# Water Quality Assessment in the Blackwater Creek Watershed

Freshwater Ecology 375 A

Spring 2010

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## Abstract

The purpose of this study was to assess water quality in the Blackwater Creek Watershed, and determine if land use practices, particularly urbanization, have had a significant impact on the water quality of streams in the watershed. In order to obtain a thorough representation of stream water quality, we examined three parameters: physical, chemical and biological, including macroinvertebrates and fish. The field experiments were conducted at seven different sampling sites, in seven different subwatersheds, that represent different land use areas. Through collaboration and interpretation of experiment data, it was concluded that urbanization does have a significant impact on water quality, but that in urbanized areas with best management practices (BMP's) present the impacts of urbanization on water quality were to a lesser degree. In order to improve the water quality in the Blackwater Creek Watershed we proposed the implementation of varying BMP practices, and the creation of programs to help raise awareness on issues related to water quality in the Blackwater Creek Watershed.


## Introduction

The Blackwater Creek Watershed is located in south-central Virginia at the bass of the Blue Ridge Mountains, and is bordered by the James River to the north, (Fitzsimmons 2006). The Blackwater Creek Watershed has a drainage area of about 42,000 acres (Figure 1), and this encompasses three municipal jurisdictions that manage the land throughout the watershed: Lynchburg City, Bedford County and Campbell County (Shahady 2006).

The region encompassing the Blackwater Creek Watershed consists primarily of rolling hills, streams, forest, crop land and increasing urbanization (Fitzsimmons 2006). The climate in this location is temperate, with long growing seasons, warm summers and more mild winters (Fitzsimmons 2006). The main type of rock formation present in this location is metamorphic rock, and sedimentary and igneous rock formations are also present; the soils here are typically fine-textured (Fitzsimmons 2006).

There are varying types of land use practices in the Blackwater Creek Watershed that include: Forest, Agriculture, Commercial and Residential (Figure 1). The western part of the Watershed, in Bedford County, is primarily made up of forested and agricultural land, and then

the eastern part which encompasses Lynchburg City and Campbell County is very urbanized (Fitzsimmons 2006). Although there is a portion of land in the Watershed that is still forest and agricultural, the western part of the Watershed is experiencing development pressures and farms are being purchased to build residential developments on (Fitzsimmons 2006).

The Blackwater Creek Watershed is divided into eight subwatersheds that all have varying degrees of land use. The first watershed that is located in the northwest portion of the watershed is Subwatershed BW-1 Upper Ivy (Figure 2). This subwatershed has a drainage area of 8882.3 Acres and has the least amount of impervious surface and development (Fitzsimmons 2006). The land here is composed of 53% forest, 42% agricultural, and 5% commercial (Table 1). Although this subwatershed has little residential land use, this is the portion of the watershed that is being threatened by residential development pressures (Fitzsimmons 2006).

The second subwatershed is BW-2 Middle Ivy (Figure 3), that has a drainage area of 12,222.6 acres (Fitzsimmons 2006). The landuse in the subwatershed is 45% forest, 35% agriculture, 14% commercial and 6% residential (Table 2). The subwatershed is mostly agricultural and forest but as in the case with the subwatershed BW-1 Upper Ivy, the area is experiencing development pressures (Fitzsimmons 2006). However, despite the development pressures that water quality and environmental health in this location is considered to be good (Fitzsimmons 2006).

The third subwatershed is BW-3 Lower Ivy (Figure 4), that has a drainage area of 2840.7 acres (Fitzsimmons 2006). The land use in the subwatershed is much different than the previous two subwatersheds, with 60% residential, 29% forest, 5% agriculture, 5% commercial and 1% high residential (Table 3). This subwatershed is heavily urbanized resulting in a large amount of impervious surface. There is also a greater stream flow, which is resulting in the alteration of

streams by means of erosion and channel widening (Fitzsimmons 2006). In addition stream banks are unstable, and one of the greater concerns facing this subwatershed is non-point source pollution (Fitzsimmons 2006).

The fourth subwatershed is BW-9 Lower Blackwater (Figure 5), this subwatershed has a drainage area of 2,180.1 acres (Fitzsimmons 2006). The land use here is composed of 44% residential, 34% forest, 18% commercial, 2% agriculture, and 2% high residential (Table 4). This subwatershed is similar to BW-3 Lower Ivy, with heavy urbanizations resulting in a large amount of impervious surface, also having greater stream flow which has altered the stream by means of erosions and channel widening (Fitzsimmons 2006). Non-point pollution is also a concern to this subwatershed.

The fifth subwatershed is BW-5 Burton (Figure 6), that has a drainage area of 3,812.3 acres (Fitzsimmons 2006). The land use in this subwatershed is 37% commercial, 31% residential, 23% forest, 7% agriculture and 2% high residential (Table 5). This subwatershed is experiencing similar impacts as the previous two watersheds, with high urbanization, increased impervious surface and greater stream flow (Fitzsimmons 2006).

The sixth subwatershed is BW-4 Dreaming (Figure 7), that has a drainage area of 2802.4 acres (Fitzsimmons 2006). The land use in this subwatershed is 36% residential, 25% commercial, 20% forest, 17% agriculture and 2 % residential (Table 6). In this subwatershed the substrate is made up of sediment primarily, with many unstable banks, with a high amount of underscuts and vertical banks with limited vegetation (Fitzsimmons 2006). The stream channel also travels through culverts that go under residential roads and highways (Fitzsimmons 2006).

The seventh subwatershed is BW-7 Tomahawk (Figure 8), that has a drainage area of 5,231.1 acres (Fitzsimmons 2006). The land use in the subwatershed is 37% commercial, 27%

agriculture, 21% forest, and 15% residential (Table 7). This subwatershed is characterized by having housing and new development present, stable banks leading to less stable banks, and the stream travels through culverts (Fitzsimmons 2006). There is another subwatershed in the Blackwater Creek Watershed which is BW-8 Middle Blackwater, but this subwatershed was not included in the study conducted.

The purpose of this study was to examine water quality in seven of the Blackwater Creek subwatersheds, in order to determine the impact of land use practices on water quality. Studies on water quality in the Blackwater Creek Watershed have been conducted by the Lynchburg College Freshwater Ecology class from 2003-present and they have found conclusive evidence on the impacts of different land use practices, like urbanization, on water quality.

For the first study year, 2003, the class determined that there was a correlation between water quality and land use practices, when they used chemical and physical analysis. The study showed that there were high levels of phosphorous and nitrogen, that exceeded maximum levels set, and this was evident in urbanized locations including Dreaming Creek, the Cracker Barrel location and Jefferson Forest ( ENVS 375, 2003). In addition, their study showed that Chaffin Farm, located in the BW-1 Upper Ivy subwatershed, had the best water quality. They attributed this to BMP practices in this location including fences, and vegetative buffer and also this location had a high number of species for the EPT test (ENVS 375, 2003). Although this study indicated that increased urbanized areas had higher nutrient levels, their study primarily relied on chemical analysis which is really only good at showing nutrient levels for that one day, in order to find out the true impact of urbanization on water quality through chemical analysis, chemcical testing on streams would have had to be done over a longer period of time.

The second study on water quality in the Blackwater Creek Watershed was conducted by the Freshwater Ecology class in 2004. From this study the researchers discovered that Chaffin Farm had the best water quality due to BMP practices that they had in place including cattle rotation and riparian buffers (ENVS 375, 2004). The class also determined that Rock Castle Creek and Dreaming Creek had the worst water quality, and they attributed this to the urbanization in the area (ENVS 375, 2004).

The third study was conducted in 2005, by the Freshwater Ecology class. In their study they also found Rock Castle Creek and Dreaming Creek to exhibit the worst water quality. Then in the study conducted in 2006 by the Freshwater Ecology class, they determined that locations where there were construction practices with little buffer had poor water quality, and then locations where there was no construction practices and good buffers in place had better water quality (ENVS 375, 2006). A site that they saw as particularly concerning was Rock Castle Creek, that had a considerable amount of construction and a loss of riparian zone.

The study in 2008 was favorable to Chaffin Farm exhibiting the best water quality and Rock Castle Creek exhibiting the worst water quality, but they also arrived at other conclusions regarding streams in the Blackwater Creek Watershed. The class determined that Hollins Mill had better water quality, evident by looking at macroinvertebrate populations and fish population (ENVS 375, 2008). This was not what was expected, but the level of water quality was likely affected by the BMP practices that were implemented at the Hollins Mill location.

It is evident through past studies that in locations where urbanization was higher, this usually led to decreased water quality in these locations. Urbanization is never ending and it has significant impacts on water quality. Widespread impacts on water quality due to urbanization today include: channelization, loss of riparian zone, sedimentation, nutrient runoff, and

impervious surfaces. Best Management Practices (BMPs) however help to counteract these effects, but if not done properly they become less efficient.

Over time society has found urbanization inevitable due to population growth and a demand for new aged buildings that are bigger and more advanced. While urbanization continues to bring convenience into everyday life it also has a number of consequences. Negative effects urbanization has on the environment include increased runoff, increased surface water, groundwater pollution, increased flooding, and decrease natural sewage treatment. Impervious surfaces and urbanization go hand in hand. Impervious surfaces include any type of structure that prevents water from infiltrating into the earth and into the underground water tables. Parking lots, sidewalks, roads and buildings are prime examples of impervious surfaces. Blocking infiltration disrupts natural groundwater recharge systems as well as increases storm water runoff which leads to sedimentation build up in streams and rivers.

Erosion can also be attributed to the impervious surfaces, specifically storm water runoff. Even areas that are less developed in rural settings can still contribute to degradation of water quality. Nutrient runoff poses to be a problem in rural settings due to the fertilizers that aid farmers grow crops. Nutrient runoff is a problem anywhere that excess phosphorous and nitrogen is added. This is not only a problem in rural settings, but on construction sites, when septic tanks leak and anywhere fertilizers are used for lawn care. Nutrient runoff can cause an increase in biomass of phytoplankton, which reduces dissolved oxygen. This can negatively affect macrophyte species and fish populations.

Sedimentation is another negative impact on water quality as a result of impervious surfaces. During storms rain water runs across impervious surfaces collecting small particles along its way, once in the stream or river the sediment settles onto the bottom of the stream,

overtime collecting so much sediment resulting in loss of habitat for aquatic species and reducing water clarity. Riparian buffer zones are essential to sedimentation control. The riparian buffer is a term used to describe the land adjacent to streams where vegetation is strongly influenced by the presence of water. These plants help to prevent sediment, nitrogen, phosphorus and other toxins from accessing the stream. The presence of trees and plants is crucial to stream quality.

Channelization is another negative impact on the quality of streams and rivers. Channelization is the modification of existing river channels. Channelization straightens and deepens rivers and streams so water will move faster, often interfering with the natural systems already in place. Rivers may be channelized for flood control, land drainage improvement, creation of new spaces for urbanization or agriculture, and maintenance or improvement of navigation. The impacts on the environment and the quality of water are often overlooked, but essential to humanity and should be treated with delicacy.

Based on the varying types and degrees of land use practices in the Blackwater Creek Watershed, urban development on the rise, and the understanding of urbanization impacts on water quality, this study was designed to determine if with increased urbanization there is a decrease in water quality. Our class hypothesizes that with increased urbanization there will be a correlating decrease in water quality, however if BMP practices are implemented we believe that the impacts of urbanization on water quality will be less. In order to get a thorough interpretation of water quality we used three different analysis: chemical, physical and biological, and based on these analysis we were able to determine water quality for different subwatersheds, compare to previous years and determine if urbanization impacts water quality.

