suplee Road within a pasture area where cattle have direct access to the stream. Sample Point 4 is located just upstream of Maple Rd. on the eastern branch of the stream. The sample point is within a pasture area that is grazed by cattle. Sample Point 5 is located on an unnamed tributary that drains from the west just south of Todd Rd. While the sample point is located within a forested section of the unnamed tributary, active agricultural fields to the south of the tributary have only a minimal buffer from the stream. This unnamed tributary also receives flows from an industrial area, a pasture area where livestock have recently been fenced out of the stream, and a residential area within Honey Brook Borough. Sample Point 6 is located at the stream crossing of Todd Rd. over the western branch of the stream. This point is located within a pasture area where cattle have direct access to the stream. While the area draining to this sample point has some forested sections, the majority of the tributary stream area is located within pastureland. Some portions of this tributary have had streambank fencing installed since 2010. Sample Point 7 is located downstream of the crossing of Todd Rd. over the eastern branch of the stream. Sample Point 7 is within an area that is currently maintained with streambank fencing and riparian buffer plantings. Water draining to Sample Point 7 comes from upslope pastureland and a mix of forested and pastureland areas within the headwaters. At several locations upstream of this point, cattle have direct access to the stream. Sample Point 8 was sampled for the first time in this study. Sample Point 8 is located along Pleasant View Rd. downstream of the point where an unnamed tributary discharges into the stream. This portion of the Upper West Branch Brandywine Creek is the location of a streambank restoration project and streambank fencing project that was completed in 2015.

3.2 Macroinvertebrate Sampling

The Pennsylvania Department of Environmental Protection (DEP) *Instream Comprehensive Evaluation Survey* (ICE) protocol (DEP 2013) was utilized to collect benthic macroinvertebrates at each of the sample locations. Field sampling occurred on November 30, 2017 and is compared here to sampling that occurred on April 15, 2010. Sampling methods were the same for both studies. The 6 D-frame method of sample collection was utilized in accordance with the DEP Standardized Biological Field Collection and Laboratory Methods (DEP "Methods", Section V.C.). Samples were processed, sub-sampled, and identified in the lab following DEP protocols. Identification of collected organisms was conducted with the aid of established taxonomic keys (Merrit and Cummins 1996).

Data analysis included the evaluation of six metrics for the macroinvertebrate community at each site. The six metrics were combined via an established DEP weighting function to determine the more robust Index of Biological Integrity (IBI) value for each site. The IBI value allows for comparison with the established DEP threshold for biological impairment. BRC considers sites with an IBI value above the threshold as "Blue" for macroinvertebrates while those falling below the threshold are considered "Red" for macroinvertebrates. The six metrics that comprise the IBI value include:

3.2.1 Total Taxa Richness

The total taxa richness of a site is a count of the total number of taxa within the sub-sample and is a measure of the diversity of the macroinvertebrate community at the site. In general, the more impaired or "Redder" a stream segment is, the lower the total taxa richness will be. As water quality and habitat improves, the stream segment will be less impaired or "Bluer". As a stream segment becomes "Bluer", the total taxa richness and corresponding community diversity typically increase.

3.2.2 Ephemeroptera + Plecoptera + Trichoptera Taxa Richness

The Ephemeroptera, Plecoptera, and Trichoptera (EPT) Taxa Richness metric is a count of the total number of pollution sensitive taxa (Pollution Tolerance Value 0-4) within the mayflies, stoneflies, and caddisflies. In general, "Red" stream segments will have a lower EPT Taxa Richness while "Blue" stream segments will have a higher EPT taxa richness.

3.2.3 Beck's Index

This version of the Beck's Index evaluates taxonomic richness and tolerance as a weighted count of pollution sensitive taxa with Pollution Tolerance Values of 0, 1, or 2. Within the analysis, the more pollution sensitive an organism is, the greater weight it receives within the metric. As such, a higher Beck's index score generally indicates a "Bluer" stream segment.

3.2.4 Shannon Diversity Index

This metric measures community composition by evaluating both taxonomic richness and evenness of individuals across taxa of the sub-sample. In general, this metric decreases in a "Redder" stream segment as fewer pollution-tolerant taxa dominate. The Shannon Diversity Index typically increases in "Bluer" stream segments.

3.2.5 Hilsenhoff Biotic Index

This metric evaluates community composition by determining an average pollution tolerance value for the individuals in a sub-sample. As pollution tolerance value is higher in tolerant taxa, the Hilsenhoff Biotic Index typically is higher in a "Red" stream segment than in a "Blue" stream segment

3.2.6 Percent Sensitive Individuals

Percent Sensitive Individuals is a determination of the percentage of individuals within a sub-sample with Pollution Tolerance Values of 0-3. This metric typically decreases in a "Redder" stream segment and increases in a "Bluer" stream segment.

3.3 Habitat Analysis

Twelve parameters including instream cover (fish), epifaunal substrate, embeddedness, velocity/depth regimes, channel alteration, sediment deposition, frequency of riffles, channel flow status, condition of banks, bank vegetative protection, grazing or other disruptive pressure, and riparian vegetative zone width were assessed at each sample location. Each parameter was given a score of 1 to 20 in accordance with the DEP *Instream Comprehensive Evaluation Survey* protocol and DEP "Methods" (DEP 2013). The sum of all scores at each sample location gives a cumulative score for habitat impairment. Stream segments scoring a 132 or above are considered "Blue" while those scoring a 120 or less are considered "Red". A cumulative score of 240-192 is considered "optimal"; "suboptimal" 180-132; "marginal" 120-72; and "poor" 60 or less. The decision gaps between categories allows for the discretion of the field investigator (DEP 2013).

