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A Study of the Effectiveness of the Buffalo Creek Acid Precipitation Treatment System and its Ecological Effects on Buffalo Creek, Union County, Pennsylvania

A Report to the Buffalo Creek Watershed Alliance
January 12, 2011

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Introduction

Acid precipitation, any precipitation with a pH of less than 5.7 (Eby, 2004), is a widespread problem with significant effects on the environment for many regions throughout the world. Although rain and other precipitation can be naturally acidic, humans have lowered the pH in many regions by increasing the release of chemicals into the atmosphere from power plants, vehicle exhaust, and the burning of fossil fuels (EPA, 2008). These chemicals that are released into the atmosphere react with water, oxygen, and other chemicals to form more acidic compounds that make precipitation more acidic (EPA, 2008). When the precipitation becomes too acidic, it can no longer be buffered and neutralized by alkaline materials found in the surrounding environment (*i.e*, bedrock geology, streams, and soils), and eventually these alkaline materials can be completely depleted by acid precipitation (EPA, 2008).

Pure rainfall was historically estimated to be about a pH of 5.6 in areas away from sulfur and nitrogen sources (SO_x and NO_x being the main pollutants to cause acid rain), but because of more human interactions with the environment it can be estimated to be closer to around a pH of 5 (Montgomery, 2008). In central Pennsylvania and the northeastern United States, pH is on average below a pH of 4.5 (Montgomery, 2008) because of the large number of coal-fired factories, vehicles emitting NOx, and smokestacks of fossil fuel power plants upwind that release pollutants which travel downwind and affect this area (Eby, 2004). This highly acidic rainfall causes acidified soil stunting plant growth, kills fish and other aquatic life by acidifying stream and lake waters, and can corrode buildings and monuments (Montgomery, 2008).

The Buffalo Creek Watershed Alliance (BCWA) is a non-profit organization established in January 2002 to help educate the public and raise awareness of the problems plaguing the Buffalo Creek Watershed and to acquire support to fix these issues (BCWA, 2009). Surveys indicate that the Buffalo Creek headwaters and the upper portions (approx. 7-8 miles in total stream length) of the stream do not comply with Pennsylvania Water Quality Standards. Therefore, the BCWA installed the Buffalo Creek Acid Precipitation Treatment System (BCAPTS) in 2009 to remediate the effects of acid precipitation on the stream (BCWA, 2009). Dissolved aluminum concentrations were also measured, and they exceeded toxic levels for macroinvertebrates and brook trout for most of the same stream length with low pH.

BCAPTS is a passive treatment system for acid precipitation and consists of a diversion dam where some of the water from the stream is diverted into the treatment system where it then flows through a limestone basin and vertical flow wetland (VFW) before it is reintroduced to Buffalo Creek *via* an effluent channel (Fig. 1). The limestone basin and VFW are designed to produce alkaline waters, and the combination of both systems will allow the system to be effective during baseflow and storm flow events (Kirby, 2009). The alkaline waters reintroduced into Buffalo Creek are meant to mix with the acidified stream waters to produce a more natural pH.

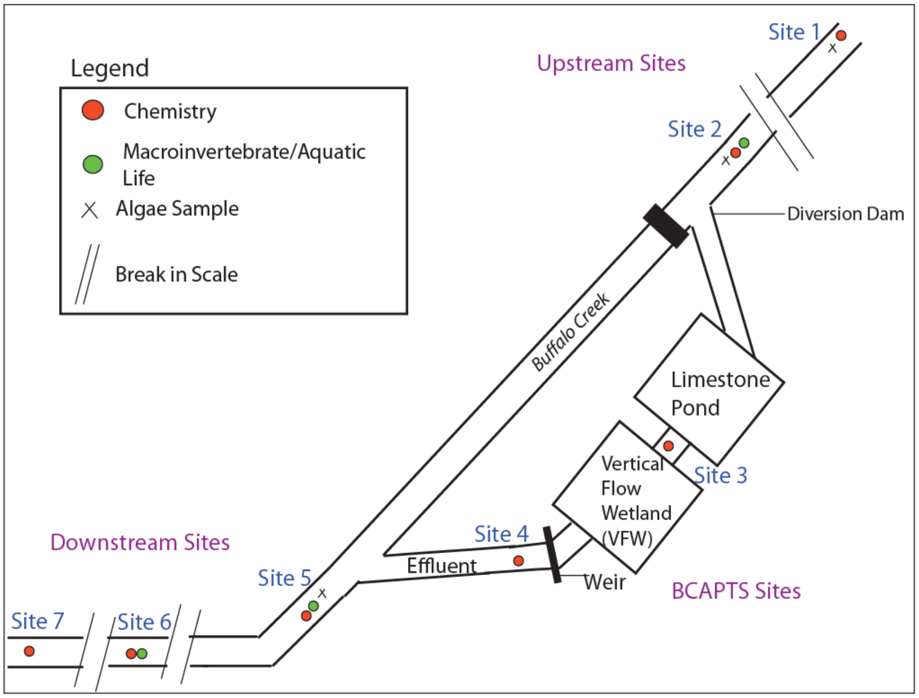

Figure 1. Schematic map of sampling site locations along Buffalo Creek. See Table 1 for more information on specific sample site locations.

Physical Setting

The Buffalo Creek Watershed is located in Centre and Union County, Pennsylvania and is a tributary to the West Branch of the Susquehanna River (Kirby *et al*., 2008). Buffalo Creek drains approximately 134 square miles and flows approximately 28 miles through the Appalachian Mountain section of central Pennsylvania's Valley and Ridge Province. The creek originates from the sandstone ridges northwest of Hartleton and joins the West Branch Susquehanna River at Lewisburg (Kirby *et al*., 2008). Because Buffalo Creek headwaters flow through the Tuscarora Formation, there is no buffering effect from the bedrock geology to help neutralize the acid rain and waters of the stream (Kirby *et al*., 2008).

Objectives

The primary purpose of conducting this research was to further the understanding of how BCAPTS is affecting the water chemistry of Buffalo Creek. Geochemical data collected at sites upstream and downstream of BCAPTS can be compared in order to distinguish differences in water chemistry. The differences in water chemistry downstream of BCAPTS provides valuable information on the effectiveness of BCAPTS raising pH, raising alkalinity, and lowering dissolved aluminum concentrations to restore Buffalo Creek back to a healthy stream system.

In order to focus on how BCAPTS is affecting the downstream Buffalo Creek ecology, algae samples were collected at different sites from upstream of BCAPTS and downstream of BCAPTS for comparison. Mayflies, stoneflies, caddisflies, and other macroinvertebrates were collected in both upstream and downstream Buffalo Creek sites to establish an EPT Index. An EPT Index is the number of *Ephemeroptera*, *Plecoptera*, and *Trichoptera* (mayflies, stoneflies, and caddisflies) in a given sampling which acts as a health indicator for the stream.

Sites within BCAPTS were monitored in order to observe how the different treatment system components are operating and if they are operating in the manner they were intended. The data collected at each site in BCAPTS indicates how the water chemistry is altered as it flows through the system. This data can be used to see if BCAPTS is functioning properly and whether any part of the system needs to be changed or altered in order to become more effective.

Methods

Seven different sites along seven miles of Buffalo Creek were monitored with the first site located at the origin. The seven sites, as seen in Figure 1, are split up into three different categories consisting of: upstream of BCAPTS, BCAPTS, and downstream of BCAPTS.

Using a YSI multimeter, all sites were monitored for dissolved oxygen, pH, specific conductance, and temperature. The YSI multimeter was calibrated once before sampling for dissolved oxygen and pH and also halfway through sampling for the same parameters.

A 500-mL raw water grab sample was collected at all sites. These samples were stored on ice until transported back to the lab where they were refrigerated until further testing. Alkalinity was measured in the lab from the samples using a pH meter, digital titrator, and magnetic stirrer. The titrations were completed 2-3 days after sample collection. KCl was added to the water samples before starting the titration in order to help stablilize pH readings because of the low ionic strength of the water. The data were then entered into the USGS alkalinity calculator using the Gran Titration calculation method to come up with the values for alkalinity (USGS, 2009). Major cation and anion concentrations were measured from the 500-mL raw water grab samples using high-pressure liquid chromatography (HPLC). The samples were first filtered using a 0.2 µm filter before using HPLC.

The dissolved calcium and magnesium concentrations were analyzed using inductively-coupled plasma atomic emission spectroscopy (ICP). 60-mL filtered (0.2 µm filter) and acidified (trace metal grade nitric acid) samples were collected at all sites along with raw and acidified (trace metal grade nitric acid) 60-mL samples. These samples were collected at all sites (where possible) for both 6/15/2010 and 7/12/2010. These samples were also used to analyze dissolved aluminum concentrations using a graphite furnace atomic absorption spectrometer. Subsamples of the 60-mL filtered and unfiltered samples were also sent to commercial labs to be analyzed for dissolved metals using an inductively-coupled plasma atomic emission mass spectrometer.