**Figure 1. Land Use in the Blackwater Creek Watershed**

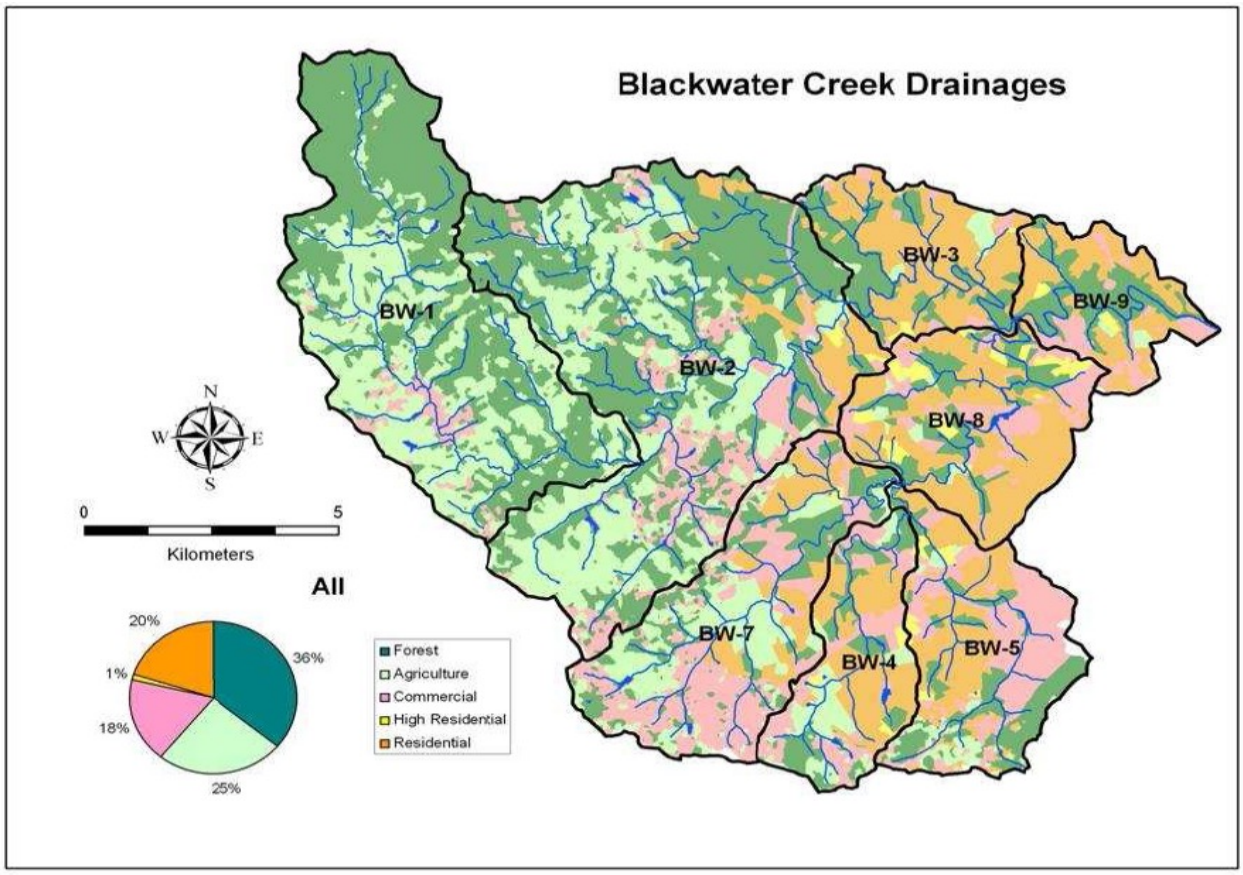


**Figure 2. Subwatershed BW-1 Upper Ivy**

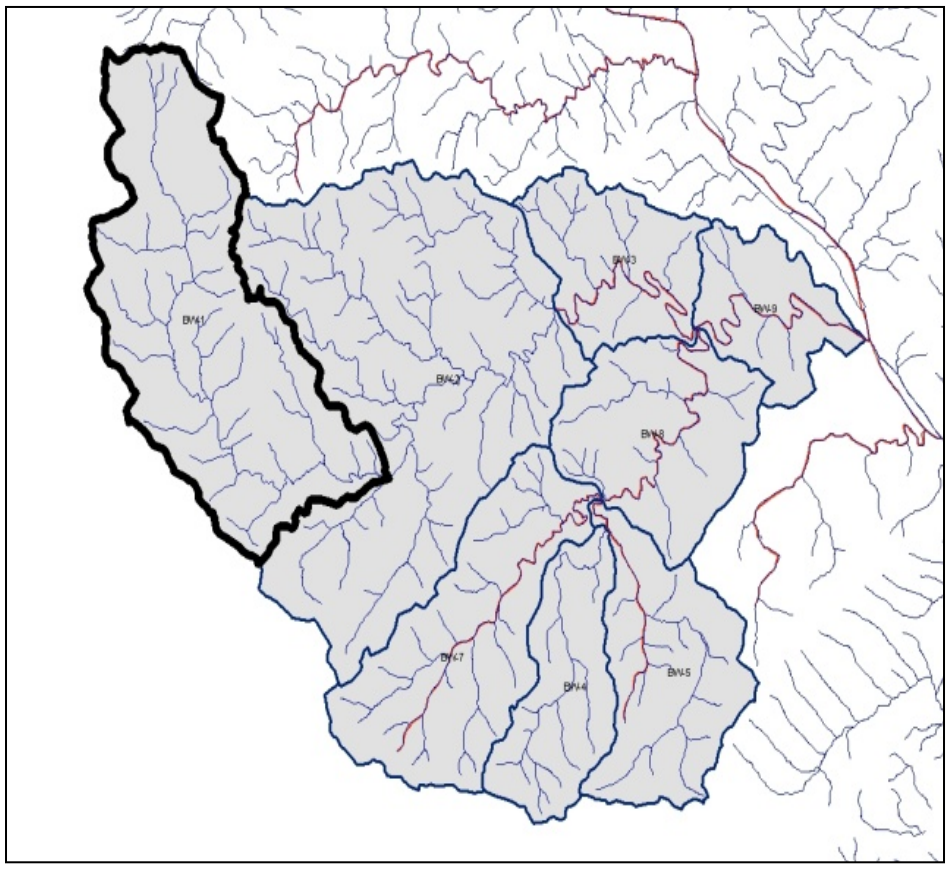


**Table 1. Land Use in Subwatershed BW-1 Upper Ivy**

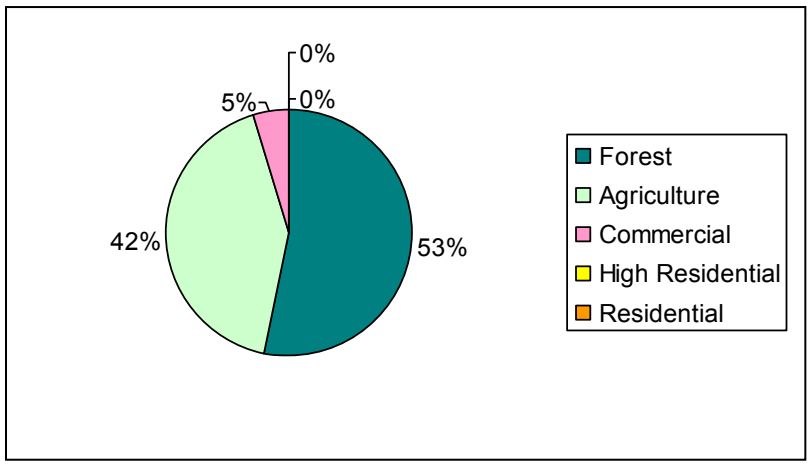


**Figure 3. Subwatershed BW-2 Middle Ivy**

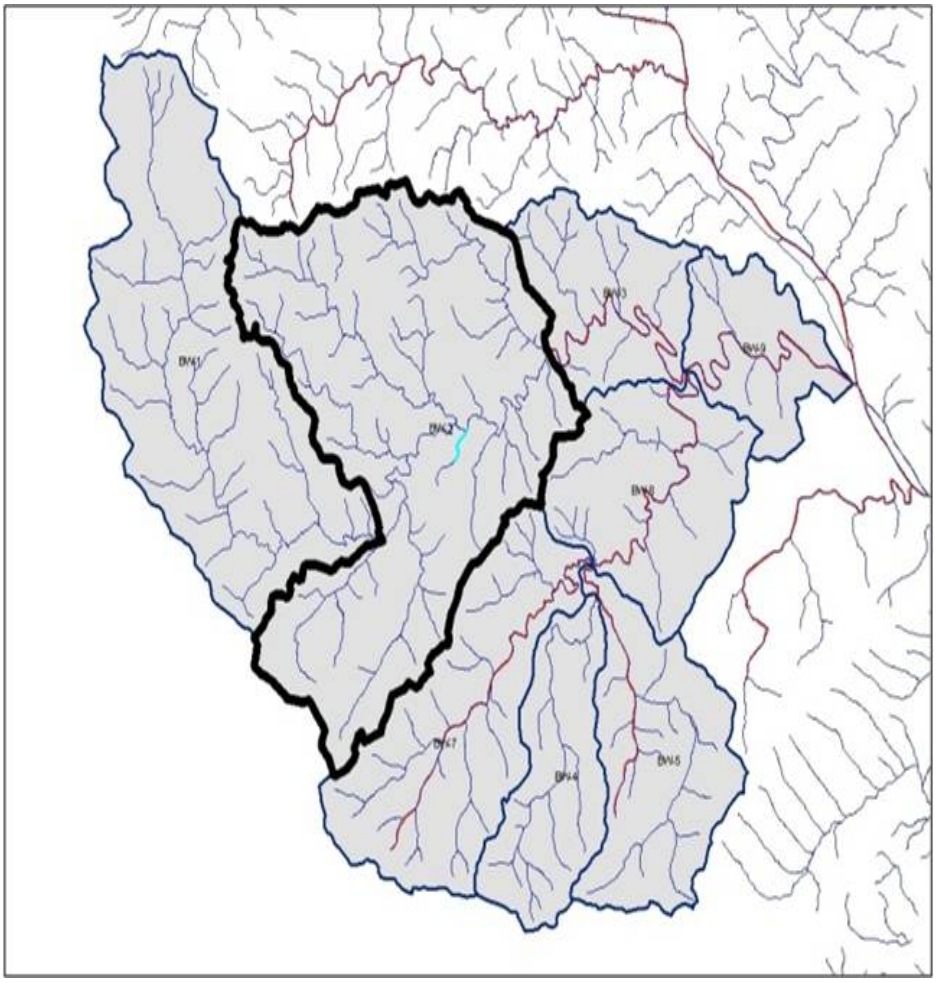


**Table 2. Land Use in Subwatershed BW-2 Middle Ivy**

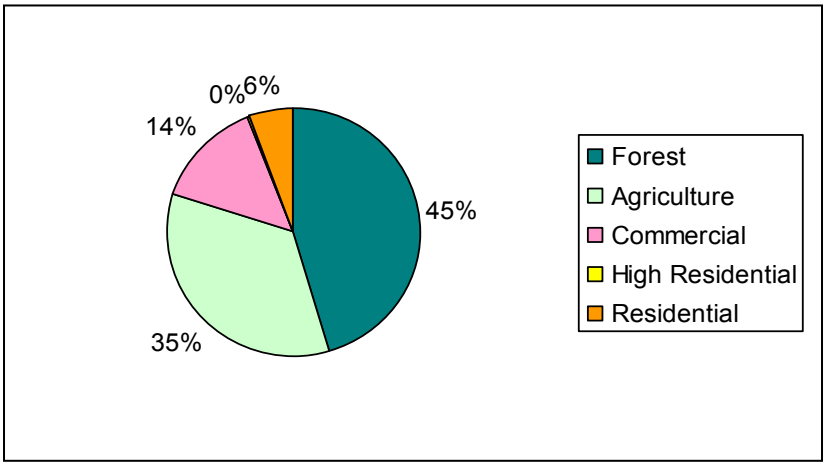


**Figure 4. Subwatershed BW-3 Lower Ivy**

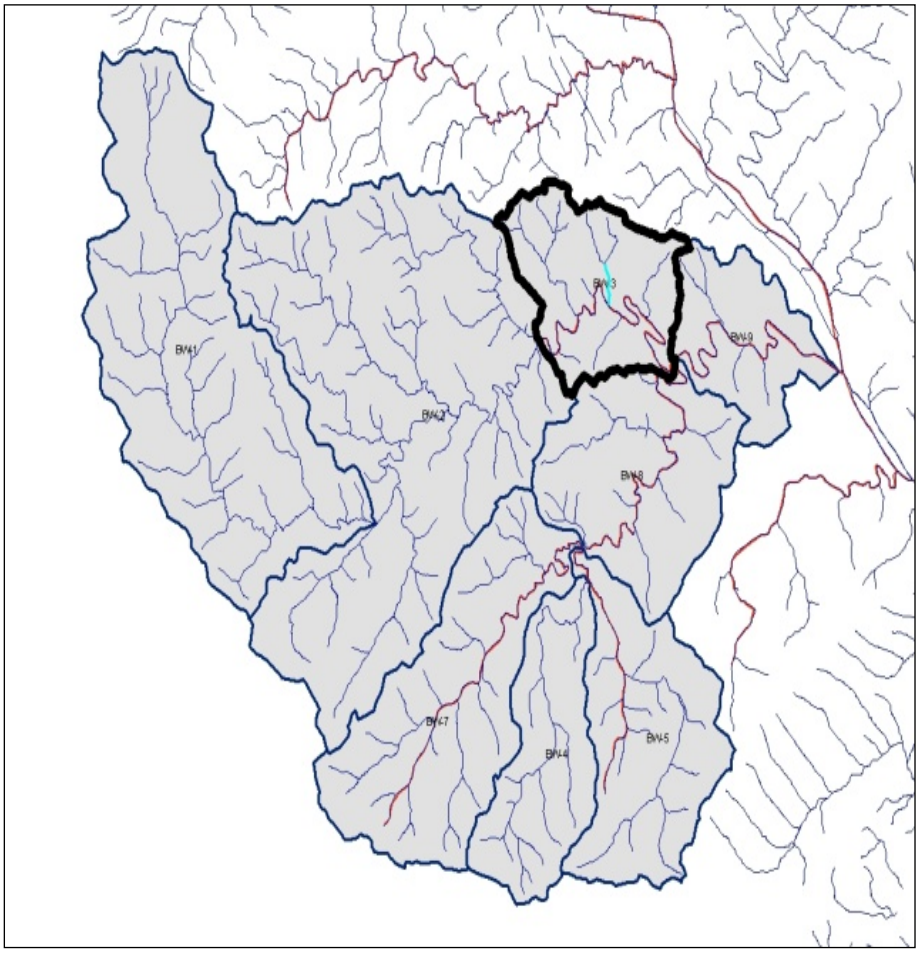


**Table 3. Land Use in Subwatershed BW-3 Lower Ivy**

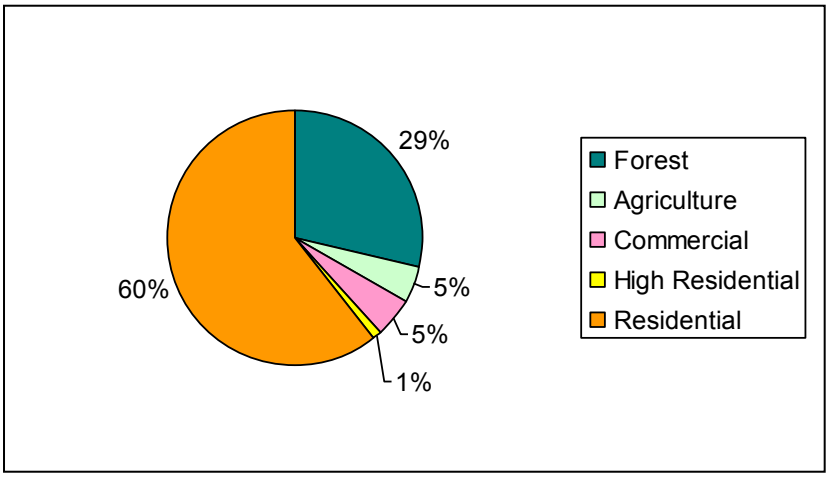


**Figure 5. Subwatershed BW-9 Lower Blackwater**

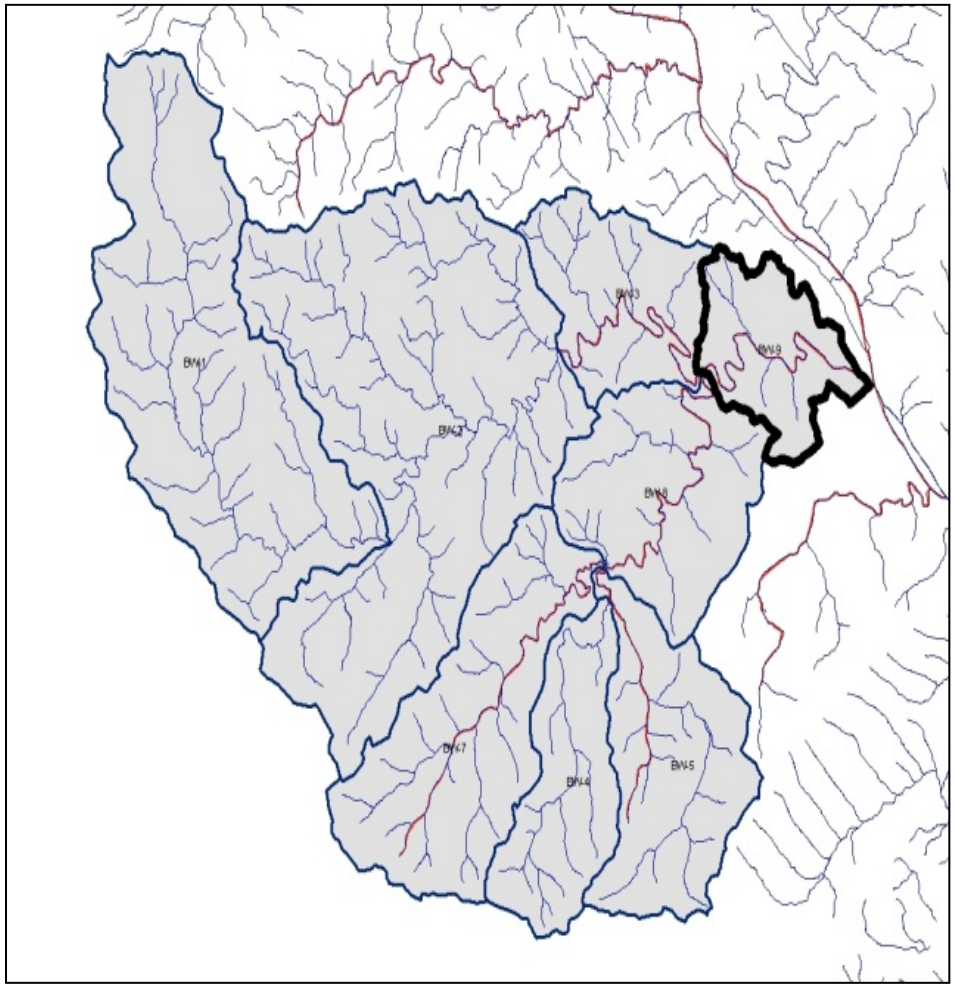


**Table 4. Land Use in Subwatershed BW-9 Lower Blackwater**

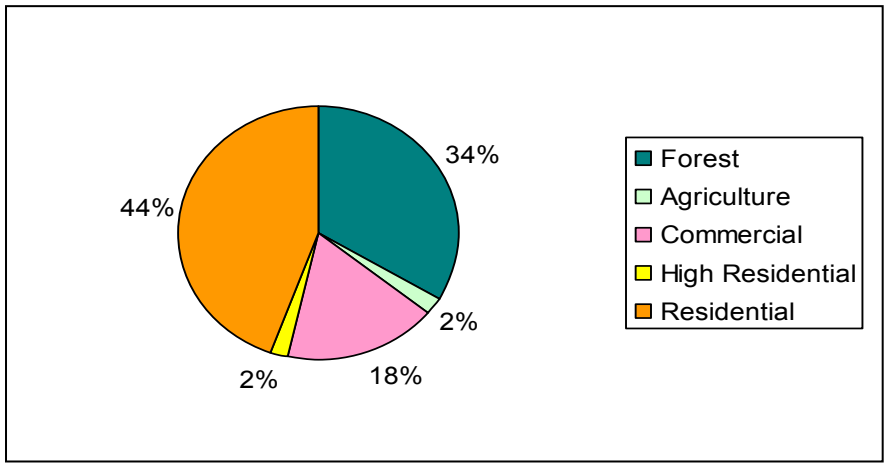


**Figure 6. Subwatershed BW-5 Burton**

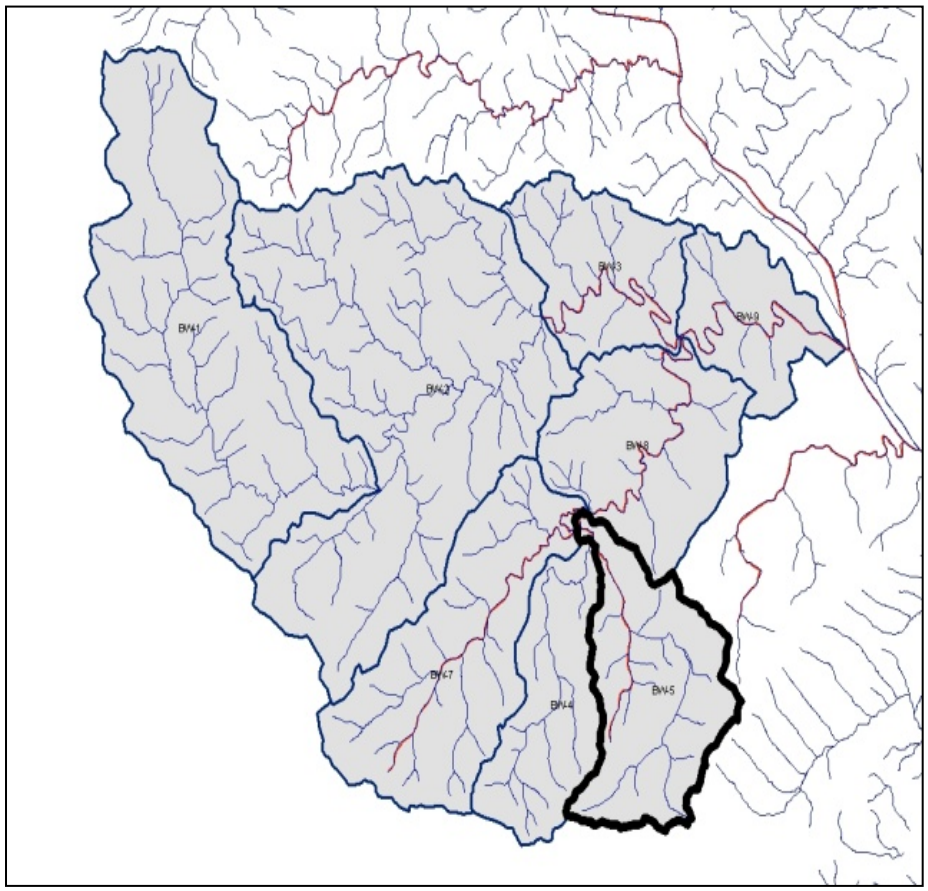


**Table 5. Land Use in Subwatershed BW-5 Burton**

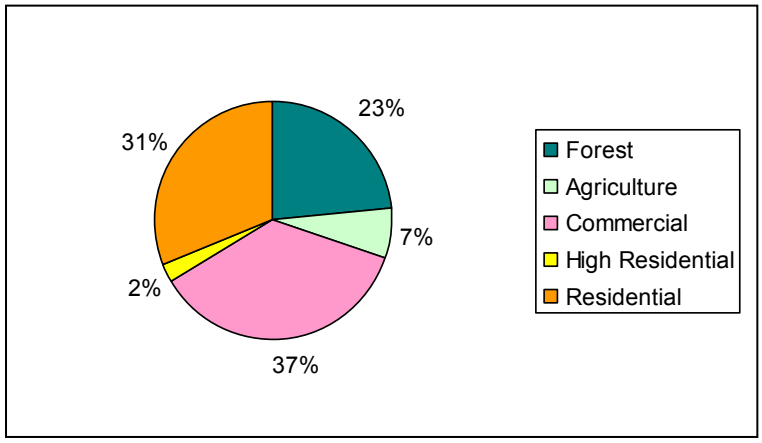