3.4 Water Quality Analysis

Water quality analysis was conducted at each of the sample points. Chemical and physical water quality analysis were conducted in accordance with the Department of Environmental Protection *Instream Comprehensive Evaluation Survey* protocol (DEP 2013). Field measurements of dissolved oxygen and temperature were taken in-situ with a YSI Pro20 portable dissolved oxygen meter. Conductivity and pH were measured in the field with a YSI-63 portable handheld meter. All meters were calibrated in accordance with the manufacturer's recommendations. A two point (4.00 and 7.00) slope calibration was utilized to calibrate the pH meter.

The City of Wilmington, Delaware Department of Public Works completed laboratory analysis. Analysis included pH, turbidity, conductivity, nitrite, nitrate, total nitrogen, alkalinity, and orthophosphate.

3.5 Bacteriological Analysis

Bacteriological analysis samples were collected in the field on the sampling day and transported on ice to the City of Wilmington, Department of Public Works for analysis. Bacteriological analysis included total coliform and *Escherichia coli*.

4.0 RESULTS

4.1 Macroinvertebrate Sampling Results

Macroinvertebrate taxa richness, the proportion of sensitive individuals, IBI Value, and other indicators of improved water quality increased at the sample location where watershed renaissance initiative stream restoration occurred (Site 3) and at the site that is downstream of the restoration sites (Site 1). While the increasing IBI Values reflect a direct measurement of improved water quality from successful restoration projects, they also reflect that more work needs to be done to address additional pollution issues in the watershed as the stream remains impaired.

West Branch Brandywine Ag-1 Watershed Benthic Macroinvertebrate Data

	Modified Becks Index		EPT Taxa Richness (TV 0-4)		Total Taxa Richness		Shannon Diversity Index	
	4/15/2010	11/30/2017	4/15/2010	11/30/2017	4/15/2010	11/30/2017	4/15/2010	11/30/2017
Site 1	1	2	1	2	13	23	1.59	2.05
Site 2	2	1	1	3	10	26	1.20	2.39
Site 3	1	2	0	0	12	16	1.68	1.76
Site 4	0	2	0	1	17	19	2.33	1.91
Site 5	1	2	0	4	13	20	1.90	1.79
Site 6	3	2	3	5	18	26	2.00	2.23
Site 7	5	3	2	1	18	13	2.03	1.76
Site 8		1		3		22		1.84

					Overall Weighted Summary	
	HBI Index		% Sensitive Individuals (TV 3 or less)		IBI Value	
	4/15/2010	11/30/2017	4/15/2010	11/30/2017	4/15/2010	11/30/2017
Site 1	6.52	5.52	3.98	14.69	25.08	38.29
Site 2	6.20	6.10	5.62	6.31	22.72	39.41
Site 3	6.37	5.80	11.17	3.06	25.94	28.43
Site 4	7.32	6.25	0.54	4.32	27.78	31.07
Site 5	7.01	6.74	8.53	10.19	25.92	33.61
Site 6	6.43	6.47	2.50	10.47	32.55	40.70
Site 7	6.96	6.42	6.59	7.81	32.44	27.90
Site 8		5.88		5.67		34.50

West Branch Brandywine Ag-1 Watershed

Impairment Determination Values

	Macroinvertebrate IBI Value		Habitat Value	
Site	4/15/2010	11/30/2017	4/15/2010	11/30/2017
1	25.1	38.3	127	153
2	22.7	39.4	108	206
3	25.9	28.43	117	120
4	27.8	31.07	151	154
5	25.9	33.61	147	164
6	32.5	40.7	138	149
7	32.4	27.9	167	176
8	-----	34.5	-----	189

Macroinvertebrate and habitat impairment are based upon the DEP ICE protocol (2013).
Blue values indicate unimpaired; red values indicate impaired.

4.2 Habitat Analysis Results

The habitat analysis data for West Branch Brandywine Ag-1 Watershed indicates that Sample Site 3 is "Red" (impaired) for habitat (Table 3). At this site, cattle have extensively grazed the riparian zone and are not excluded from the stream. This site is considered "Marginal" for habitat (DEP 2013 The cumulative impacts from upslope erosion contribute to the impaired nature of this site. Sample Sites 4, 5, 6, and 7 have remained "Blue" (un-impaired) for habitat since the 2010 sampling. According to the ICE protocol, these four sites are considered "sub-optimal" for habitat (DEP 2009). Sample Sites 4, 5, 6, and 7 are located higher in the watershed and have slightly steeper gradients than the other sample sites. While still impaired by sediment, the steeper gradient contributes to flushing of some of the excessive siltation through the system. Sample Site 4 is located in an active pasture area. But, the pasture isn't heavily grazed. The increased habitat score for Sample Site #6 likely reflects the improved habitat that is a result of the streambank fencing that has been implemented in that area. Sample Sites 5 and 7 were located in areas with some riparian buffer. Sample Site 5 is downstream of a pasture that is not as heavily grazed as it was in 2010. Sample location 7 is located at the upstream end of an area where streambank fencing, stabilized cattle crossing areas, and riparian buffers had been installed prior to the BRC study. The improved habitat score likely reflects the positive impacts of the trees maturing in the riparian buffer planting area. Sample Points 1 and 2 have moved from "Red" to "Blue" as a result of the stream restoration projects located at Sample Site 2 and upstream of Sample Site 1. New Sample Point 8 was "Blue" for habitat due to the recent stream restoration project. Before restoration, that site would

likely have scored as "Red" due to the cattle in that area having unrestricted access to the stream and heavily grazing the streambanks and riparian zone.

4.3 Water Quality Analysis Results

Considering seasonal variability in weather patterns, flow levels, and discharges to the stream, the physical and chemical water quality properties of DO, pH, specific conductance, and alkalinity were within the same general range when measured in 2017 as the values measured in 2010. The DO, pH, specific conductance, and alkalinity are likely not negatively impacting the in-stream community if they consistently stay within the ranges measured for the sites.