All macroinvertebrate samples were collected using the kick-net method and sorted through either on site or in the lab. All samples were taken in a riffle section of the stream and the substrate consisted of large blocks of Tuscarora sandstone. A 1-ft by 1-ft hand net with 1 mm mesh size was held down firmly to the bed of the creek. Starting from one bank of the stream, the net was held in the water by one person while another stood directly upstream of the net and kicked for 45 seconds. This procedure was repeated across the width of the stream. The macroinvertebrates collected from the sites were then identified and sorted using a microscope and freshwater macroinvertebrate identification guide (Water Action Volunteers, 2007). The 6/15/2010 algae samples were collected and stored in 500-mL grab samples and then refrigerated until further analysis. The 6/30/2010 algae sampling was collected in 500-mL grab samples and preserved with Carosafe and refrigerated until further analysis.

Results and Discussion

The pH at Site 2 in Table 1 (6/11/2010 sampling), upstream of BCAPTS, was measured as 4.0 with zero alkalinity. At this site, there were many different species of algae including *Tribonema*, *Spirogyra*, and *Mougeotia* (Holt, 2010). All of these algae thrive and live in acid waters. Directly downstream of BCAPTS, Site 5, the pH was measured at 6.5 with 26 mg/L as $CaCO_3$ alkalinity. The substrate at Site 5 was covered in a "white slime" substance, which will be discussed later in these results. Following the same trend, in Table 2 (6/15/2010 sampling) the pH and alkalinity both rise from Site 2 to Site 5 as some water gets treated through BCAPTS. From Site 5 to Site 7, the alkalinity drops considerably which raises concerns to why the alkalinity drops to almost zero in a short span of distance. During the 6/15/2010 sampling. All seven sites were sampled along Buffalo Creek and in BCAPTS.

At Site 2, a macroinvertebrate sample was collected on 5/1/2010 and 6/4/2010.

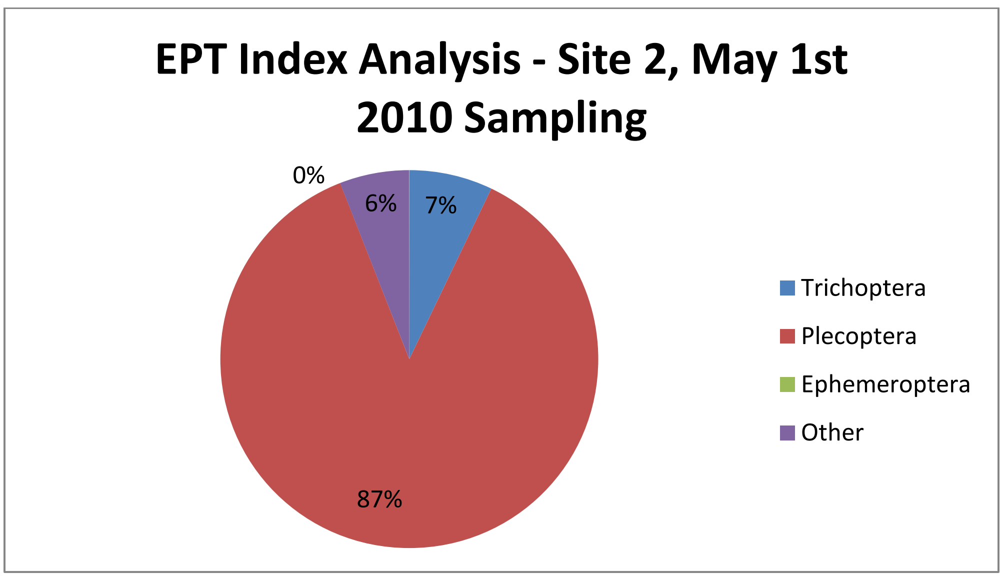

Figure 2. Pie chart displaying EPT Index analysis for Site 2.

The EPT index for the 5/1/2010 sampling was 4 (Figure 2) and the 6/4/2010 sampling yielded an index of 4 (methods described in Appendix A). Both results indicate poor water quality for Site 2 which agrees with the water chemistry samples collected.

The sampling sites in BCAPTS provide valuable information to determine if BCAPTS is functioning as intended. Site 3, the effluent pipe from the first limestone pond, indicates a steep rise in pH from 4.1 to 8.1. As the pH begins to rise, the alkalinity rises as calcium ions are released into the water from the dissolving limestone, producing high alkaline waters with the ability to buffer acidic waters. This indicates that the first limestone pond in BCAPTS is functioning as intended and sufficiently raising the pH of the water.

Table 1. Summary of chemical measurements taken at Buffalo Creek sites on 6/11/2010.

	pH	Spec. Cond. (mS/cm)	Temp. (°C)	DO (% sat)	DO (mg/L)	Alk. (mg/L as $CaCO_3$)
Site 2 – Upstream BCAPTS	4.0	0.02	15	110	11	0.0
Site 5 – Buffalo Flat Rd	6.5	0.07	18	93	9.0	26
Site 7 – Aikey Rd	5.7	0.02	15	110	11	0.40

Spec. cond. = specific conductance; Temp. = temperature; DO = dissolved oxygen; Alk. = alkalinity

Table 2. Summary of chemical measurements taken at Buffalo Creek sites on 6/15/2010.

Site # and Name	pH	Spec. cond. (mS/cm)	Temp. (°C)	DO (% sat)	DO (mg/L)	ORP (mV)	Alk. (mg/L as $CaCO_3$)
1 - Buff Creek Headwaters	4.0	0.02	14	49	5	300	0
2 - Upstream BCAPTS	4.1	0.02	15	100	10	nd	0
3 - Limestone Pond Effl (east pipe)	8.1	0.06	18	110	10	nd	19
3 - Limestone Pond Effl (west pipe)	8.3	0.04	18	100	9.4	nd	nd
VFW effl (east pipe)	6.4	0.37	18	< 9.0	< 0.5	-160	nd
VFW effl (west pipe)	6.4	0.41	18	< 10	< 1.0	-180	nd
4 - Effl below weir	6.6	0.28	20	18	1.6	-110	100
5 - Buffalo Flat Road	6.7	0.12	17	58	5.5	6	43
6 -Frederick Trail Bridge	5.9	0.03	14	120	12	180	8.0
7 -Aikey Road	5.1	0.02	16	108	11	nd	0.20

nd = no data, DO = dissolved oxygen, Spec. cond. = specific conductance, Alk. = alkalinity, Temp. = temperature; ORP = oxidation/reduction potential

From Site 3 to Site 4 the alkalinity rises from 19 mg/L to 100 mg/L while dropping in pH (Table 2). Between Site 3 and 4, the water flows through the VFW which causes these results to be seen as well as the drop in dissolved oxygen amounts. The increase in CO_2 partial pressure from the organic layer in the VFW causes the solubility of calcite to increase. This results in more calcite from the limestone layer dissolving into the water, which increases the alkalinity. At Site 4, the pH and DO are both initially low but from Site 4 to Site 5 both begin to rise as water regains equilibrium with the atmosphere.

In Table 2, Site 5 is approximately 15m downstream of the mixing zone of the untreated and treated waters. The acidic, untreated waters mix with the more alkaline treated waters to produce a more neutral pH. The pH continues to rise as the water continues to regain equilibrium with the atmosphere. From Site 5 to Site 7 in Table 2, the pH and alkalinity continue to drop suggesting acidic water is continuing to enter the stream downstream of BCAPTS. The pH values were measured at each of the sites using the YSI multimeter. This means that the pH values could not be skewed as a result from the dilution of samples that were collected to calculate alkalinity. All the samples which were used to calculate alkalinity were diluted in the lab and calculated using the same method, which means the drop in alkalinity cannot be attributed to dilution alone based on how the values rise and fall as seen in Table 2.

The phosphorus concentrations seen in Table B1 are extremely high at Sites 4 and 5 because of the breakdown of organic material from the VWF. The stream substrate at Site 5 is covered in "white slime". This "white slime", possibly the skeletons of the algae *Cheatophora* (Holt, 2010), suggests that the high phosphorus levels in the stream water (nutrient rich) can allow for massive algae blooms. However, analysis using a microscope revealed that this "white slime" is dead and not a living organism. The *Cheatophora* could have bloomed in the nutrient rich waters and then either a viral or bacterial disease quickly wiped out the algae leaving only the skeletons behind (Holt, 2010). The presence of high amounts of *Euglena*, a genus of unicellular protists, also indicates the waters at Site 5 are very nutrient rich because *Euglenas* thrive on this type of environment (Holt, 2010). There is also a lack of macroinvertebrate diversity, which may cause excess nutrients in the water to become available.