**Figure 7. Subwatershed BW-4 Dreaming**

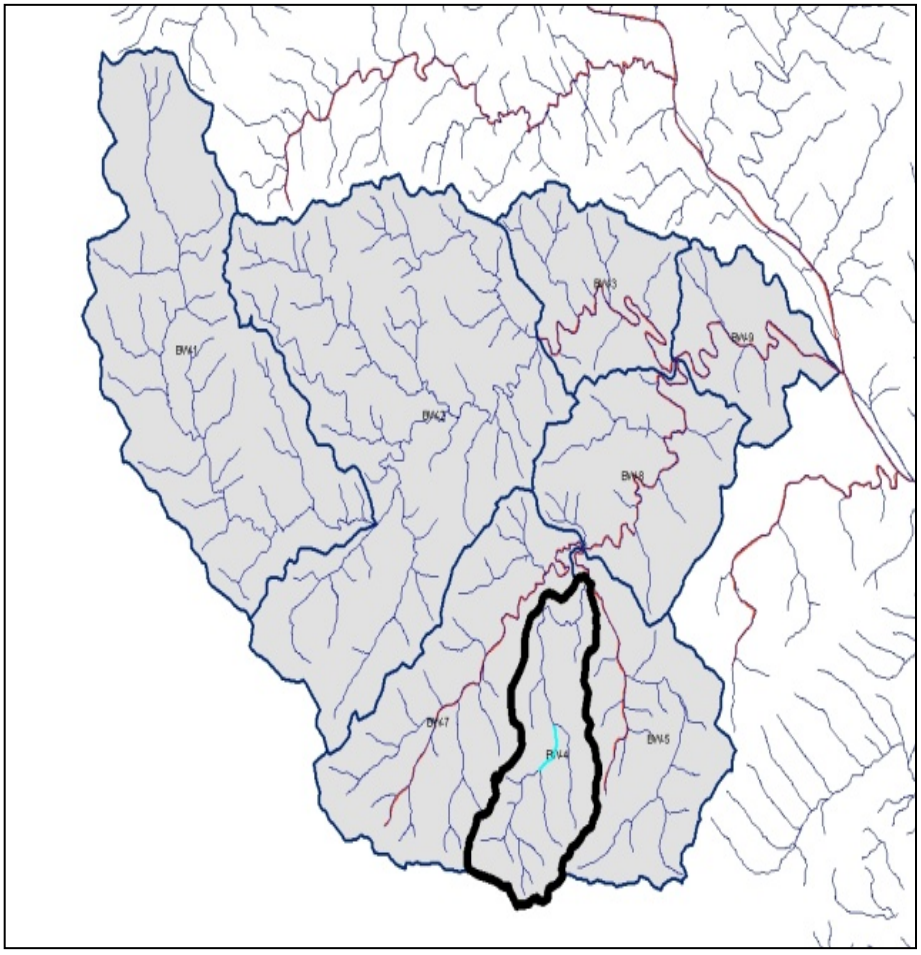


**Table 6. Land Use in Subwatershed BW-4 Dreaming**

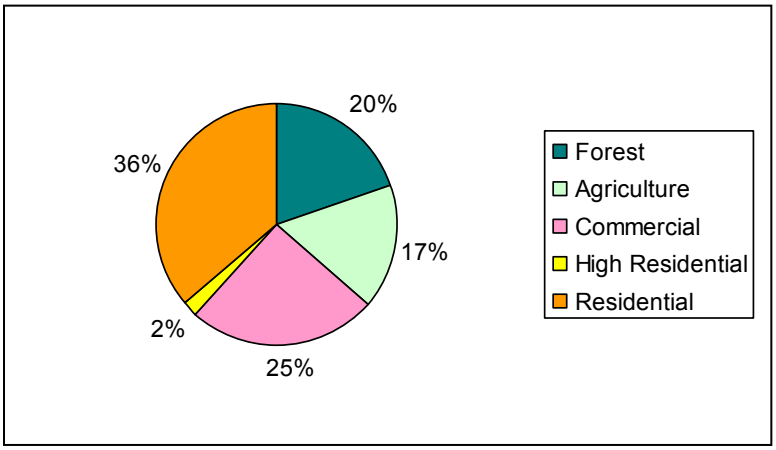


**Figure 8. Subwatershed BW-7 Tomahawk**

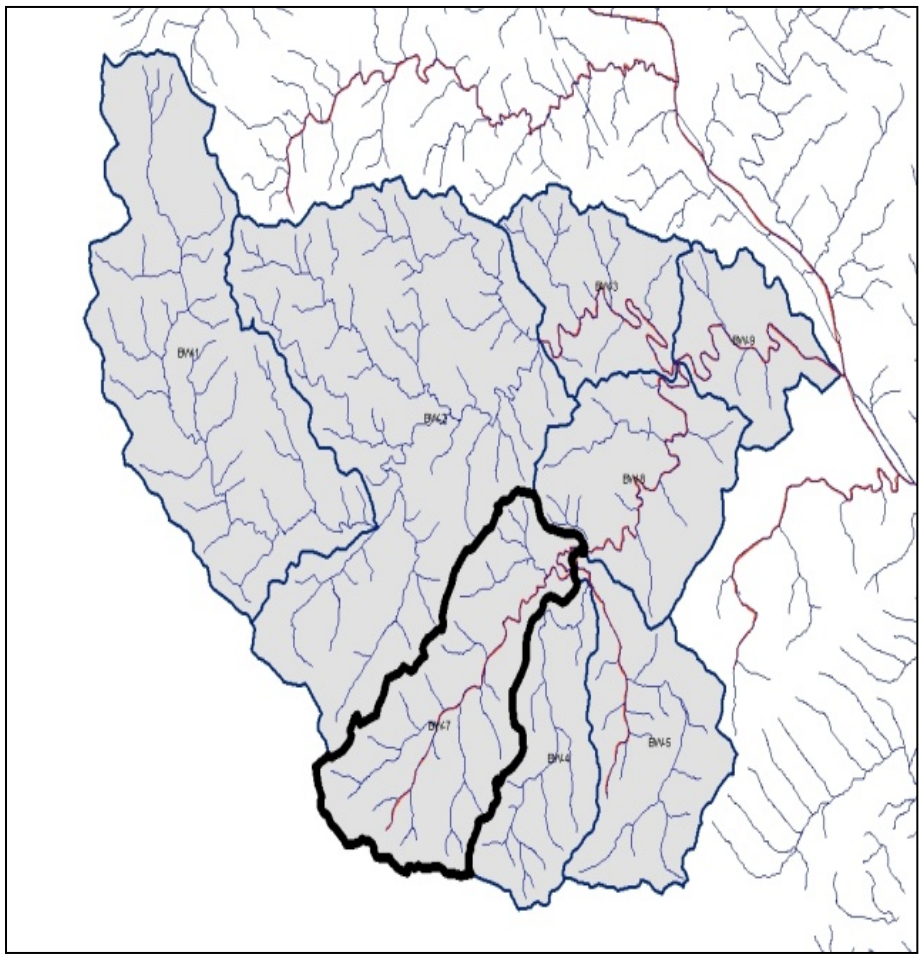
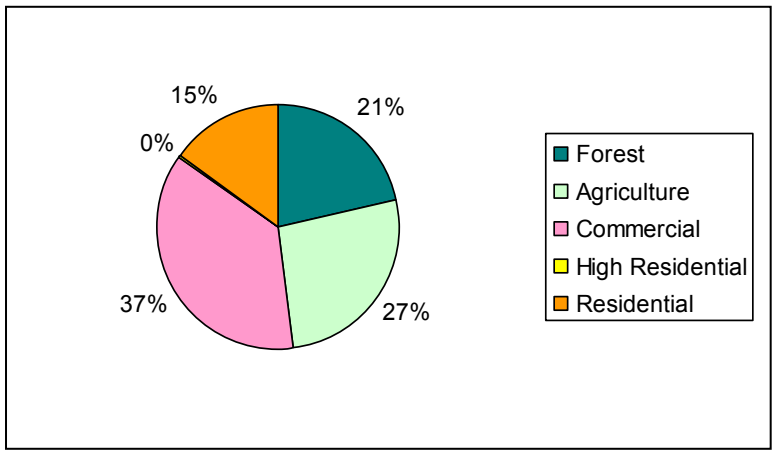


**Table 7. Land Use in Subwatershed BW-7 Tomahawk**



# Material & Methods

## Sampling

In order to attain an accurate interpretation of overall stream health we used four different types of analysis: physical, chemical, macroinvertebrate and fish. We used these four types of analysis to obtain information on different aspects influencing stream health to determine what parameters are being affected in the stream and obtain an overall picture of stream water quality. The stream sampling was conducted in the late winter - early spring, when the environmental conditions are the least extreme. This time of the year is good to sample in because if this study were conducted in the winter, fish populations would likely be low due to cold temperatures and if it were the summer the hot conditions may lead to higher stream chemical concentrations. In addition, conducting this research during the same time of year as previous studies on the Blackwater Creek Watershed assists in the validity of data comparison.

## Physical

The equipment used when testing was a laser Self leveler, tape measure, Tripod, a Garmin GPS, and a meter stick. The laser self leveler was used to ensure a constant height from one bank to the other and kept data consistent. The tape measure was used to record the distance at each increment and the distance from the tripod. A Garmin GPS was used to ensure correct sitting of locations and used to determine the distance to the bridge as well as used in the stream walk for distances. The tripod held the Laser Self leveler in place at the exact location given by the GPS, the Laser Self leveler recorded a specific height. The meter stick was used to elevate

the sensor for the Self leveler and record the height, depth, and length at specific points along one meter increments.