Spring 2010
West Branch Brandywine Ag-1 Watershed
Mean Water Sampling Data

Site	Temp (°C)	DO (mg/L)	DO (% sat.)	pH	Cond. (umhos)	Specific Cond. (umhos)	Alkalinity (mg/L)
1	12.5	9.97	94.2	7.16	229.5	301.1	59
2	13.0	10.53	101.0	7.27	228.1	288.1	60
3	12.7	9.89	94.1	7.24	211.1	274.1	55
4	12.8	9.84	93.0	7.13	152.8	199.6	44
5	12.7	9.64	91.6	7.61	352.7	456.8	137
6	14.3	9.27	91.3	7.09	195.0	245.6	41
7	14.9	9.97	100.4	6.96	142.6	176.3	36

30-Nov-17
West Branch Brandywine Ag-1 Watershed
Water Sampling Data

Site	Temp (°C)	DO (mg/L)	DO (% sat.)	pH	Cond. (umhos)	Specific Cond. (umhos)	Alkalinity (mg/L)	Turbidity (NTU)
1	5.8	12.60	101.4	7.41	210.4	324.7	64.0	0.9
2	5.2	9.90	78.5	6.88	202.4	325.6	65.0	1.9
3	5.4	10.07	80.2	6.97	200.3	320.2	62.0	1.9
4	4.4	11.24	87.5	7.04	141.0	232.5	46.0	3.0
5	4.1	11.81	91.2	7.70	356.1	591.0	144.0	1.1
6	6.5	10.64	87.2	6.76	179.5	279.3	45.0	1.0
7	3.9	10.57	80.9	7.51	94.8	158.9	37.0	4.2
8	5.9	13.59	109.7	7.25	213.0	336.4	62.0	1.5

Nutrient sampling throughout the watershed indicated that substantial inputs of nitrogen and phosphorus are continuing to occur in the watershed. At all eight sample sites, the November 30, 2017 total nitrogen concentration exceeded the threshold of 2.01 mg/L for impaired streams (Sheeder and Evans 2004). Sheeder and Evans found that impaired streams typically exceed a total phosphorus concentration of 0.07 mg/L (2004). As the measured orthophosphate concentration alone exceeded the threshold at each sample site on November 30, 2017, phosphorus appears to continue to be a major pollutant within the watershed.

4.4 Bacteriological Analysis Results

Total coliform concentrations at each of the sample sites within the watershed on November 30, 2017 exceeded the DEP threshold of 200 colonies/100mL for safe recreation. *Escherichia coli* concentrations ranged from 56.5 to 1986.3 colonies/100mL. The high levels of bacterial pathogens at all eight sample locations indicates that agricultural pathogens continue to be a substantial pollutant throughout the watershed.

Spring 2010
West Branch Brandywine Ag-1 Watershed
Mean Nutrient and Bacterial Sampling Data

Site	TKN (mg/L)	Nitrite (mg/L)	Nitrate (mg/L)	Total Nitrogen (mg/L)	Total Phosphorus (PO4) (mg/L)	Total Coliform (#/100mL)	*Escherichia coli* (#/100mL)
1	0.65	0.061	1.6	1.8	1.44	>3214.2	1973.2
2	0.73	0.034	1.5	1.8	1.48	>3387.4	2210.2
3	0.40	0.028	1.7	1.6	0.67	>3387.4	>2503.6
4	0.39	0.017	1.5	1.6	1.43	>3214.2	>2044.5
5	0.34	0.028	0.7	2.1	1.26	>2900.9	916.9
6	0.60	0.039	2.0	1.6	1.37	>2766.0	1413.5
7	0.59	0.013	1.6	1.1	1.71	>2563.0	>1767.7

November 30, 2017
West Branch Brandywine Ag-1 Watershed
Mean Nutrient and Bacterial Sampling Data

Site	Nitrite (mg/L)	Nitrate (mg/L)	Total Nitrogen (mg/L)	Orthophosphate (mg/L)	Total Coliform (#/100mL)	*Escherichia coli* (#/100mL)
1	0.004	4.4	5.9	0.40	>2419.6	365.4
2	0.005	3.7	5.7	0.36	>2419.6	127.4
3	0.005	3.9	7.0	0.38	>2419.6	83.9
4	<0.002	1.7	3.7	0.29	>2419.6	56.5
5	0.002	2.1	3.5	0.30	>2419.6	90.6
6	0.006	3.5	8.2	0.43	>2419.6	1986.3
7	0.002	2.3	2.8	0.25	2419.6	727.0
8	0.003	5.1	7.3	0.20	2419.6	193.5

5.0 DISCUSSION

This study demonstrates that within the West Branch Brandywine Ag-1 Watershed, eight sample sites spread throughout the watershed all are impaired for biology, phosphorus, nitrogen and pathogens. The dominant impairments at each of the eight sites are related to agriculture. Yet, hope remains for the watershed. At each of the sample locations where a combination of stream restoration, riparian buffer plantings, and streambank fencing were combined at the site or upstream, water quality and instream habitat have improved since 2010. To restore the function of the West Branch of the Brandywine Creek in this area, a continuing effort is needed to improve upland agricultural practices, fence cattle out of additional miles of stream, restore native vegetative stream buffers, and stabilize/ restore the stream channel.