A macroinvertebrate sample was collected for Site 5 on both 5/1/2010 and 6/4/2010.

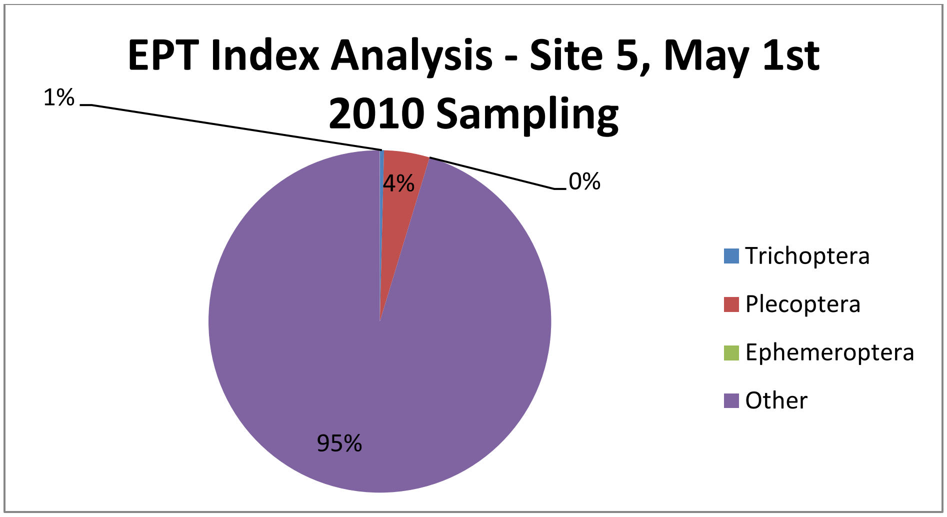

Figure 3. Pie chart displaying EPT Index analysis for 5/1/2010 sampling.

The EPT Index calculated for this site was 2 indicating the water quality is poor. Figure 3 illustrates that the dominant species at Site 5 was in the "other" category. The "other" category consisted primarily of *Diptera Chironomidae* (see Appendix A) which appeared to thrive in the "white slime" substance attached to the substrate. This dominance could prevent other macroinvertebrates from inhabiting the site causing a decrease in diversity of organisms. Also, because of the recent installation of BCAPTS, a normal population may have not had time to establish itself naturally. Despite the pH and the alkalinity being normal at this site, the EPT is still not normal and the abundance of "white slime" causes the dominance *Diptera Chironomidae* in the nutrient rich waters (Holt, 2010).

Both calcium and magnesium concentrations rise as the water flows through BCAPTS (Sites 3 and 4; Table B1). The concentrations drop again once the treated water mixes with the untreated water further supporting the other data and results collected (pH and alkalinity measurements in Table 1 and 2). The calcium and magnesium concentrations continue to drop after Site 5 which indicates that the stream is losing its buffering ability and the alkalinity of the stream is dropping.

The dissolved metal concentrations of calcium, magnesium, and aluminum were also measured at all seven sites along Buffalo Creek. The dissolved aluminum concentrations are expected to drop as the water passes through BCAPTS because as the water flows though the VFW, the CO_2 partial pressure drops beneath the layers of compost and limestone. The lower CO_2 partial pressure provides the right conditions for the dissolved aluminum to precipitate out of the water. The dissolved calcium and magnesium concentrations are expected to rise as the water passes through BCAPTS because the limestone beds add calcium and magnesium to the water.

Table 3 and 4 indicate that the calcium and magnesium levels do rise as they passed through BCAPTS. The Tables also further support the fact that Buffalo Creek is losing alkalinity downstream of Site 5 because the calcium and magnesium levels both drop significantly.

Table 3. Dissolved metal concentrations (mg/L) of Buffalo Creek samples taken on 6/11/2010.

Filtered (0.2 µm filter) and Acidified (Nitric Acid)							
	Site 1	**Site 2**	**Site 3**	**Site 4**	**Site 5**	**Site 6**	**Site 7**
Ca	nd	0.27	nd	nd	9.7	nd	1.4
Mg	nd	0.18	nd	nd	0.63	nd	0.52
Al	nd	0.29	nd	nd	0.15	nd	0.05

nd = no data, Mg = magnesium, Ca = calcium, Al = aluminum

Table 4. Dissolved metal concentrations (mg/L) of Buffalo Creek samples taken on 6/15/2010.

Filtered (0.2 µm filter) and Acidified (Nitric Acid)							
	Site 1	**Site 2**	**Site 3**	**Site 4**	**Site 5**	**Site 6**	**Site 7**
Ca	0.11	0.23	9.2	44	17	3.9	1.3
Mg	0.09	0.17	0.36	2.7	1.3	0.58	0.52
Al	0.16	0.27	0.27	0.07	0.12	0.07	0.05
Raw and Acidified (Nitric Acid)							
	Site 1	**Site 2**	**Site 3**	**Site 4**	**Site 5**	**Site 6**	**Site 7**
Ca	0.10	0.23	9.8	49	18	3.9	1.3
Mg	0.09	0.17	0.37	3.1	1.3	0.57	0.52
Al	nd	0.29	0.26	0.10	0.15	nd	nd

nd = no data, Mg = magnesium, Ca = calcium, Al = aluminum,

Table 3 and Table 4 indicate that BCAPTS is lowering the dissolved aluminum concentrations in Buffalo Creek. Looking at the filtered samples in Table 5, the water enters the treatment system with an aluminum concentration of 0.27 mg/L. As the water leaves the treatment system at Site 4, there is a considerable drop to 0.07 mg/L in the water. The concentration of aluminum consequently rises at Site 5 once it mixes with untreated water but continues to drop in concentration up to Site 7. Similar measurements were taken in the raw and acidified samples in Table 4 and the other measurements in Table 3.

Macroinvertebrate samples were taken at Site 7 on 5/1/2010 and 6/4/2010. Site 7 yield the highest diversity of macroinvertebrates collected during both samples and was the only site to have a fair water quality rating from the EPT Index.

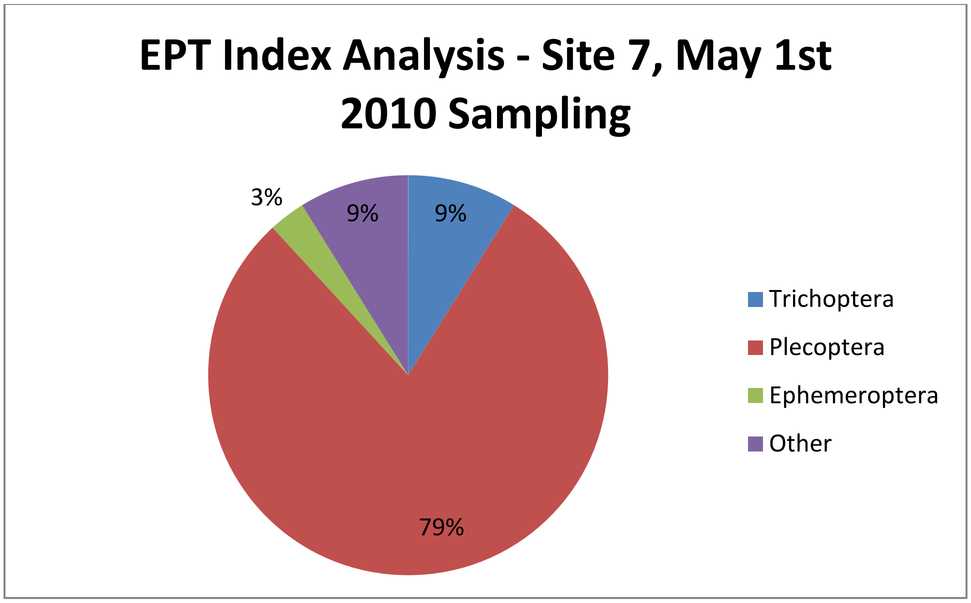

Figure 4. Pie chart displaying EPT Index analysis for 5/1/2010 sampling.

The EPT Index for Site 7 was a 9 indicating a "fair" water quality rating. This helps support that BCAPTS is effectively raising the pH and lowering dissolved aluminum amounts enough to help start restore the stream's natural ecosystem. The pH could not have been effectively raised without BCAPTS due to the geology that the Buffalo Creek headwaters flow through. Buffalo Creek runs through the Tuscorora Formation, which consists of sandstone. The sandstone geology allows for no calcium or magnesium to be leached into the geology which could raise pH and alkalinity. Dilution alone would not be the only factor because dilution would increase the pH from previous sites due to the introduction of more OH^- ions. Table 2 indicates that the pH consistently drops from Site 5 to Site 7.