A physical stream assessment was an important way to determine the health of a stream. There were a number of different parameters that were the focus of the stream walks. These were very important to note because the conditions of these and any changes from past years can show how the streams health is improving or declining.

For conducting the stream walks a new method for analyzing streams was implemented called the Unified Stream Methodology (USM), which is becoming universally used throughout Virginia. Upon completing the USM form the effect of different parameters on the overall health of a stream can be determined.

The first step when arriving at the stream locations was to set up the tripod with the self level scanner secured to the top. The tape measure was attached to the tripod and expanded across the length of the stream. The self leveler was turned on along with the locator attached to the meter stick. Starting at the far bank of the stream the level indicator on the top of the meter stick was aligned with the self leveler on top the tripod. Then the measurements were taken of the height of the meter stick and the length on tape. This information was recorded and repeated consecutively at roughly one meter increments. When measuring in the water the water depth was recorded. When reaching the tripod the height of the tripod was recorded.

The next step was to perform the stream walk and take note of the channel condition, riparian buffers, in-stream habitat, and channel alteration. After noting the stream conditions based on the listed criteria, a USM form was completed with each criteria receiving a score based on how well the stream represented the different descriptions on the USM form. Notes were also taken to help provide reference later to describe why the stream scored as it did. When

determining the channel condition the steepness and slope of the banks, amount of erosion and the shape of the channel were all noted. When observing the riparian buffers we assessed them for 100 feet off of the side of each bank; for this step we had to note the size of the trees that bordered the stream, the amount of vegetation, the percent of tree cover, the amount of open/maintained lawns/pastures along the stream and the amount of impervious surface. The in-stream analysis included observations on pools, runs, and riffles in the stream as well as types of substrate, woody and leaf debris, the velocity, depth of the water, root mats, the shade, and the embedded level of the substrate. Pictures were also taken of the top and bottom of each reach and the banks on each side as well as any other predominant feature in the stream to give a visual record of the stream's physical condition. Notes were also taken on any other significant feature. After scoring each of these criteria their scores were entered into a spread sheet that gave each of the streams an overall score that reflected the health of the stream.

The USM river quality form was filled out according to the directions and the quality seen at the stream location. The reach is 30 times the distance to the width of the stream. Using a Garmin GPS the exact latitude and longitude location of the tripod was recorded then the distance to the bridge was recorded as a transect line. During the stream walk pictures were taken and in accordance with the USM sheet the quality of the reach was considered and recorded.

**Chemical**

The materials used to collect chemical data include, YSI-85 meter, used to obtain the temperature in ( $C^{O}$ ), dissolved oxygen and conductivity (uS), and the YSI-60 meter was used for gathering pH levels. Eight clean sampling bottles were brought to take water samples from the six sites and at one site, Hollins Mill Dam, two samples were taken. A spectrophotometer was used for testing absorbance. In addition we used a nitrate chemical testing kit and a phosphorus chemical testing kit.

On April 8, 2010 sites 1,2,4,6 and 7, were sampled and during sample collections at sites 4, 6 and 7 there was a rain event. Sites 3 and 5 were then sampled on April 15, 2010. Upon arriving at each site a water sample was gathered. This was performed by rinsing out the bottle with the water from the site and then filling the bottle about ¾ full with water from the stream site; the bottle was then labeled with the site location, the date the sample was gathered and the time of day. Next the YSI-85 was used to collect additional data, including: temperature, dissolved oxygen, and conductivity. One team member would stick the probe into the water and read off the numbers to the other team member who recorded the data. After the data was recorded the probe was taken out of the water and cleaned off with deionized (DI) water and properly put away. Using the same techniques we repeated the process with the YSI-60 to obtain pH levels. After sampling all the sites, the filled bottles of sample water were taken to a freezer for holding until nitrogen and phosphorous testing were conducted. The team tested the 7 water samples for phosphorus and nitrate. To test for nitrate the spectrophotometer was set to 655nm. The team made 5 standards of 10,5,2,1, and 0.5 mg/L. Once the standards were made they were placed in vials which then were placed in the spectrophotometer to read the absorbance values. Additionally, ammonia cyanurate reagent powder pillow was added to new vials for each water sample site to test the absorbance of the samples. Once the standards of absorbance had been collected a calibration curve was created on excel to obtain a y= equation to determine chemical concentrations.

To obtain phosphorus absorbance the spectrophotometer was set to 880nm. Again standards were created. Five standards of phosphate were created of 5,2,1,0.5, and 0.1 mg/L. Once the standards were made they were placed in vials, in then into the spectrophotometer to read each absorbance. The team then added PhosVer 3 phosphate powder pillow to vials filled

with sample site water to test the sample site water absorbance. After finding the absorbance of all the standards and the sites another graph was produced to determine the concentrations of the phosphate from the y=.

**Macroinvertebrates**

Collection of the macroinvertebrates was performed with a Hess Sampler and a Kick net. The Hess Sampler covers a surface area of 0.1 m^2 per sample. The Hess Sampler was used by first locating the riffle in a stream, which is the most suitable habitat for macroinvertebrates. The sampler was placed in the stream bed with the net facing downstream and the water screen facing upstream. The sampler was twisted and turned until the bottom was firmly in the stream bed. The area that was inside the sampler was stirred well, upturning all of the sediment and rocks inside. Organisms inside the area were uplifted and flowed through the net into a cup at the end of the sampler. After a thorough stirring, the sampler was removed from the water. Then the Kick net was unrolled and placed flush with the stream bottom while the rocks and sediment upstream were disturbed. Macroinvertebrates were uplifted, due to the disturbance, and flowed down the riffle into the kick net. After a thorough sampling, the net was lifted out of the water and the organisms were collected.

Macroinvertebrates were mainly sampled in riffles. At Peaks View Park no riffles could be found so the sampling was taken at a run. Samples were taken in riffles that had a large amount of rocks and riffles with a medium amount of rocks. Samples were taken in locations where the water was shallow, measuring at approximately one foot deep.

At each site two Hess samples were taken in addition to one kick net sample. Three replications were performed to ensure that a sufficient sample was collected. If just one sample was taken the population of macroinvertebrates may have been falsely represented for the given

area. Organisms from each sample were placed in sample bottles according to the site, sample number and sample method. Propanol was used to preserve the organisms until they could be identified. Once the team was ready to identify the organisms, the organisms were rinsed with deionized (DI) water and placed into a small dish with a small amount of DI water. Then using A Guide to Freshwater Invertebrates of North America by Voshell and a microscope, the organisms were identified and then sorted by family.

**Fish**

First the battery was installed into the back compartment of Electrofishing back pack and the compartment was closed. Then the team suited up into waders or tall boots. One member, who was trained in shocking, strapped on the Electroshocking back pack. Then all of the members except for the shocker carried nets, and two members carried buckets. When everyone was in the stream getting reading for the shocking, all nonshocking members stood behind the shocker. The Electrofishing back pack was then turned on, and shocking began with the shocking rod being held in the water in front of the shocker, and the shocking tail was in the water behind the shocker. The shocker could not bend more than 45 degrees or the device would shut down. The shocker moved upstream holding the trigger on rod to begin shocking; the shocker used slow sweeping movements with the shocking rod moving forward. Then the members with nets walked slowly behind the shocker to catch stunned fish. Once the fish were captured they were placed in buckets with water. After the fish were collected they were identified, each species counted and then the fish were released back into the stream.

The team shocked for thirty minutes at every location except Tomahawk Creek and Dreaming Creek. The team shocked for 45 minutes, and an extra 15 minutes at Tomahawk Creek because a sufficient numbers of fish for the data analysis was not be obtained. However at Dreaming Creek, a rainstorm forced us to stop shocking five minutes early for a total of 25

minutes. The measurements were standardized using the catch per unit effort (CPUE). In this situation the team wanted to multiply the quantity of fish at each site to equal a 60 min shock period. For all of the sites that were sampled for 30 minutes, the team multiplied the fish quantities by two. For Dreaming Creek fish quantities were multiplied by 2.4, and Tomahawk Creek by 1.33. The CPUE gave the most accurate data taking into account variations in shock times.