The West Branch Brandywine Ag-1 Watershed is a headwater area of the Brandywine Creek. The highest elevations within the watershed are atop Welsh Mountain in the northern portion of the watershed. Within this area, residences are spread throughout the largest concentration of forestland in the watershed. The Chickies formation in this area is also host to a limestone quarry operation in the Northeast corner of the watershed. Two sub-watersheds were identified for study within this area in the 2010 BRC study. Sub-watershed 1 includes several unnamed tributaries that originate within a forested area and converge within the farmland at the foot of the mountain. The streams converge within an open pasture area where livestock have unrestricted access to the stream. Down slope of the open pasture area, streambank fencing and a forested riparian buffer have been installed. The riparian buffer is planted with appropriate native vegetation. Since the 2010 study, the trees have grown large enough to provide a canopy over the stream. Sample Site 7 is located within the riparian buffer zone. The habitat score has increased at this sample site since the 2010 study. A combination of the upslope area where livestock have un-restricted access to the stream, continued agricultural impacts, and decades of excessive nutrient loading to the watershed likely contributed to the biology and nutrient metrics continuing to be impaired for this stream section. As the riparian buffer becomes more established, it will likely increase in benefits to the stream downstream of this site. The impaired nature of this site indicates that upslope water-quality must be addressed before a substantial recovery in the aquatic community will occur in this sub-watershed.

Moving downstream, Sample Site 4 is located within a pasture area where livestock have direct access to the stream. Grazing pressure in this area is not very heavy. The macroinvertebrate community and habitat in this area are similar to what they were in 2010.

Sub-watershed 2 during the 2010 study was similar in land use to Sub-watershed 1. The principle exception from a water quality standpoint being that livestock within this Sub-watershed was not restricted from stream access at all in 2010. Since 2010, BRC and Chester County Conservation District (CCCD) have worked to install streambank

fencing and stable agricultural crossings in this area. The macroinvertebrate community and in-stream habitat have improved since 2010.

Sub-watershed 3 from the 2010 study receives flows from within the Borough of Honey Brook as well as from some farmland areas. Sample Site 5 is located near the downstream boundary of this subwatershed. Since 2010, one of the farms directly upstream of the site has limited the access of livestock to the stream. But, plowing and tilling continues to occur with only a minimal vegetative buffer. The macroinvertebrate community and in-stream habitat have improved since 2010.

Sample Sites 1, 2, and 3 were impaired for habitat, biology, and nutrients during the 2010 study. Sample Site 8 was not sampled in 2010. Since 2010, a limited riparian buffer project was completed in the area of Sample Site 3. As livestock still have direct access to the stream at the sample location and upstream agricultural impacts are not being attenuated, this sample location continues to be impaired for both habitat and macroinvertebrates. Sedimentation, embeddedness of epifaunal substrate, grazing pressure, and the lack of riparian buffers are major factors in causing habitat impairment in this area.

Downstream of Sample Point 3, CCCD and BRC completed three extensive stream restoration projects that included in-stream structures, streambank stabilization, riparian zone plantings, and streambank fencing. These projects were funded through a Growing Greener Watershed Renaissance Initiative and other funding sources. CCCD and BRC also worked with a local farmer to complete a streambank fencing project in an area that did not require in-stream work.

Sample Site 2 is located within the upstream watershed renaissance initiative project. The habitat score for this site improved from 108 to 206 from 2010 to 2017 due to the restoration project. This shift from impaired to unimpaired has caused the habitat in this area to go from "Red" to "Blue". The macroinvertebrate IBI Value improved from 22.7 to 39.4. Total macroinvertebrate taxa richness went from 10 to 26 taxa. As the riparian vegetation continues to mature, additional increases in bio-diversity and a shift from pollution tolerant macroinvertebrate taxa to more sensitive macroinvertebrate taxa is anticipated. Additional conservation best management practices and restoration will be needed upstream of this site, for this sample location to one day meet the goal of being considered un-impaired for macroinvertebrates.

Sample Site 8 was not sampled in 2010. This sample location is within the most downstream of the Watershed Renaissance Initiative projects. Before restoration, this area was over-grazed to the water's edge and contained livestock that had direct access to the stream channel. Work within this area included streambank stabilization, stablized livestock crossings, in-stream structures, streambank fencing, and riparian buffer plantings. The habitat score within the project area was un-impaired after the restoration. The macro-invertebrate population is impaired likely due to the water quality that is reaching the site. With time, the restoration project here and upstream

will become established and should improve the water quality in this area. Should additional conservation measures be completed upstream, this area can one day be restored to an un-impaired condition.

Sample Point 1 is located at the downstream extent of the Ag-1 watershed study area. One of the most promising aspects of the conservation and restoration work that has been done in the watershed is that the results of the upstream work are making a positive impact in this area. While livestock in this area still are able to graze the riparian zone, the upstream projects have reduced sedimentation and improved water quality coming to this area. With those improvements, the habitat score in this area has improved from 127 to 153 and has gone from "Red" to "Blue". The macroinvertebrate IBI value in this area is still impaired although it increased from 25.1 to 38.3. The macroinvertebrate biodiversity of the area has increased with the total taxa richness going from 13 to 23 taxa present. The increases in total taxa richness and in IBI value are best explained by the decrease in sedimentation to the site and corresponding decrease in pollutant loading from the upstream project areas due to the completed restoration work and conservation measures in the watershed.

Here, we have demonstrated that in those area where a holistic watershed restoration approach has been implemented, water quality has improved, the aquatic community has increased in bio-diversity, and the riparian zone habitat is no longer impaired. Going forward, a principle concern within the watershed remains the presence of pathogens and high levels of nutrients within the stream system. The high levels of bacteria at all of the sample sites indicate that fecal based pathogens continue to enter the stream at multiple locations. The principal way to reduce these health and water quality concerns within the West Branch Ag-1 Watershed is to limit the direct access of livestock to the stream, restore the stream channel and riparian zone, and manage the application of manure.

6.0 LITERATURE CITED

Clauser, A. S. and K. S. Clauser. 2010. *West Branch Brandywine Ag-1 Watershed Assessment Report.* Brandywine Valley Association.