This summer was very dry, and due to this fact the 7/12/2010 sampling was taken when there was little to no flowing water in Buffalo Creek. As indicated in Table 5, most water samples were taken from the remaining pool sections of the creek in standing water. The dissolved oxygen measurements taken on this date were appeared to be skewed (much lower compared to 6/15/2010 sampling) due to the fact there was no running water allowing oxygen to easily enter the stream system. Due to the dry conditions, there was barely any water flowing out of the limestone effluent pipes and no water flowing out of the VFW effluent pipes. Both the limestone and VFW pools were very low with much of the compost exposed in the VFW and most of the limestone subaerially exposed in the limestone pool.

Table 5. Summary of chemical measurements taken at Buffalo Creek on 7/12/2010.

	pH	Spec. Cond. (mS/cm)	Temp. (^oC)	DO (% sat)	DO (mg/L)	ORP (mV)	Alk. (mg/L as CaCO3)
Site 1 - Buff Creek Headwaters	nd	nd	nd	nd	nd	nd	nd
Site 2 - Upstream BCAPTS	4.1	0.04	18	74	7.1	160	0
Site 3 - Limestone Pond Effl (east pipe)	**	**	**	**	**	**	52
Site 3 - Limestone Pond Effl (west pipe)	nd	nd	nd	nd	nd	nd	nd
VFW effl (east pipe)	nd	nd	nd	nd	nd	nd	nd
VFW effl (west pipe)	nd	nd	nd	nd	nd	nd	nd
Site 4 - Effl below weir	nd	nd	nd	nd	nd	nd	nd
Site 5 - Buffalo Flat Road	6.5	0.09	19	45	4.2	13	30
Site 6 -Frederick Trail Bridge	6.5	0.05	15	100	11	100	3.0
Site 7 -Aikey Road	5.4	0.04	19	62	5.8	86	0.70

nd = Indicates no data was able to be collected because the stream was dry.
**** Indicates a water sample was able to be taken.**
Spec. cond. = specific conductance, Temp. = temperature, DO = dissolved oxygen, Alk. = alkalinity; ORP = oxidation/reduction potential.

For this sampling date, the measurements were taken from the leftover pool sections of the stream that had not dried up. This has resulted in drastic changes in some measurements from the previous sampling.

Site 6 was the only site with flowing water.

The cation and anion concentrations found in the water samples appear to be affected by this dry period. In Table B2, most of the cation and anion concentrations increased from the previous samplings for each site. The rise in concentrations of most cation and anions could be from the lack of flow of water distributing these concentrations throughout the stream system. Instead, as the cations and anions are introduced by natural processes (rainwater, breakdown of organic material, leaching, decay, etc) into the standing pools of water that remain, they become more concentrated in the standing water.

This indicates that during dry periods, there is very little water running through the system. From Tables 4 and 6, one can see that the calcium concentrations in the water greatly increase from the 6/15/2010 sampling to the 7/12/2010 sampling.

Table 6. Dissolved metal concentrations (mg/L) of Buffalo Creek samples taken on 7/12/2010.

	Filtered (0.2 µm filter) and Acidified (Nitric Acid)						
	Site 1	**Site 2**	**Site 3**	**Site 4**	**Site 5**	**Site 6**	**Site 7**
Ca	nd	0.15	24	nd	8.7	2.1	1.7
Mg	nd	0.27	2.6	nd	0.91	0.52	0.50
Al	nd	nd	0.06	nd	nd	0.05	0.06
	Raw and Acidified (Nitric Acid)						
	Site 1	**Site 2**	**Site 3**	**Site 4**	**Site 5**	**Site 6**	**Site 7**
Ca	nd	0.14	24	nd	9.8	2.1	1.6
Mg	nd	0.22	2.1	nd	0.91	0.46	0.56
Al	nd	nd	0.06	nd	0.30	nd	nd

nd = no data was able to be collected because stream was dry. Ca = calcium, Mg = magnesium, Al = aluminum; Aluminum data is from a commercial lab.

The increase in calcium concentrations is due to the low water conditions. The small amount of water flowing through the system on 7/12/2010 became highly concentrated with calcium ions from the limestone pond. The calcium concentration decreases considerably though after the treated water and untreated water mix at Site 5, most likely due to a lack of water flowing through the treatment system and more flow of the untreated, acidic waters. The aluminum data is also altered by the lack of flow of water. Because there was little to no water flowing through BCAPTS (no water coming from the effluent pipes of the VFW) there was no mixing of treated and untreated water. This resulted in the sampling at Site 5 to contain a very high aluminum concentration. This is also due to the sample being taken from a pool of water where the dissolved metals are highly concentrated from the water evaporating from the pools.

Conclusion

The phosphorus concentrations are extremely high below BCAPTS possibly causing the “white slime” algae blooms and are responsible for the high amount of *Chironomidae* which offset the natural diversity of macroinvertebrates that should exist in the stream. Further monitoring of Site 5 would be needed to better understand how the phosphorus levels are affecting downstream

Buffalo Creek and to determine if the why the phosphorus levels are as high as they are. Also, further monitoring of the “white slime” at Site 5 would help determine what triggers blooms of this possible algae and its life cycle.

The macroinvertebrate sampling indicates that insect diversity is increasing downstream of BCAPTS. This is due to the successful rise in pH of the water which allows for these insects to thrive and survive. Site 7, the furthest site downstream of BCAPTS had the highest EPT score and diversity of macroinvertebrates and insects inhabiting the site. Because the alkalinity is almost back to zero at Site 7, further monitoring of water chemistry and insect and macroinvertebrate sampling is recommended in order to see if the site remains stable.

Overall, BCAPTS is effectively raising the pH and alkalinity of Buffalo Creek and helping restore Buffalo Creek back to a healthy stream system. Based on the data collected, the alkalinity and pH of Buffalo Creek increased downstream of BCAPTS and aluminum concentrations were decreased. However, data from the downstream sites (Site 6 and Site 7) indicate that the stream loses almost all of its alkalinity and the pH begins to drop as well. Although BCAPTS is functioning as intended (pH and alkalinity normal at Site 5), it may not be enough for the downstream reaches of Buffalo Creek. The downstream pH and alkalinity decreases suggest that acidic groundwater is entering downstream of the treatment system. Further monitoring of Buffalo Creek and BCAPTS suggested to understand seasonal variations and variations in the treatment system throughout the year and to check if BCAPTS is maintaining effectiveness.

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Appendix A

Macroinvertebrate Data

The EPT Index is calculated by using three orders of common aquatic insects as an indicator of stream health and water quality (Watershed Science Institute). The EPT is calculated by the "total number of *taxa* within the groups of *Trichoptera*, *Plecoptera*, and *Ephemeroptera*" (Watershed Science Institute), but for the purpose of this study, the insects were only identified to the *Family taxa* in order to reduce error of identification. Table A1 clearly illustrates the EPT index ranges for water quality ratings.

Table 1. Example of EPT index ranges and their corresponding water quality ratings.

(modified from NCDENR, 1997).

Rating	Excellent	Good	Good-fair	Fair	Poor
EPT	>27	21-27	14-20	7-13	0-6

http://www.wsi.nrcs.usda.gov/products/w2q/strm_rst/docs/wshed_cond/Watershed_Condition-EPT_Index_Tech_Note_3.pdf

Sampling Locations

Site 2 is a shaded with abundant tree coverage and located behind Hay's Lane Camp Barn about 75 feet above the diversion dam to the Buffalo Creek Acid Precipitation Treatment System.

Site 5 is a sometimes shaded area located downstream of the Buffalo Creek Acid Precipitation Treatment System. The site is located directly above where Buffalo Flat Road crosses over Buffalo Creek.

Sampling site 7 is a shaded site with abundant tree coverage and located directly below where Aikey Road crosses over Buffalo Creek in Hartleton, Pennslyvannia.

May 1st, 2010 Macroinvertebrate Sampling

During this sampling, the weather was cloudy and around 56 °F. It was raining for the end of the Site 5 sampling and for all of the sampling done at Site 7. The identification of macroinvertebrates was done using a macroinvertebrate identification guide (Water ActionVolunteers, 2007). Site 2 and 5 were sorted in the field and Site 7 was sorted in the lab and all were preserved with 100% ethyl alcohol and water. These samples were identified on May 17th, 2010 with the supervision of Christopher Donaghy.

Site 2

Table A2. Macroinvertebrates collected at Site 2 on 6/1/2010.