# Results & Discussion

## Physical Analysis Results

**Figure 10. Cross-section of Subwatershed BW-1 Upper Ivy: Richard Chaffin Farm**

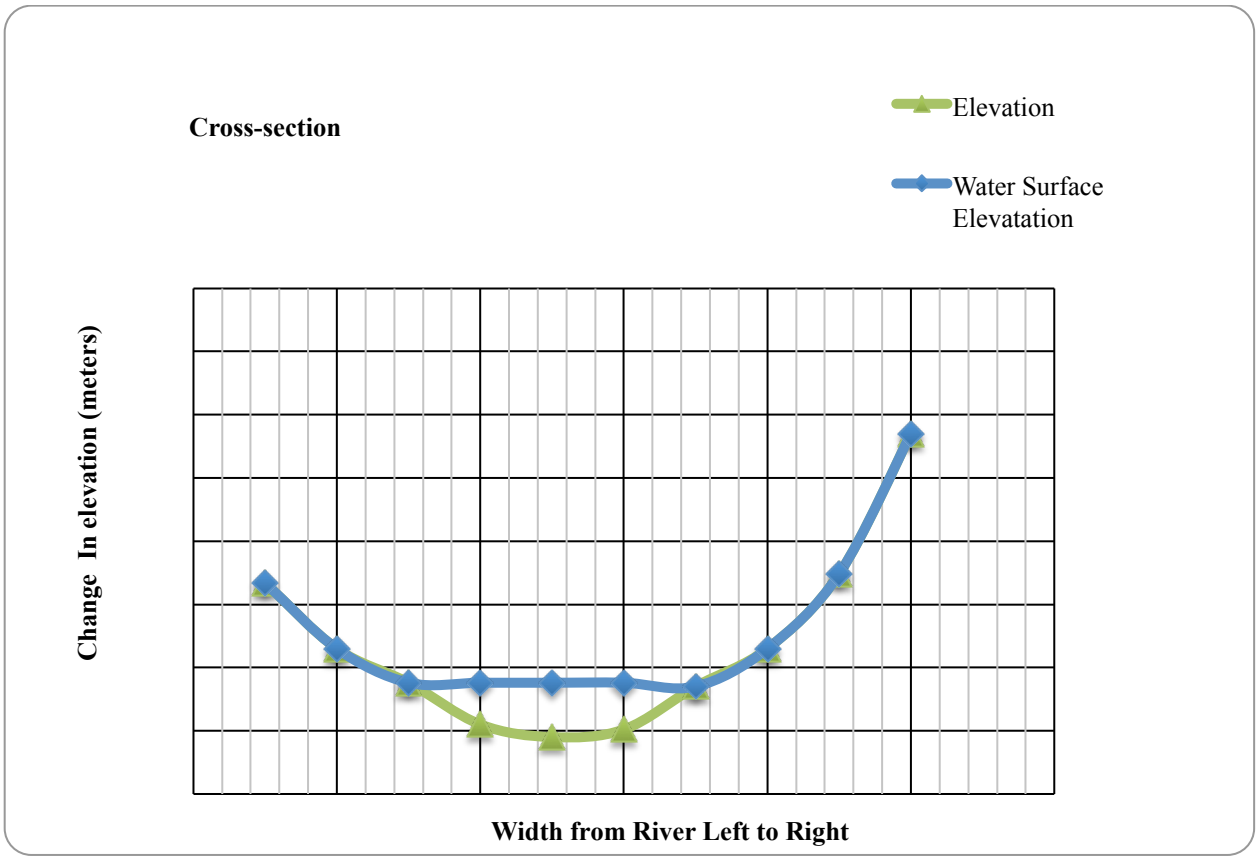



**Figure 11. Sample Site: Richard Chaffin Farm Image**

**Figure 12. Cross-section of Subwatershed BW-2 Middle Ivy: Hooper Road**

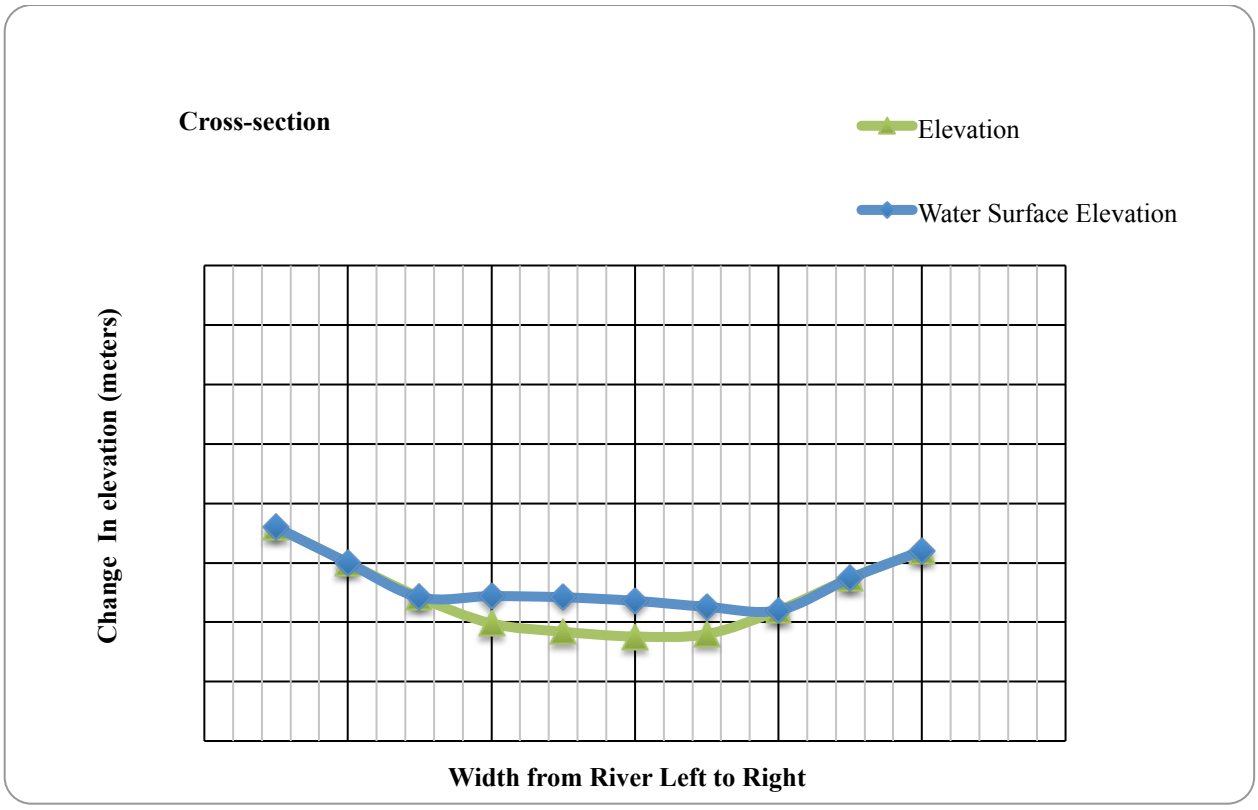



**Figure 13. Sample Site: Hooper Road**

**Figure 14. Cross-section of Subwatershed BW-3 Lower Ivy: Peaks View Park**

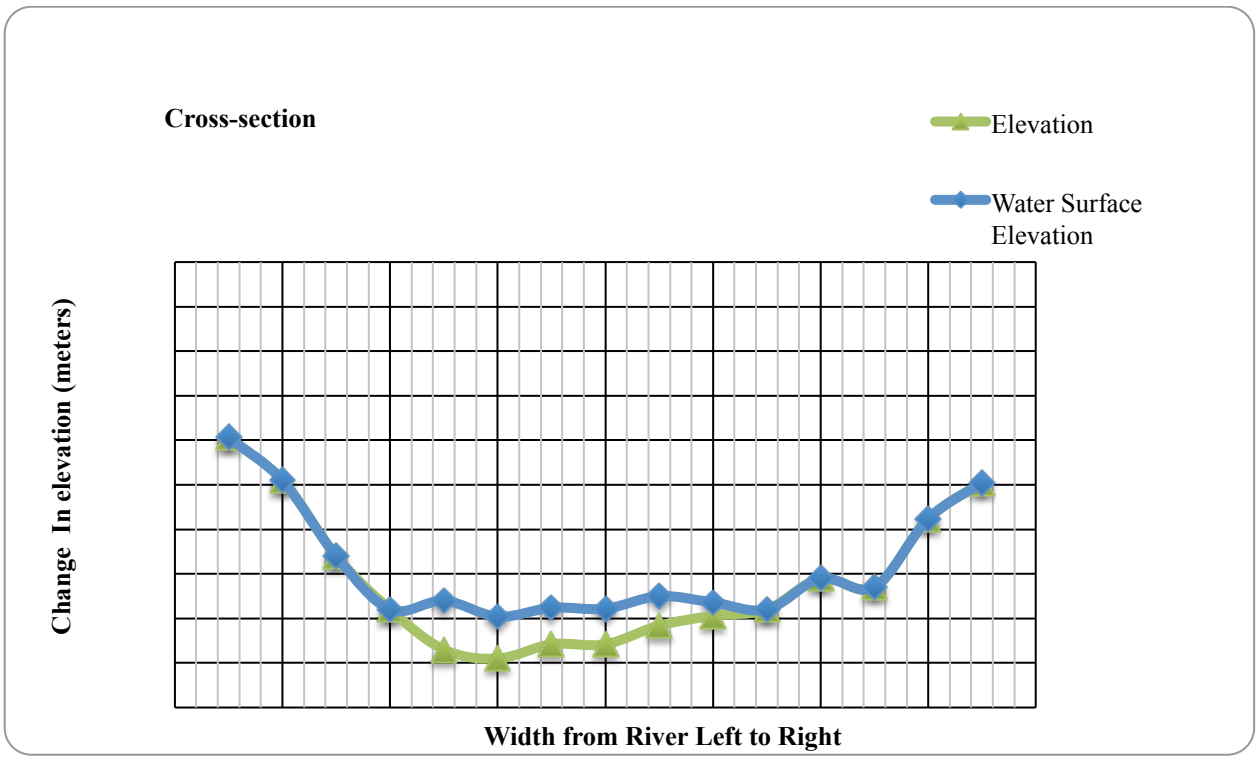



**Figure 15. Sample Site: Peaks View Park**

**Figure 16. Cross-section of Subwatershed BW-9 Lower Blackwater: Hollins Mill Dam**

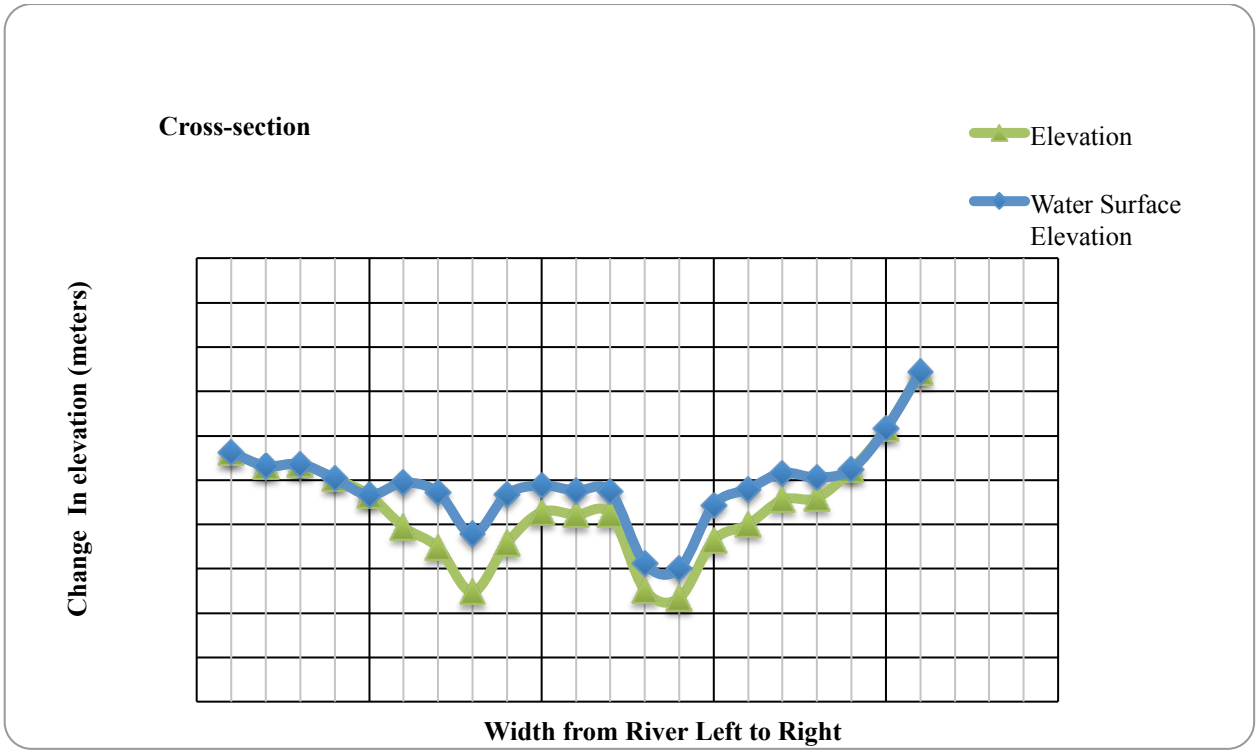



**Figure 17. Sample Site: Hollins Mill Dam**

**Figure 18. Cross-section of Subwatershed BW-5 Burton: Cracker Barrel**

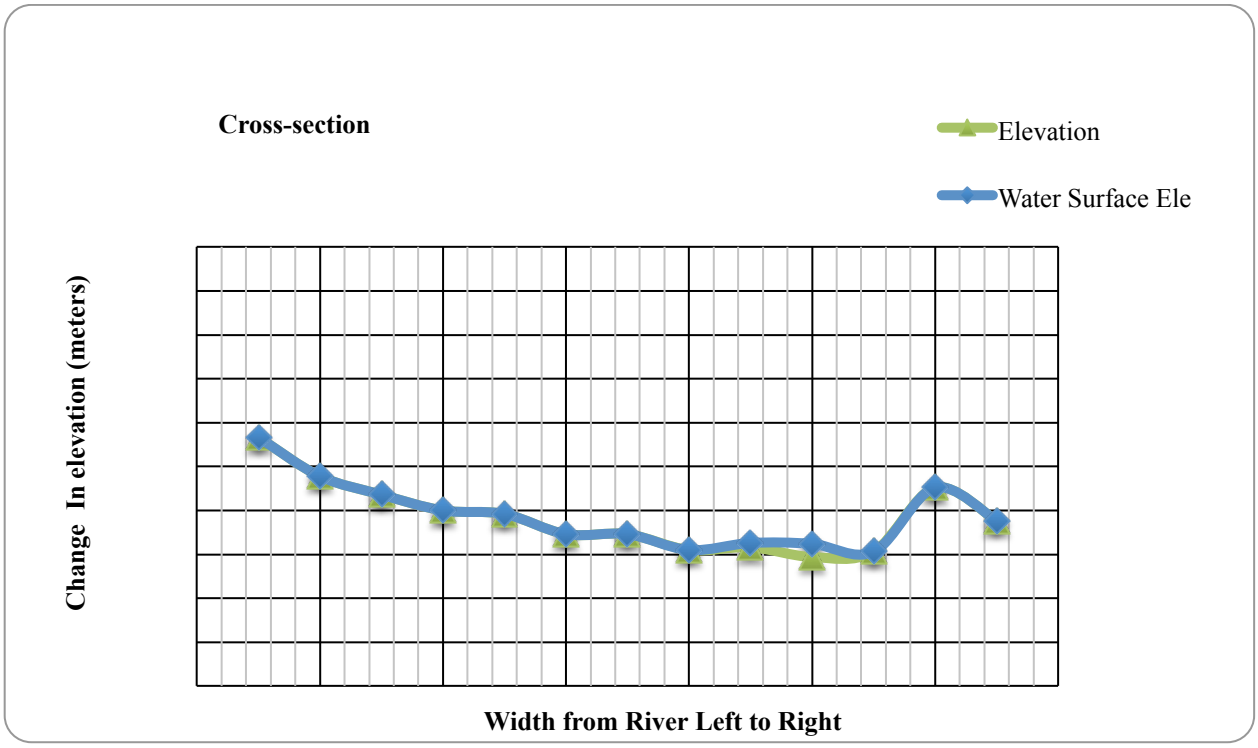



**Figure 19. Sampling Site: Cracker Barrel**

**Figure 20. Cross-section of Subwatershed BW-4 Dreaming: Heritage Funeral Home**

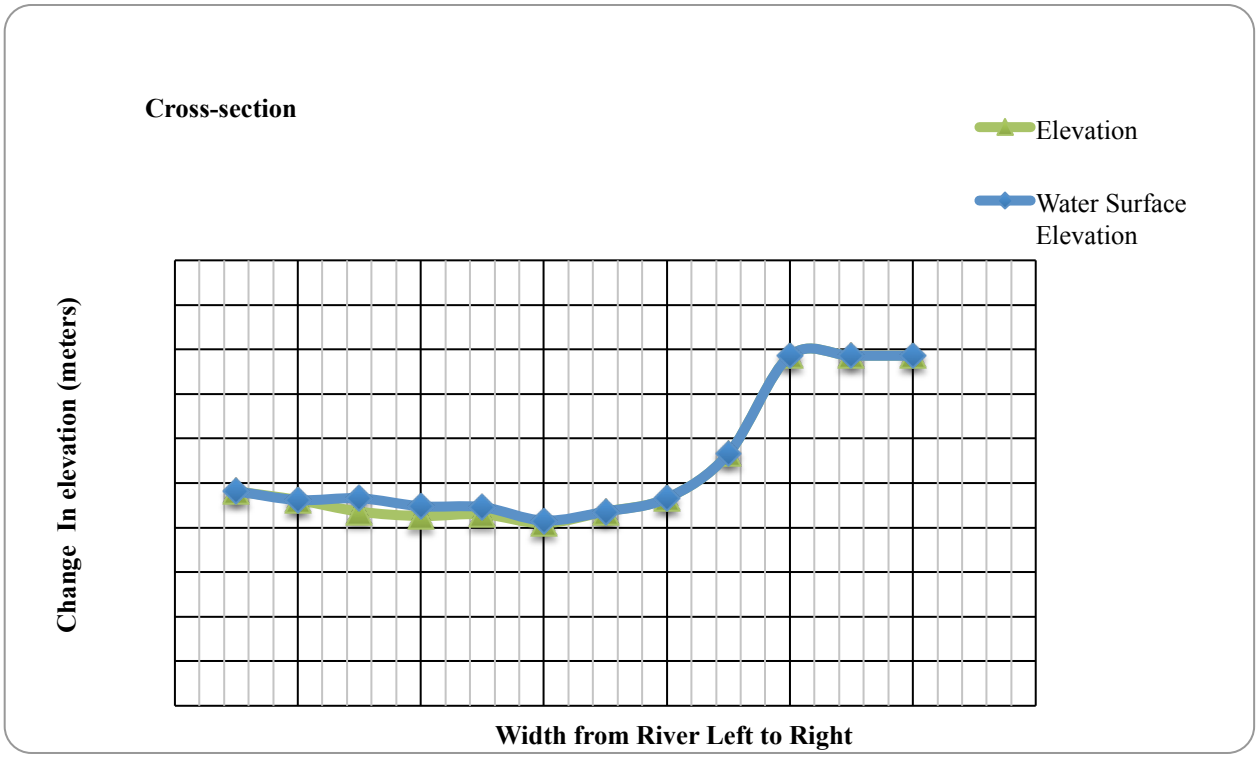



**Figure 21. Sampling Site: Heritage Funeral Home**

**Figure 22. Cross-section of Subwatershed BW-7 Tomahawk: McConville Road**

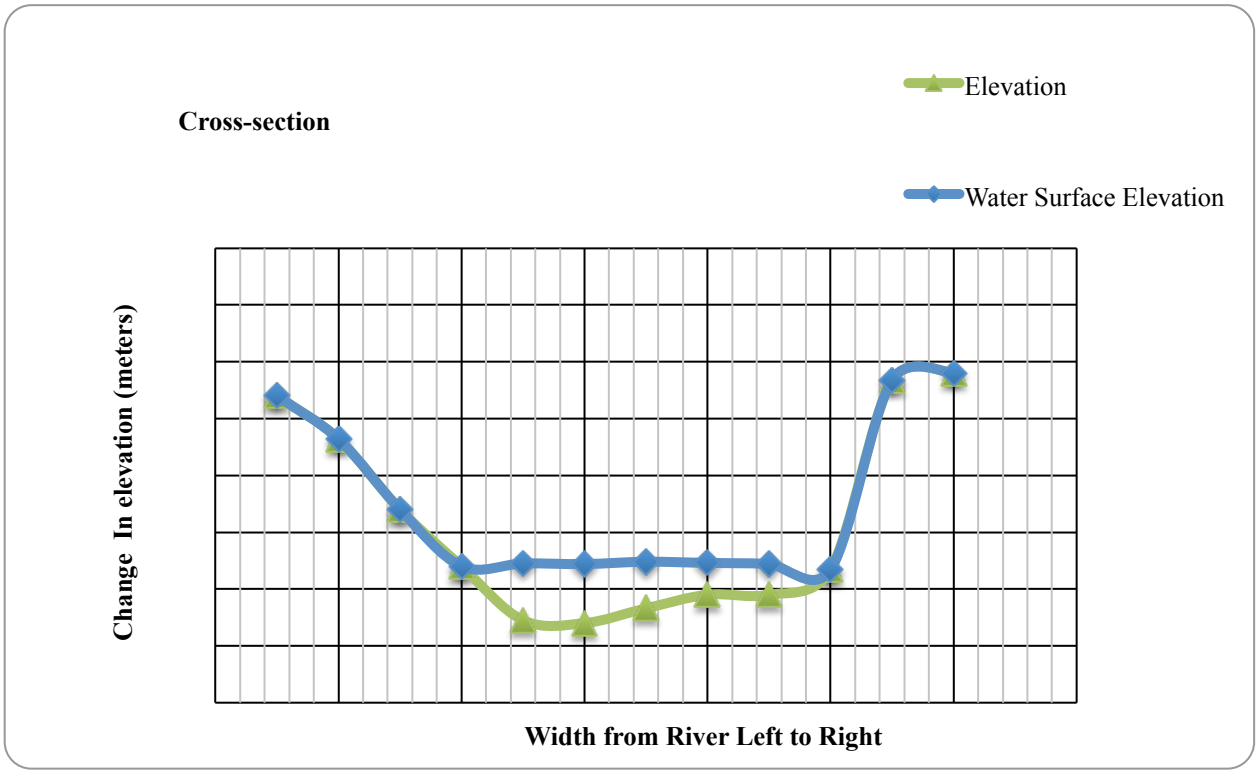