Merrit R.W. and K.W. Cummins. 1996. *Aquatic Insects of North America.* 3rd Ed. Kendall/Hunt Publishing Company. Dubuque, Iowa. 862 pp.

Pennsylvania Department of Environmental Protection (DEP). 2013. *Instream Comprehensive Evaluation Surveys.*

Pennsylvania Department of Environmental Protection (DEP). 2015. *Index of Biological Integrity for Benthic Macroinvertebrate Communities in Pennsylvania's Wadeable, Freestone, Riffle Run Streams.*

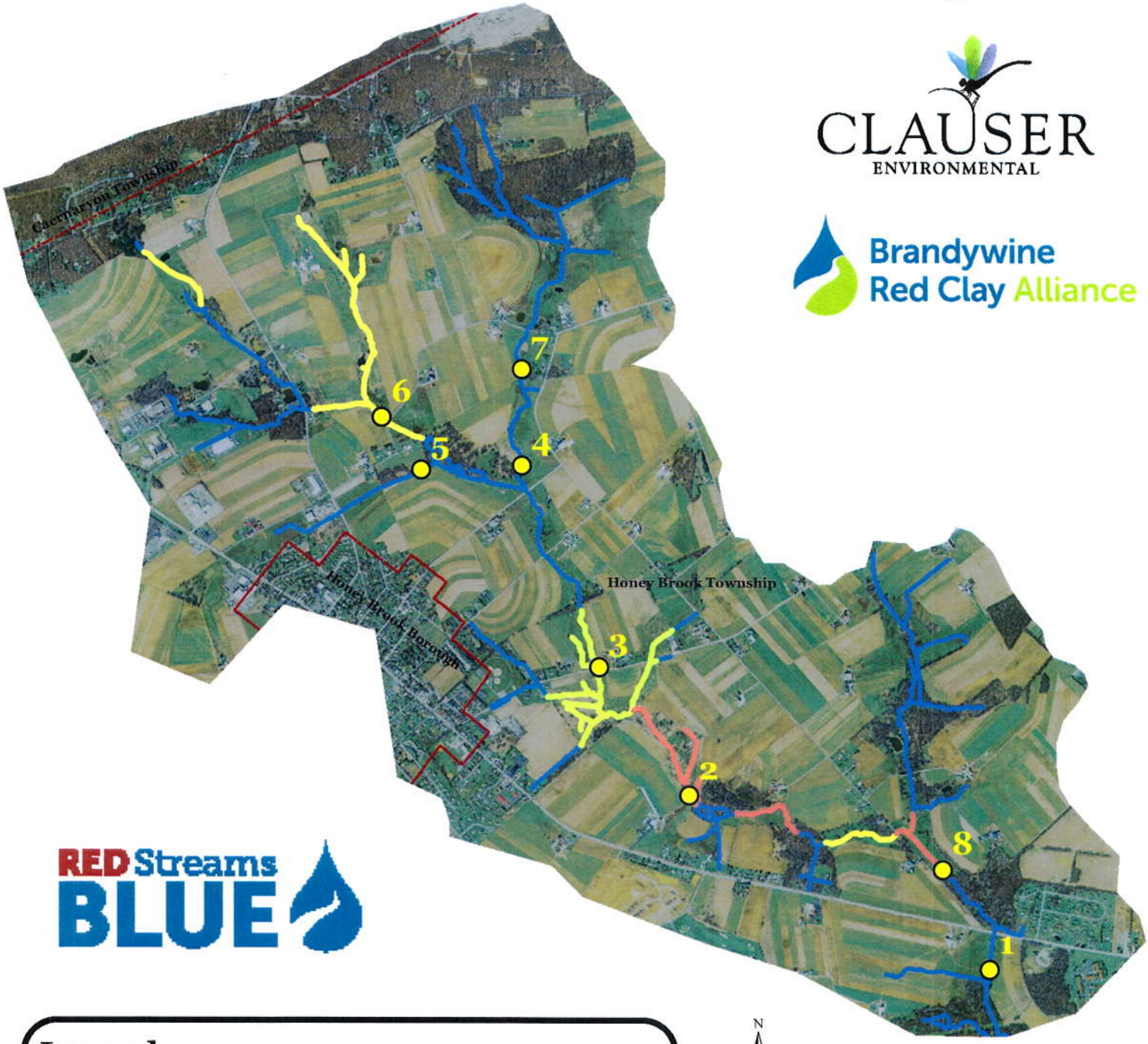
Pennsylvania Department of Environmental Protection (DEP). 2008. *Pennsylvania Integrated Water Quality Monitoring and Assessment Report.*

Sheeder S. A. and B. M. Evans. 2004. *Estimating Nutrient and Sediment Threshold Criteria for Biological Impairment in Pennsylvania Watersheds.* Journal of the American Water Resources Association 40 (4): 881–888.

Towne, D.A. 2001. *Historical Trends and Concentrations of Fecal Coliform Bacteria in the Brandywine Creek Basin, Chester County, Pennsylvania.* U.S. Geological Survey. Water-Resources Investigations Report: 01-4026.