Macroinvertebrate (*Family taxa)*	**Counts**
Odonata Libellulidae	1
Trichoptera Polycentro-podidae	2
Trichoptera Rhyacophilidae	4
Diptera Simuliidae	4
Plecoptera Leuctridae	23
Plecoptera Capniidae	50

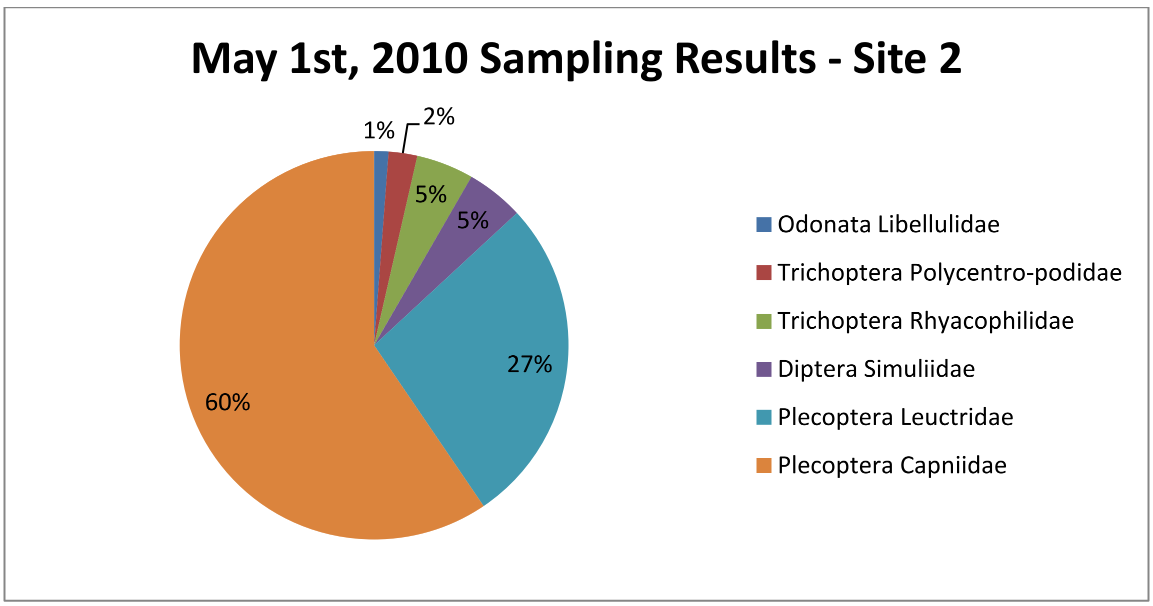

Figure A1. Pie chart displaying percentages of macroinvertebrates from Site 2.

Although there appears to be a diversity of macroinvertebrates collected from Site 2, only the *Plecoptera*, *Trichopter*, and *Ephemeroptera* are indicators of stream health due to their sensitivity to acidic waters. The lack of diversity within these Families indicates poor stream health and a low EPT index.

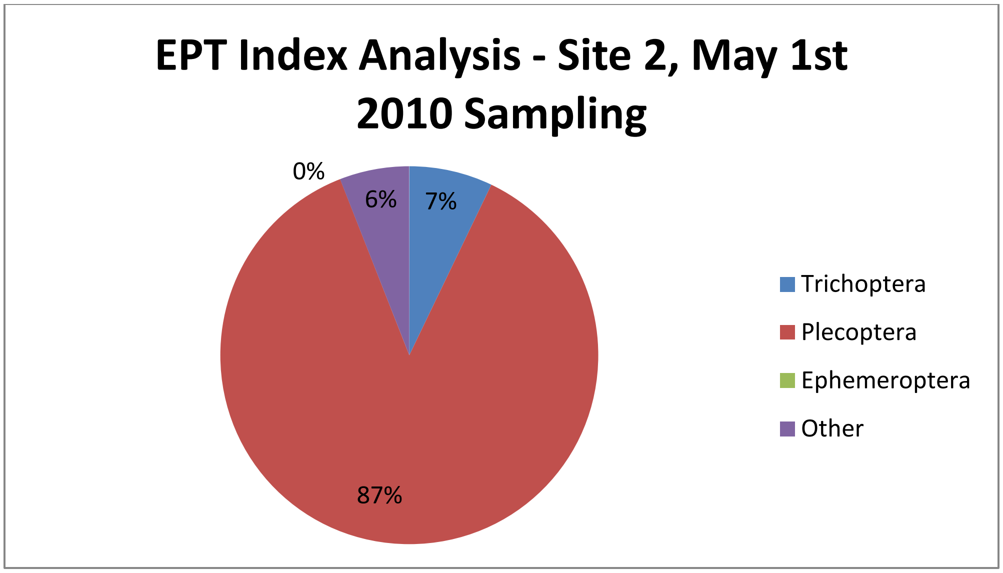

Figure A2. A pie chart displaying EPT Index analysis for 6/1/2010 sampling.

EPT Index = 4
This indicates the water quality for Site 2 is poor.

Site 5

Table A3. Macroinvertebrates collected at Site 5 on 6/1/2010.

Macroinvertebrate (*Family taxa)*	**Counts**
Decapoda	1
Plecoptera Leuctridae	11
Diptera Chironomidae	243
Trichoptera Rhyacophilidae	1

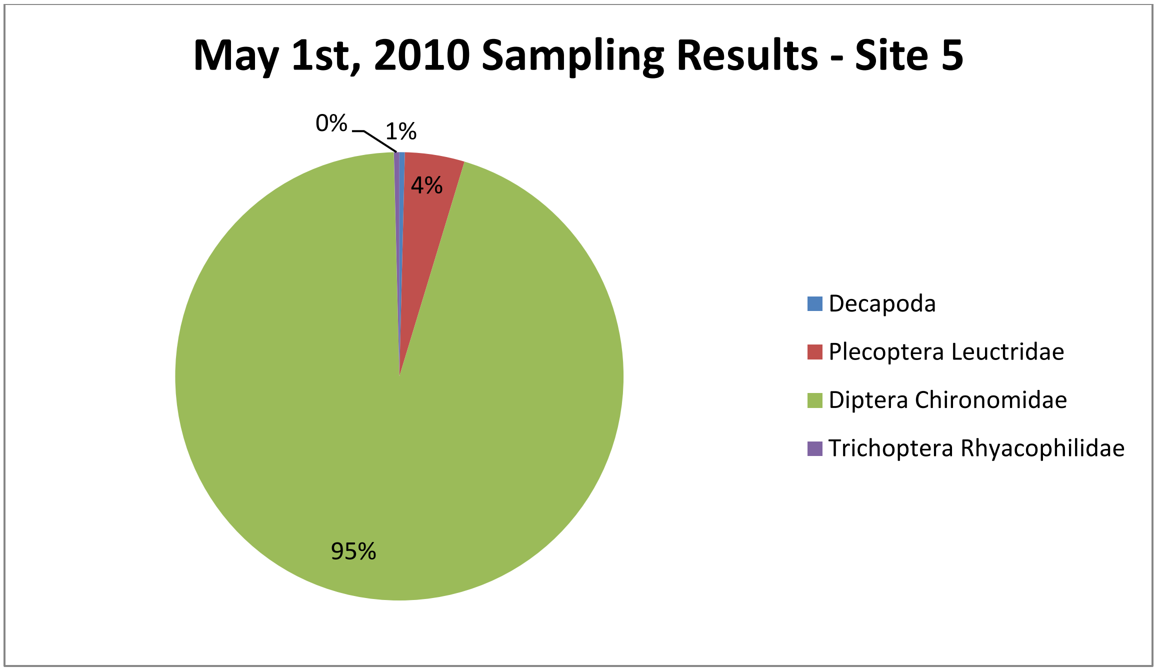

Figure A3. Pie chart displaying percentages of Macroinvertebrates from Site 5.

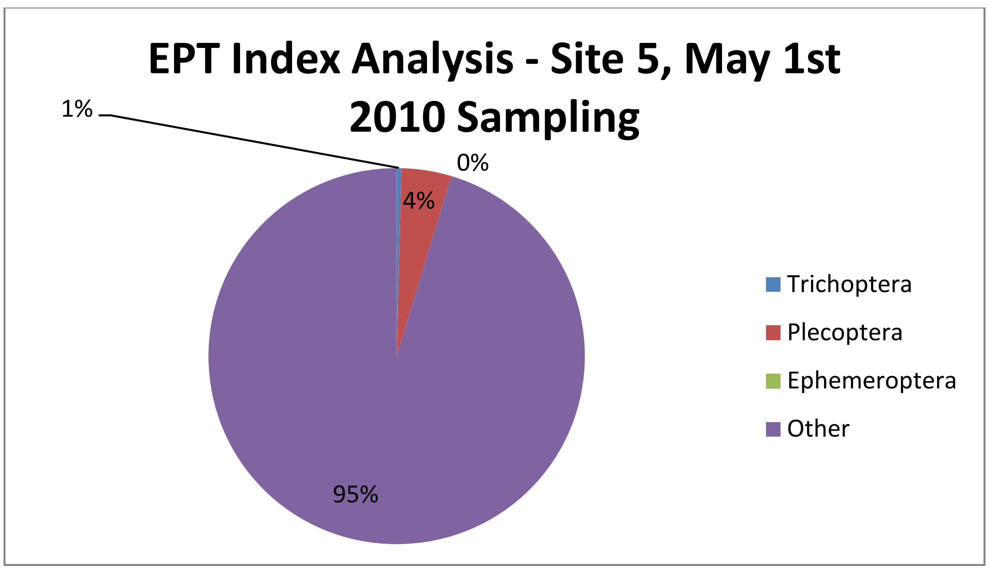

Figure A4. A pie chart displaying EPT Index analysis for 6/1/2010 sampling.