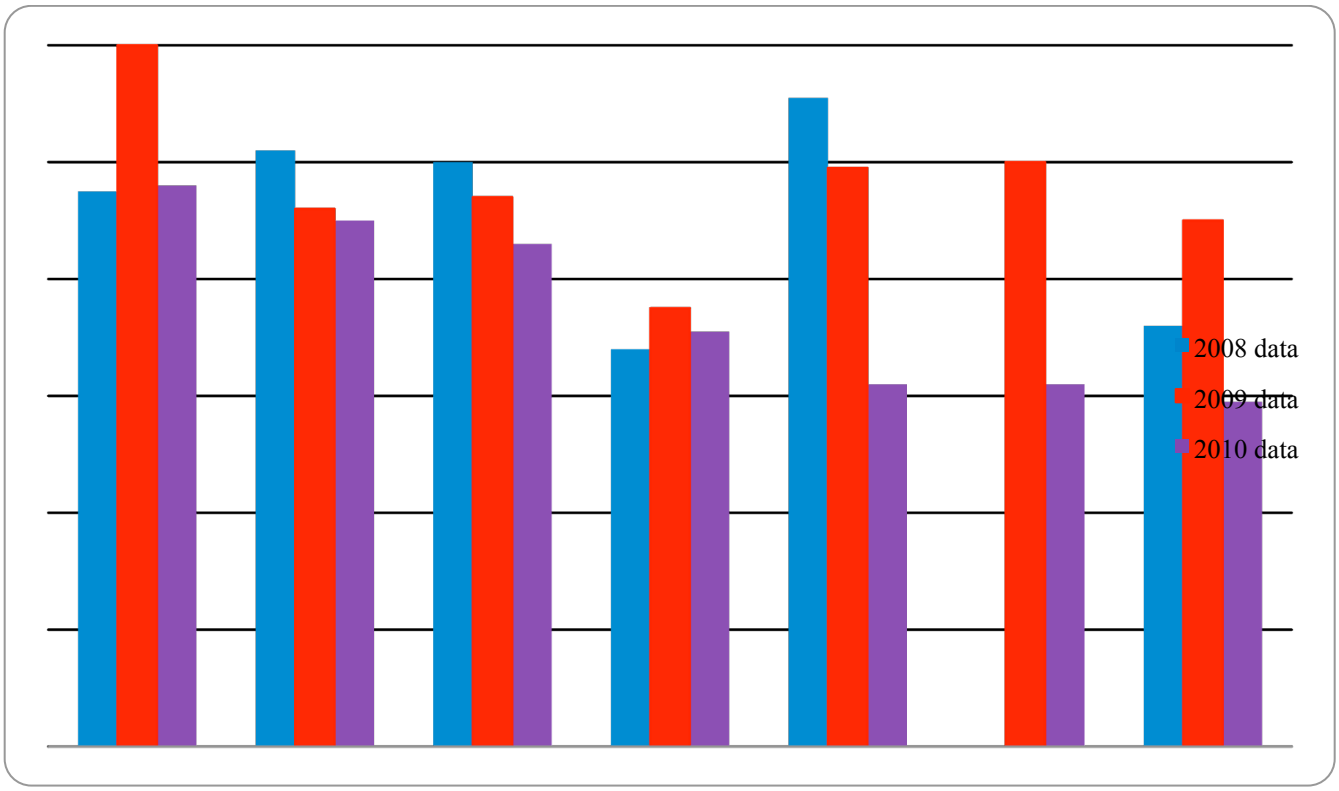



**Figure 23. Sampling Site: McConville Road**

**Figure 24. Reach Condition Index**



**Physical Analysis Discussion**

The overall stream quality was determined using the USM form and graphs of the cross section. The results showed that Rock Castle Creek at the Cracker Barrel location, (Figure 18 & 19) is the stream in the worst condition due to the fact that it is in a highly urbanized area and does not have an adequate amount of buffer surrounding it.. Dreaming Creek (Figure 20 & 21), also showed a large amount of impact, however it is from natural conditions rather than urbanization. This is due to the natural meander of the stream that has causing a large about of erosion on one side when a curve is made present, evident in Figure . The stream that had the best outcome is Black Water Creek at Hollins Mill Dam, (Figure 16 & 17). Although it is in a highly urbanized area the buffering factors are greater and the dam provides a buffer preventing sedimentation from continuing downstream.