APPENDIX A
STREAM ASSESSMENT SITE MAP

West Branch Brandywine Ag- 1 Watershed Assessment Map



CLAUSER ENVIRONMENTAL

Brandywine Red Clay Alliance

RED Streams BLUE

Legend

- Sample Locations
- Completed Watershed Renaissance Initiative Project
- BRC and CCCD Streambank Fencing Project
- Brandywine Conservancy Project
- Streams
- Municipal Boundary

N W E S

0 1,250 2,500 5,000 Feet

Data Sources:
Chester County GIS Department
www.pasda.psu.edu

APPENDIX B
MACROINVERTEBRATE TAXA LISTS

Site 1 West Branch Brandywine Ag-1 Macroinvertebrate Taxa

15-Apr-10

Class/Order/ Suborder	Family	Genus	n
Nematoda			23
Oligochaeta			13
Amphipoda	Hyalellidae	*Hyalella* sp.	1
Plecoptera	Capniidae	*Allocapnia* sp.	1
Trichoptera	Hydropsychidae	*Ceratopsyche* sp.	1
Trichoptera	Hydropsychidae	*Cheumatopsyche* sp.	1
Trichoptera	Hydroptilidae	*Orthotrichia* sp.	32
Coleoptera	Dytiscinae	*Hydaticus* sp.	5
Diptera	Ceratopoginidae	*Dasyhelea* sp.	4
Diptera	Chironomidae		88
Diptera	Simuliidae	*Cnephia* sp.	1
Diptera	Simuliidae	*Prosimulium* sp.	3
Diptera	Tipulidae	*Antocha* sp.	3
		n=	176

30-Nov-17

Class/Order/ Suborder	Family	Genus	n
Diptera	Chironomidae		108
Diptera	Tipulidae	*Antocha* sp.	10
Diptera	Empididae	*Hemerodromia* sp.	2
Diptera	Simuliidae	*Simulium* sp.	3
Diptera	Simuliidae	*Prosimulium* sp.	1
Coleoptera	Elmidae	*Oulimnius* sp.	4
Coleoptera	Elmidae	*Optioservus* sp.	2
Coleoptera	Elmidae	*Microcylloepus* sp.	12
Coleoptera	Elmidae	*Stenelmis* sp.	7
Trichoptera	Hydropsychidae	*Ceratopsyche* sp.	5
Trichoptera	Hydropsychidae	*Hydropsyche* sp.	6
Trichoptera	Hydropsychidae	*Cheumatopsyche* sp.	8
Trichoptera	Polycentropodidae	*Paranyctiophylax* sp.	1
Trichoptera	Hydroptilidae	*Leucotrichia* sp.	1
Trichoptera	Hydroptilidae	*Hydroptila* sp.	6
Trichoptera	Philopotamidae	*Chimarra* sp.	1
Acari	Hydracarina		3
Gasteropoda	Ancylidae		2
Oligochaeta			1
Turbellaria			7
Nematoda			2
Amphipoda	Crangonyctidae	*Crangonyx* sp.	2
Ephemeroptera	Heptageniidae	*Stenonema* sp.	8
Ephemeroptera	Caenidae	*Caenis* sp.	9
			211

Site 2 West Branch Brandywine Ag-1 Macroinvertebrate Taxa

15-Apr-10

Class/Order/ Suborder	Family	Genus	n
Nematoda			22
Oligochaeta			1
Ephemeroptera	Baetidae	*Acerpenna* sp.	2
Trichoptera	Hydropsychidae	*Ceratopsyche* sp.	1
Trichoptera	Hydroptilidae	*Orthotrichia* sp.	13
Trichoptera	Rhyacophilidae	*Rhyacophila* sp.	1
Coleoptera	Dytiscinae	*Hydaticus* sp.	1
Diptera	Ceratopoginidae	*Dasyhelea* sp.	10
Diptera	Chironomidae		118
Diptera	Tipulidae	*Antocha* sp.	9
		n=	178

30-Nov-17

Class/Order/ Suborder	Family	Genus	n
Diptera	Chironomidae		79
Diptera	Empididae	*Hemerodromia* sp.	3
Diptera	Simuliidae	*Simulium* sp.	14
Diptera	Simuliidae	*Cnephia* sp.	1
Diptera	Tipulidae	*Dicranota* sp.	1
Diptera	Psychodidae	*Psychoda* sp.	1
Coleoptera	Elmidae	*Stenelmis* sp.	14
Coleoptera	Elmidae	*Oulimnius* sp.	1
Coleoptera	Elmidae	*Optioservus* sp.	4
Coleoptera	Elmidae	*Microcylloepus* sp.	8
Coleoptera	Elmidae	*Dubiraphia* sp.	1
Amphipoda	Crangonyctidae	*Crangonyx* sp.	6
Trichoptera	Hydropsychidae	*Ceratopsyche* sp.	7
Trichoptera	Hydropsychidae	*Hydropsyche* sp.	3
Trichoptera	Hydropsychidae	*Cheumatopsyche* sp.	5
Trichoptera	Philopotamidae	*Chimarra* sp.	3
Trichoptera	Hydroptilidae	*Leucotrichia* sp.	1
Trichoptera	Hydroptilidae	*Hydroptila* sp.	2
Plecoptera	Capniidae	*Allocapnia* sp.	1
Nematoda			1
Oligochaeta			19
Turbellaria			17
Acari	Hydracarina		3
Gasteropoda	Ancylidae		4
Ephemeroptera	Heptageniidae	*Stenonema* sp.	3
Ephemeroptera	Baetidae	*Baetis* sp.	1
Ephemeroptera	Caenidae	*Caenis* sp.	3
		n=	206

Site 3 West Branch Brandywine Ag-1 Macroinvertebrate Taxa

15-Apr-10

Class/Order/ Suborder	Family	Genus	n
Turbellaria			8
Nematoda			23
Oligochaeta			15
Ephemeroptera	Baetidae	*Acerpenna* sp.	2
Trichoptera	Hydropsychidae	*Cheumatopsyche* sp.	2
Trichoptera	Hydroptilidae	*Orthotrichia* sp.	8
Coleoptera	Dytiscinae	*Hydaticus* sp.	1
Diptera	Ceratopoginidae	*Dasyhelea* sp.	10
Diptera	Chironomidae		96
Diptera	Simuliidae	*Prosimulium* sp.	19
Diptera	Simuliidae	*Simulium* sp.	2
Diptera	Tipulidae	*Antocha* sp.	2
		n=	188