EPT = 2
This indicates the water quality at Site 5 is poor.

The lack of diversity of any macroinvertebrates from this site is an indicator of poor stream health. Although the pH and alkalinity are normal at this site, the dominance of *Diptera Chironomidae* indicates the ecosystem still has not recovered. The high phosphorus levels at Site 5 and the abundance of "white slime" on the substrate may allow for populations of *Diptera Chironomidae* to thrive while eliminating habitat and nutrients for other macroinvertebrates.

Many families of *Trichoptera*, and *Ephemeroptera* use the substrate in streams as their habitat and *Trichoptera* use the substrate to attach casts to. The abundance of “white slime” covering the substrate may not allow these macroinvertebrates to thrive in this environment.

Site 7

Table A4. Macroinvertebrates collected at Site 7 on 6/1/2010.

Macroinvertebrate (*Family taxa*)	**Counts**
Plecoptera Perlidae	5
Plecoptera Leuctridae	38
Plecoptera Capniidae	118
Trichoptera Hydropsychidae	5
Trichoptera Philopotamidae	1
Trichoptera Rhyacophilidae	4
Trichoptera Polycentro-podidae	8
Megaloptera Sialidae	1
Megaloptera Corydalidae	2
Diptera Simuliidae	8
Diptera Chironomidae	6
Diptera Tipulidae	1
Ephemeroptera Ameletidae	4
Ephemeroptera Ephemerellidae	2

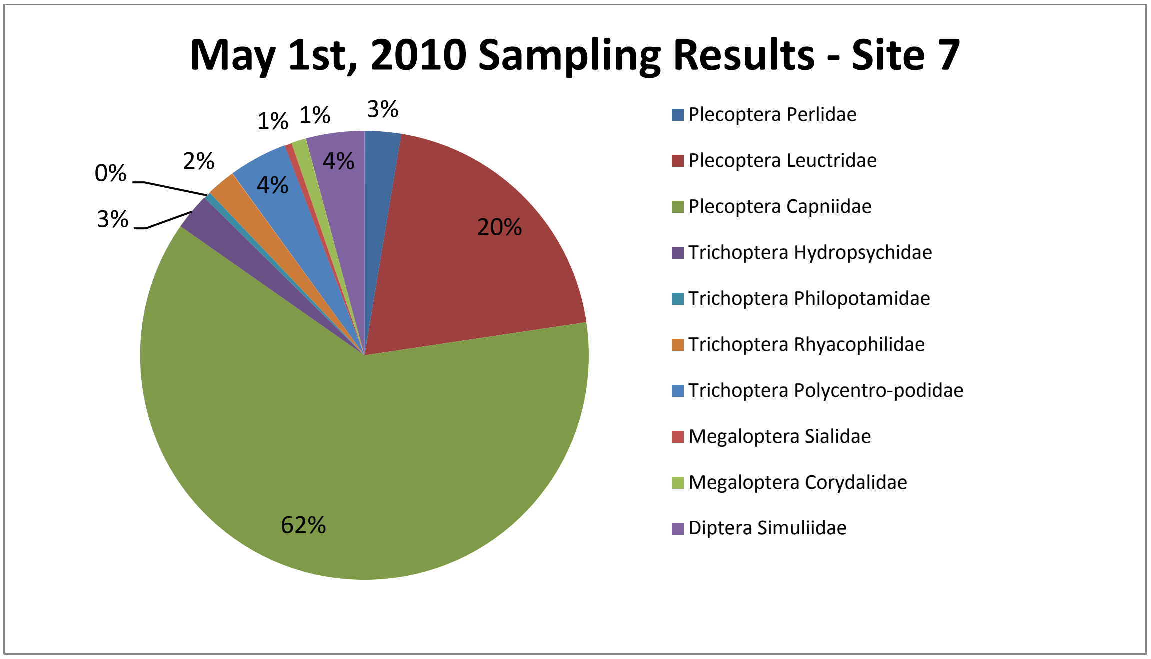

Figure A5. Pie chart displaying percentages of macroinvertebrates from Site 7.

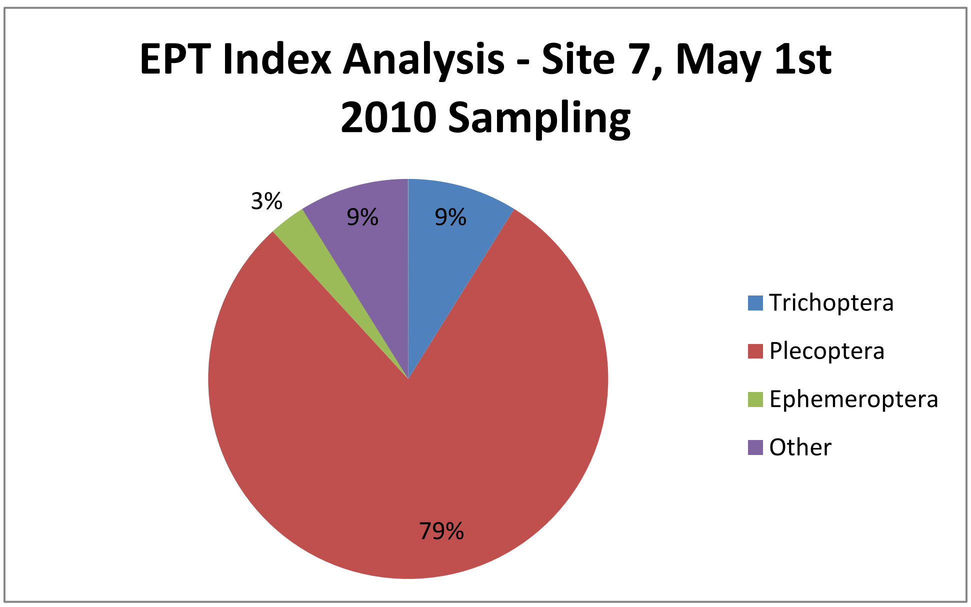

Figure A6. Pie chart displaying EPT Index analysis for 6/1/2010 sampling.

EPT = 9
This indicates that the water quality for Site 7 is fair.

At Site 7 there was the highest amount of diversity within the EPT Index and all other macroinvertebrates. Site 7 was the furthest downstream site from BCAPTS where samples were taken. The high amount of diversity at this site indicates that the stream ecology in Buffalo Creek is beginning to recover.

June 4th, 2010 Macroinvertebrate Sampling.

During this sampling it was partly cloudy and around 75 °F in the morning. All samples were collected and placed into large buckets for each site. The macroinvertebrates were taken back to the lab and were sorted and identified immediately after arrival using a macroinvertebrate identification guide (Water ActionVolunteers, 2007). The samples were then preserved with 100% ethyl alcohol and water. The samples were then looked at again by Professor Matthew McTammany to confirm the correct identifications were assigned.