30-Nov-17

Class/Order/ Suborder	Family	Genus	n
Diptera	Chironomidae		92
Diptera	Tipulidae	*Antocha* sp.	4
Diptera	Empididae	*Hemerodromia* sp.	1
Diptera	Simuliidae	*Simulium* sp.	22
Diptera	Simuliidae	*Cnephia* sp.	9
Coleoptera	Elmidae	*Stenelmis* sp.	1
Coleoptera	Elmidae	*Microcylloepus* sp.	1
Coleoptera	Elmidae	*Macronychus* sp.	1
Trichoptera	Hydropsychidae	*Ceratopsyche* sp.	38
Trichoptera	Hydropsychidae	*Cheumatopsyche* sp.	10
Trichoptera	Hydropsychidae	*Hydropsyche* sp.	4
Oligochaeta			5
Nematoda			1
Bivalvia			1
Turbellaria			6
Ephemeroptera	Baetidae	*Baetis* sp.	1
		n=	197

Site 4 West Branch Brandywine Ag-1 Macroinvertebrate Taxa

15-Apr-10

Class/Order/ Suborder	Family	Genus	n
Turbellaria			8
Nematoda			21
Oligochaeta			34
Gastropoda	Ancylidae		1
Isopoda			12
Amphipoda	Hyalellidae	*Hyalella* sp.	7
Ephemeroptera	Baetidae	*Acerpenna* sp.	36
Odonata	Calopterygidae	*Calopteryx* sp.	2
Trichoptera	Calamoceratidae	*Heteroplectron sp.*	8
Trichoptera	Hydropsychidae	*Ceratopsyche* sp.	4
Trichoptera	Hydropsychidae	*Cheumatopsyche* sp.	11
Trichoptera	Hydroptilidae	*Orthotrichia* sp.	5
Coleoptera	Dytiscidae	*Dytiscus* sp.	1
Diptera	Ceratopoginidae	*Dasyhelea* sp.	4
Diptera	Chironomidae		30
Diptera	Simuliidae	early instar	1
Diptera	Tipulidae	*Antocha* sp.	1
		n=	186

30-Nov-17

Class/Order/ Suborder	Family	Genus	n
Diptera	Chironomidae		99
Diptera	Simuliidae	*Simulium* sp.	3
Diptera	Simuliidae	*Prosimulium* sp.	1
Diptera	Empididae	*Hemerodromia* sp.	8
Diptera	Ceratopogoniidae	*Probezzia* sp.	2
Amphipoda	Hyalellidae	*Hyalella* sp.	24
Acari	Hydracarina		1
Bivalvia			10
Gasteropoda	Ancylidae		1
Coleoptera	Elmidae	*Optioservus* sp.	1
Coleoptera	Elmidae	*Dubiraphia* sp.	8
Coleoptera	Elmidae	*Microcylloepus* sp.	3
Coleoptera	Elmidae	*Oulimnius* sp.	2
Coleoptera	Elmidae	*Gonielmis* sp.	1
Coleoptera	Elmidae	*Stenelmis* sp.	6
Trichoptera	Hydropsychidae	*Ceratopsyche* sp.	5
Trichoptera	Hydropsychidae	*Cheumatopsyche* sp.	6
Trichoptera	Apataniidae	*Apatania* sp.	4
Oligochaeta			10
		n=	195

Site 5 West Branch Brandywine Ag-1 Macroinvertebrate Taxa

15-Apr-10

Class/Order/ Suborder	Family	Genus	n
Turbellaria			20
Nematoda			53
Oligochaeta			16
Isopoda			2
Ephemeroptera	Baetidae	*Acerpenna* sp.	19
Trichoptera	Hydropsychidae	*Ceratopsyche* sp.	2
Trichoptera	Hydropsychidae	*Cheumatopsyche* sp.	1
Trichoptera	Hydroptilidae	*Orthotrichia* sp.	5
Diptera	Ceratopoginidae	*Dasyhelea* sp.	6
Diptera	Chironomidae		68
Diptera	Simuliidae	*Prosimulium* sp.	17
Diptera	Simuliidae	*Twinnia* sp.	1
Diptera	Tipulidae	*Antocha* sp.	1
		n=	211

30-Nov-17

Class/Order/ Suborder	Family	Genus	n
Diptera	Chironomidae		88
Diptera	Empididae	*Hemerodromia* sp.	1
Diptera	Ceratopogoniidae	*Probezzia* sp.	3
Coleoptera	Elmidae	*Stenelmis* sp.	2
Coleoptera	Elmidae	*Dubiraphia* sp.	16
Coleoptera	Elmidae	*Microcylloepus* sp.	15
Odonata	Aeshnidae	*Boyeria* sp.	1
Trichoptera	Hydropsychidae	*Ceratopsyche* sp.	2
Trichoptera	Philopotamidae	*Chimarra* sp.	1
Isopoda			4
Collembolla			1
Nematoda			1
Gasteropoda	Ancylidae		2
Oligochaeta			56
Turbellaria			1
Acari	Hydracarina		2
Ephemeroptera	Baetidae	*Baetis* sp.	1
Ephemeroptera	Heptageniidae	*Stenonema* sp.	5
Ephemeroptera	Heptageniidae	*Stenacron* sp.	2
Ephemeroptera	Ephemerellidae	*Eurylophella* sp.	2
		n=	206