Site 2

Table A5. Macroinvertebrates collected at Site 2 on 6/4/2010

Macroinvertebrate (*Family taxa)*	Counts
Decapoda	2
Trichoptera Rhyacophilidae	2
Plecoptera Capniidae	31
Plecoptera Leuctridae	20
Diptera Simuliidae	9

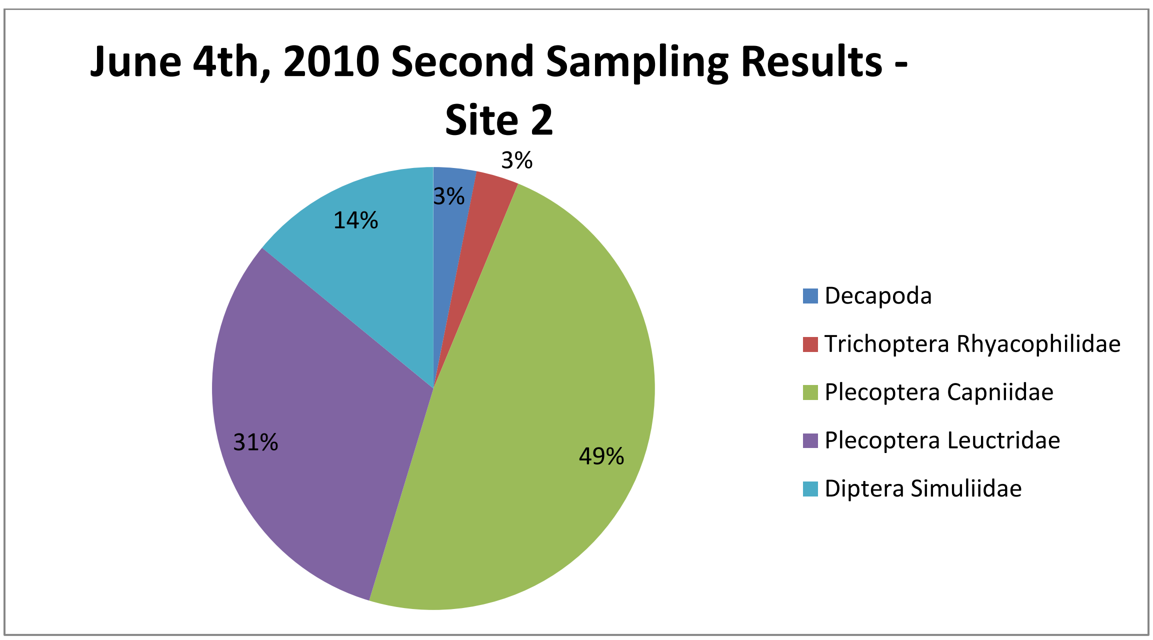

Figure A7. Pie chart displaying percentages of macroinvertebrates from Site 2.

Although there is a high number of *Plecoptera* found at Site 2, this does not indicated a healthy stream system. There are *Plecoptera* and *Trichoptera*, such as these species, that are resistant to acidic waters (McTammany, 2010). In order to have good water quality, there must be diversity of all three macroinvertebrate families.

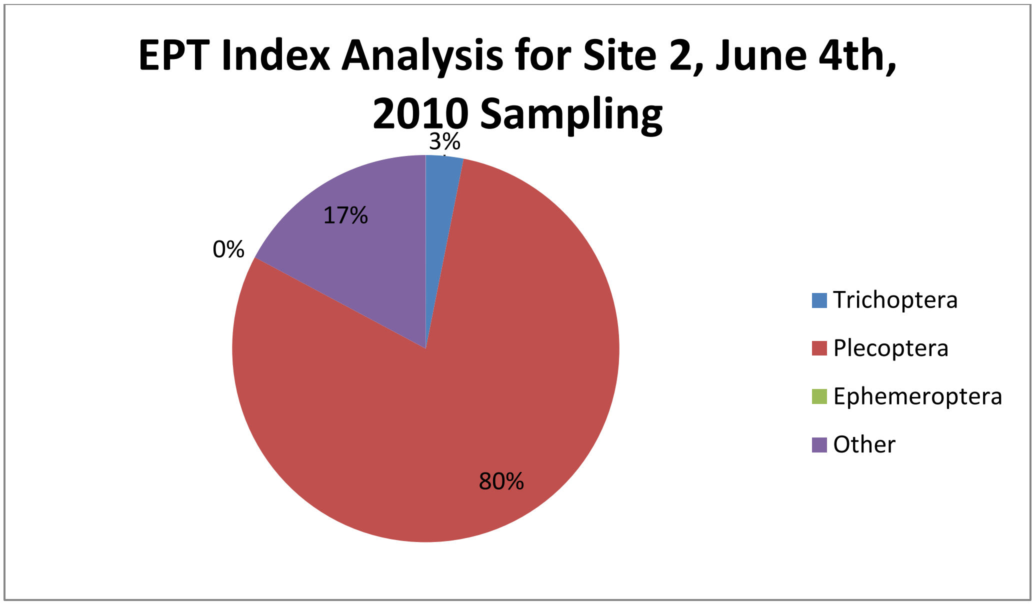

Figure A8. Pie chart displaying EPT Index analysis for 6/4/2010 sampling.

EPT = 3
This indicates the water quality at Site 2 is poor.

Site 5

Table A6. Macroinvertebrates collected at Site 5 on 6/4/2010.

Macroinvertebrate (*Family taxa)*	**Counts**
Trichoptera Rhyacophilidae	2
Trichoptera Hydropsychidae	4
Diptera Chironomidae	28
Plecoptera Capniidae	7
Plecoptera Leuctridae	126

During this sampling there was significantly fewer *Diptera Chironomidae* collected than the 5/1/2010 sampling causing the EPT Index to rise from 3 to 4. The *Diptera Chironomidae* could still be seen in the "white slime" and on the substrate when moved around. This sampling had a lot less "white slime" collected and this is where the *Chironomidae* were primarily pulled out of during the 5/1/2010 sampling. The lack of "white slime" collected and present in the stream may have had an effect on the total number collected in the sample. From direct observation of the stream bed, the *Chironomidae* still appear to have dominance over other organisms moving around on the substrate, despite the lack that were collected in the sample.

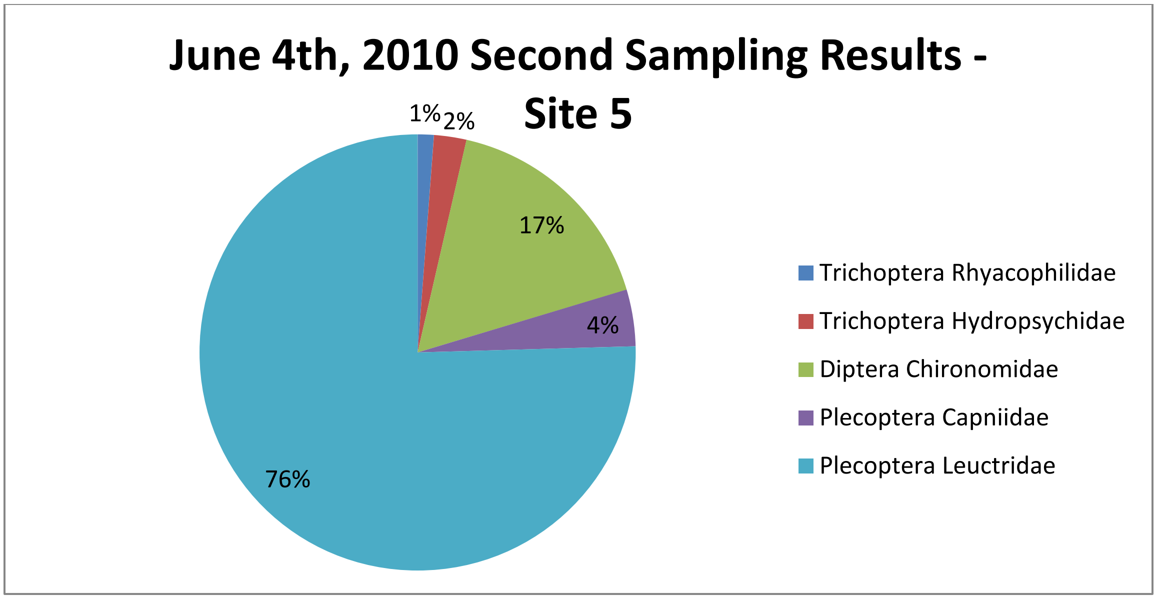

Figure A9. Pie chart displaying macroinvertebrate percentages collected at Site 5.

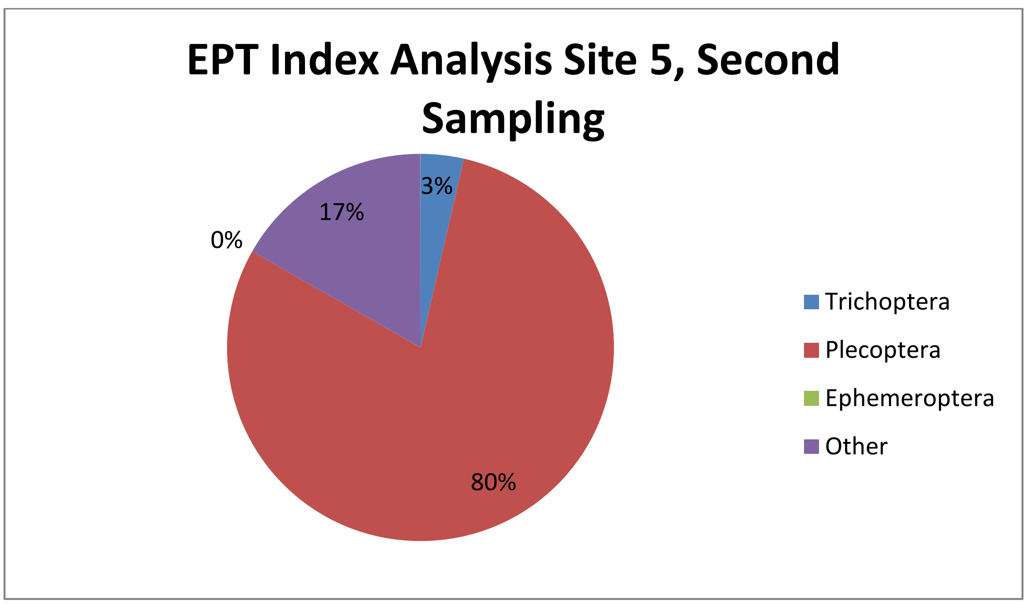

Figure A10. Pie chart displaying EPT Index analysis for 6/4/2010 sampling.