Site 6 West Branch Brandywine Ag-1 Macroinvertebrate Taxa

15-Apr-10

Class/Order/ Suborder	Family	Genus	n
Turbellaria			5
Nematoda			11
Oligochaeta			6
Isopoda			7
Amphipoda	Hyalellidae	*Hyalella* sp.	7
Acari	Hydracarina		1
Ephemeroptera	Baetidae	*Acerpenna* sp.	5
Ephemeroptera	Ephemerellidae	*Attenella* sp.	1
Ephemeroptera	Ephemerellidae	*Eurylophella* sp.	2
Ephemeroptera	Heptageniidae	*Stenacron* sp.	5
Trichoptera	Hydropsychidae	*Cheumatopsyche* sp.	1
Trichoptera	Hydroptilidae	*Orthotrichia* sp.	20
Coleoptera	Elmidae	*Ancyronyx* sp.	2
Diptera	Ceratopoginidae	*Dasyhelea* sp.	6
Diptera	Chironomidae		75
Diptera	Simuliidae	*Prosimulium* sp.	1
Diptera	Simuliidae	early instar	4
Diptera	Tipulidae		1
		n=	160

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Class/Order/ Suborder	Family	Genus	n
Diptera	Chironomidae		73
Diptera	Tipulidae	*Dicranota* sp.	8
Diptera	Simuliidae	*Simulium* sp.	1
Diptera	Empididae	*Hemerodromia* sp.	2
Diptera	Tipulidae	*Antocha* sp.	2
Coleoptera	Elmidae	*Stenelmis* sp.	10
Coleoptera	Elmidae	*Dubiraphia* sp.	2
Coleoptera	Elmidae	*Microcylloepus* sp.	7
Coleoptera	Elmidae	*Oulimnius* sp.	1
Coleoptera	Elmidae	*Optioservus* sp.	2
Trichoptera	Hydropsychidae	*Ceratopsyche* sp.	8
Trichoptera	Apataniidae	*Apatania sp.*	7
Trichoptera	Hydropsychidae	*Cheumatopsyche* sp.	3
Trichoptera	Limnephilidae	*Pycnopsyche* sp.	1
Collembolla			1
Plecoptera	Nemouridae	*Prostoia* sp.	3
Amphipoda	Hyalellidae	*Hyalella* sp.	2
Isopoda			6
Bivalvia			2
Nematoda			2
Oligochaeta			42
Turbellaria			2
Acari	Hydracarina		1
Gasteropoda	Ancylidae		3
Ephemeroptera	Heptageniidae	*Stenonema* sp.	1
Ephemeroptera	Ephemerellidae	*Eurylophella* sp.	1
		n=	193

Site 7 West Branch Brandywine Ag-1 Macroinvertebrate Taxa

15-Apr-10

Class/Order/ Suborder	Family	Genus	n
Turbellaria			6
Nematoda			5
Oligochaeta			35
Gastropoda	Ancylidae		2
Isopoda			24
Amphipoda	Hyalellidae	*Hyalella* sp.	2
Ephemeroptera	Baetidae	*Acerpenna* sp.	6
Ephemeroptera	Baetidae	*Diphetor* sp.	1
Ephemeroptera	Leptophlebiidae	*Paraleptophlebia* sp.	1
Plecoptera	Capniidae	*Nemocapnia* sp.	2
Trichoptera	Hydropsychidae	*Ceratopsyche* sp.	2
Trichoptera	Hydropsychidae	*Cheumatopsyche* sp.	3
Trichoptera	Hydroptilidae	*Orthotrichia* sp.	2
Diptera	Ceratopoginidae	*Dasyhelea* sp.	8
Diptera	Chironomidae		70
Diptera	Empididae	*Hemerodromia* sp.	2
Diptera	Simuliidae	*Prosimulium* sp.	9
Diptera	Simuliidae	*Twinnia* sp.	2
		n=	182

30-Nov-17

Class/Order/ Suborder	Family	Genus	n
Diptera	Chironomidae		96
Diptera	Empididae	*Hemerodromia* sp.	2
Coleoptera	Elmidae	*Stenelmis* sp.	4
Coleoptera	Elmidae	*Dubiraphia* sp.	3
Coleoptera	Elmidae	*Microcylloepus* sp.	12
Coleoptera	Elmidae	*Optioservus* sp.	1
Trichoptera	Hydropsychidae	*Ceratopsyche* sp.	12
Trichoptera	Hydropsychidae	*Cheumatopsyche* sp.	4
Turbellaria			1
Nematoda			6
Oligochaeta			30
Amphipoda	Hyalellidae	*Hyalella* sp.	14
Amphipoda	Gammaridae	*Gammarus* sp.	4
Ephemeroptera	Leptophlebiidae	*Paraleptophlebia* sp.	3
		n=	192

Site 8 West Branch Brandywine Ag-1 Macroinvertebrate Taxa

30-Nov-17

Class/Order/ Suborder	Family	Genus	n
Diptera	Chironomidae		109
Diptera	Tipulidae	*Antocha* sp.	4
Diptera	Simuliidae	*Simulium* sp.	1
Diptera	Empididae	*Hemerodromia* sp.	3
Diptera	Tipulidae	*Dicranota* sp.	1
Coleoptera	Elmidae	*Stenelmis* sp.	2
Coleoptera	Elmidae	*Optioservus* sp.	1
Coleoptera	Elmidae	*Microcylloepus* sp.	3
Trichoptera	Apataniidae	*Apatania* sp.	3
Trichoptera	Hydropsychidae	*Ceratopsyche* sp.	17
Trichoptera	Hydropsychidae	*Hydropsyche* sp.	4
Trichoptera	Hydropsychidae	*Cheumatopsyche* sp.	8
Trichoptera	Philopotamidae	*Chimarra* sp.	4
Trichoptera	Hydroptilidae	*Hydroptila* sp.	4
Oligochaeta			3
Nematoda			1
Gasteropoda	Ancylidae		1
Turbellaria			5
Acari	Hydracarina		3
Amphipoda	Gammaridae	*Gammarus* sp.	1
Ephemeroptera	Heptageniidae	*Stenonema* sp.	1
Ephemeroptera	Caenidae	*Caenis* sp.	15
		n=	194