EPT = 4
This indicates the water quality at Site 5 is poor.

Site 7

Table A7. Macroinvertebrates collected at Site 7.

Macroinvertebrate (*Family taxa*)	**Counts**
Decapoda	1
Plecoptera Perlidae	2
Plecoptera Capniidae	44
Plecoptera Leuctridae	41
Trichoptera Rhyacophilidae	1
Trichoptera Hydropsychidae	2
Diptera Chironomidae	5
Diptera Simuliidae	3
Diptera Tipulidae	1
Oligochaeta	3

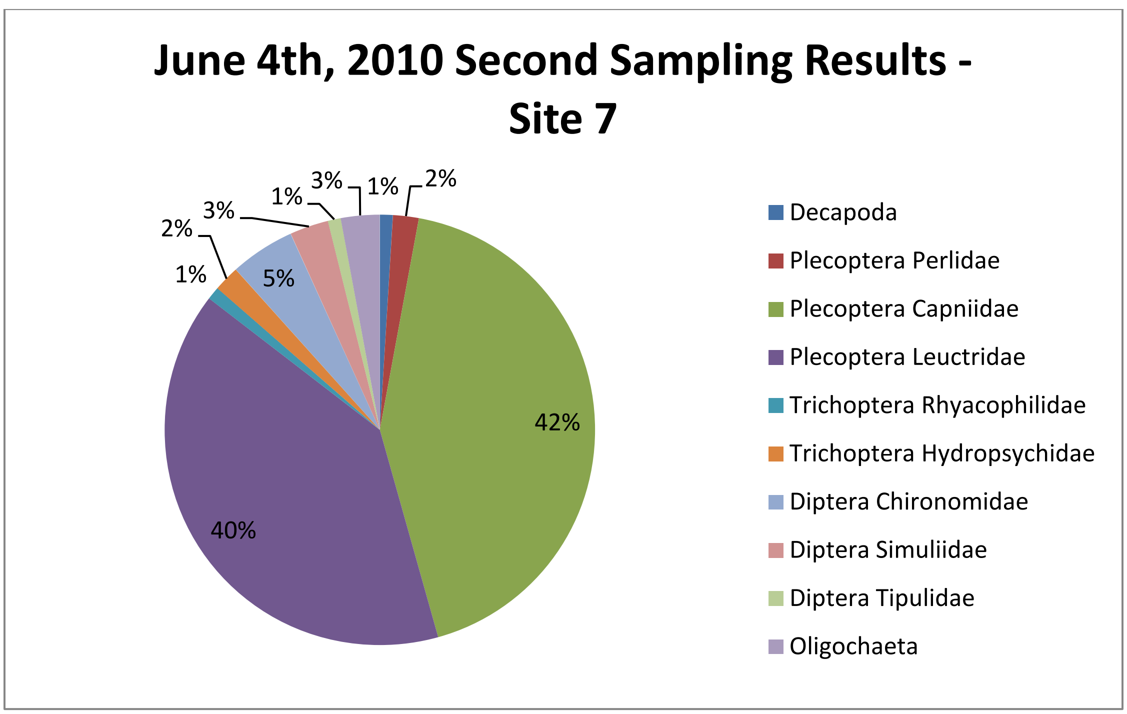

Figure A11. Pie chart displaying percentages of macroinvertebrates from Site 7.

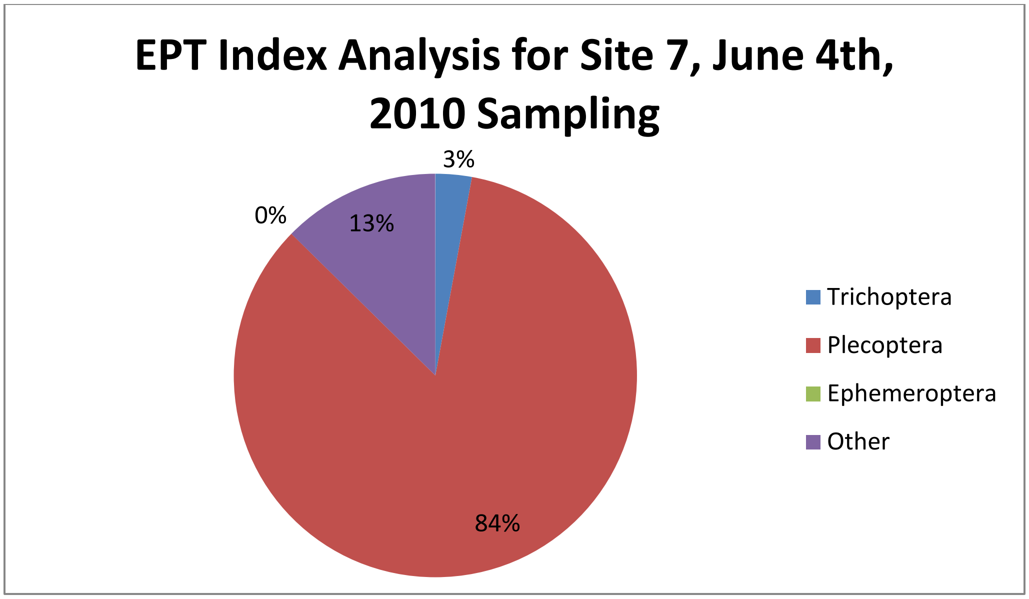

Figure A12. Pie chart displaying EPT analysis for 6/4/2010 sampling.

EPT = 5
This indicates the water quality for Site 7 is poor.

For Site 7, the 5/1/2010 sampling yielded an EPT of 7 indicating the water quality for Site 7 was fair. The value of 9 for this EPT Index is on the verge of the minimal rating a stream can have (EPT Index = 7) for a water quality rating of fair. Because the EPT was on the line between fair and poor, it is understandable to see a poor water quality rating for Site 7. Regardless, there is still the highest diversity of macroinvertebrates and other insects found at Site 7 indicating that the stream is moving towards a healthier ecosystem. There could have been less diversity of *Ephemeroptera*, *Plecoptera*, and *Trichoptera* because the sample could have corresponded to a time right after these organisms moved from the larval stage to the adult stage.

Appendix B

Cation and Anion Data

Table B1. Cation and anion concentratons (mg/L) of Buffalo Creek samples taken on 6/15/2010.

Concentration	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7
fluoride	bdl	bdl	0.11	0.14	bdl	0.19	bdl
chloride	0.82	0.68	1.2	1.4	1.0	1.1	0.83
bromide	bdl	bdl	bdl	bdl	bdl	bdl	bdl
nitrate	bdl	bdl	0.12	bdl	bdl	0.39	0.34
phosphate	bdl	bdl	bdl	10	3.2	0.28	bdl
sulfate	2.3	5.0	6.0	4.0	3.9	4.6	6.4
sodium	0.39	0.4	0.49	0.55	0.52	0.44	0.49
ammonia	bdl	bdl	bdl	bdl	bdl	bdl	bdl
potasium	0.13	bdl	0.21	0.82	0.41	0.33	0.43
magnesium	0.05	0.14	0.27	2.7	0.87	0.40	0.50
calcium	0.05	0.37	9.9	47	28	4.9	1.4

bdl = below detection limit

Table B2. Cation and anion concentratons (mg/L) of Buffalo Creek samples taken on 7/12/2010.

Concentration	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7
fluoride	nd	0.17	0.12	nd	0.35	0.35	0.21
chloride	nd	0.95	1.6	nd	3.9	3.6	1.6
bromide	nd	bdl	bdl	nd	bdl	bdl	bdl
nitrate	nd	0.52	0.51	nd	0.57	0.58	1.2
phosphate	nd	bdl	bdl	nd	1.55	bdl	bdl
sulfate	nd	1.1	15	nd	3.4	6.2	8.7
sodium	nd	0.48	0.79	nd	0.58	0.46	0.65
ammonia	nd	bdl	bdl	nd	3.83	bdl	bdl
Potassium	nd	0.30	0.50	nd	1.4	0.34	0.75
magnesium	nd	0.05	0.88	nd	0.43	0.45	0.56
calcium	nd	0.02	24	nd	11	9.5	1.9

nd = no data, bdl = below data limit