The water quality for all the sites differed. This is due to in influences and conditions surrounding the stream itself. The conditions studied varied from agricultural, urbanized, and park based. This created various influences of buffers for the stream. Areas with the least amount of buffer led to the lowest water quality and areas with the greatest amount of buffer led to better water quality. Buffers in streams, like in the case of Hollins Mill Dam caused infiltration into the stream to be slower, cleaner, and create less of an impact.

The equipment used helped to collect information to create a cross- section of the stream to see relationships between sites. The cross-sections then helped to develop a basis for comparison between sites and show the water level and the level of the stream above and below. The surrounding buffers have a direct impact on the health of the stream. Not all of the sites were impacted by urbanization and sites that had proper buffers in place appeared to be less susceptible to water quality degradation.

Ways to improve water quality include the establishment of buffers or making sure to leave a natural buffer when an area near a stream is under construction. Leaving a natural buffer in place will save the expense of implementing buffers later due to human impacts on the stream that could have been prevented. Many techniques can be used to improve stream water quality but the main goal should be to decrease storm water runoff in order to prevent erosion and sediments from creating problems in the watershed.

## Chemical Analysis Results

**Figure 25. pH Level 2003-2010 : Richard Chaffin Farm and Rock Castle Creek**

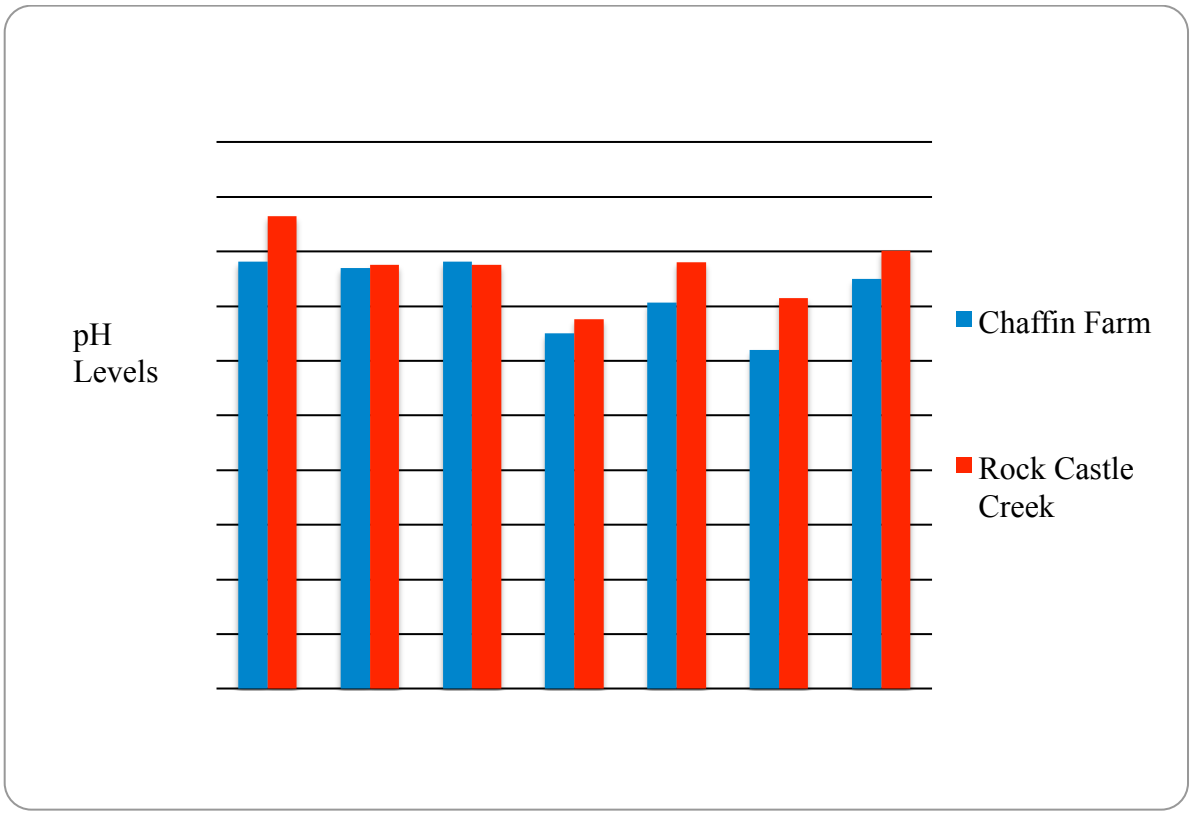



**Figure 26. Dissolved Oxygen Levels 2003-2010: Richard Chaffin Farm and Rock Castle Creek**

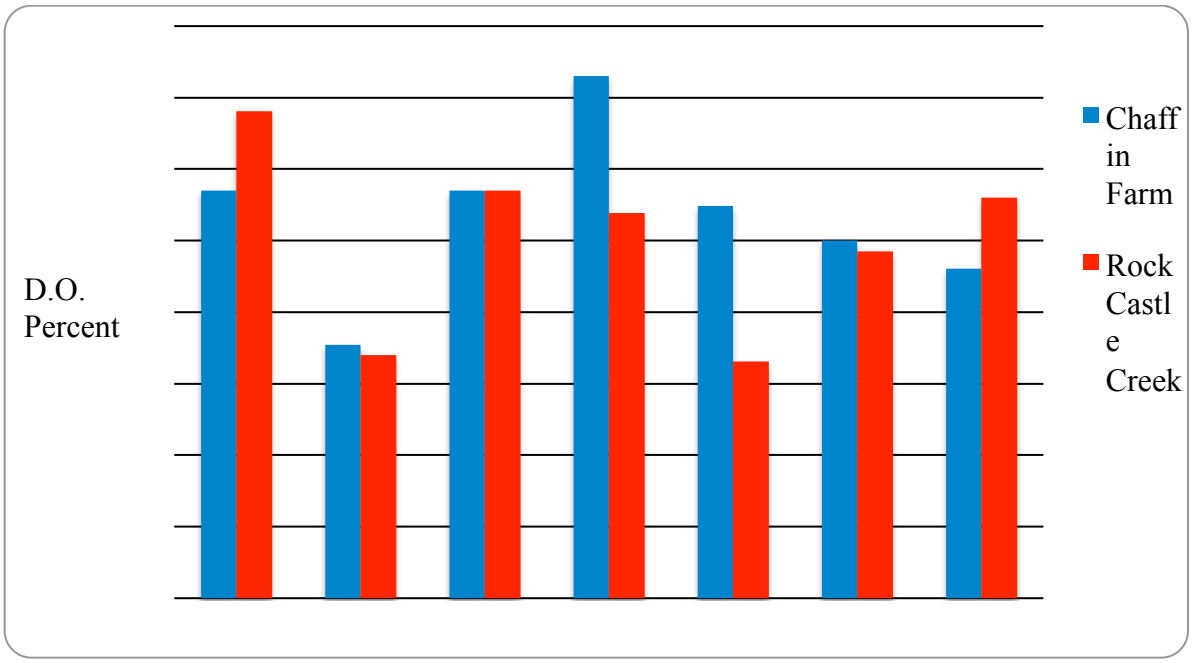



**Figure 27. Temperature ( C ) 2003-2010: Richard Chaffin Farm and Rock Castle Creek**

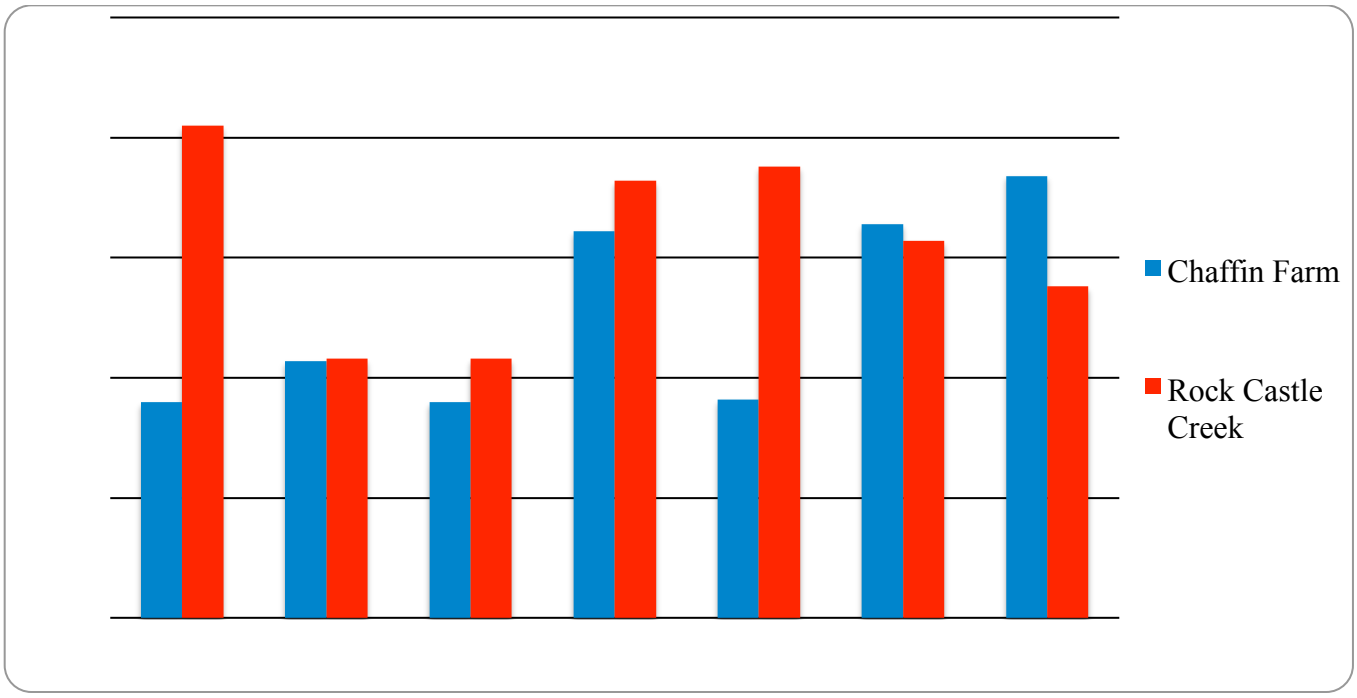



**Figure 28. Nitrate Level 2003-2010: Richard Chaffin Farm and Rock Castle Creek**

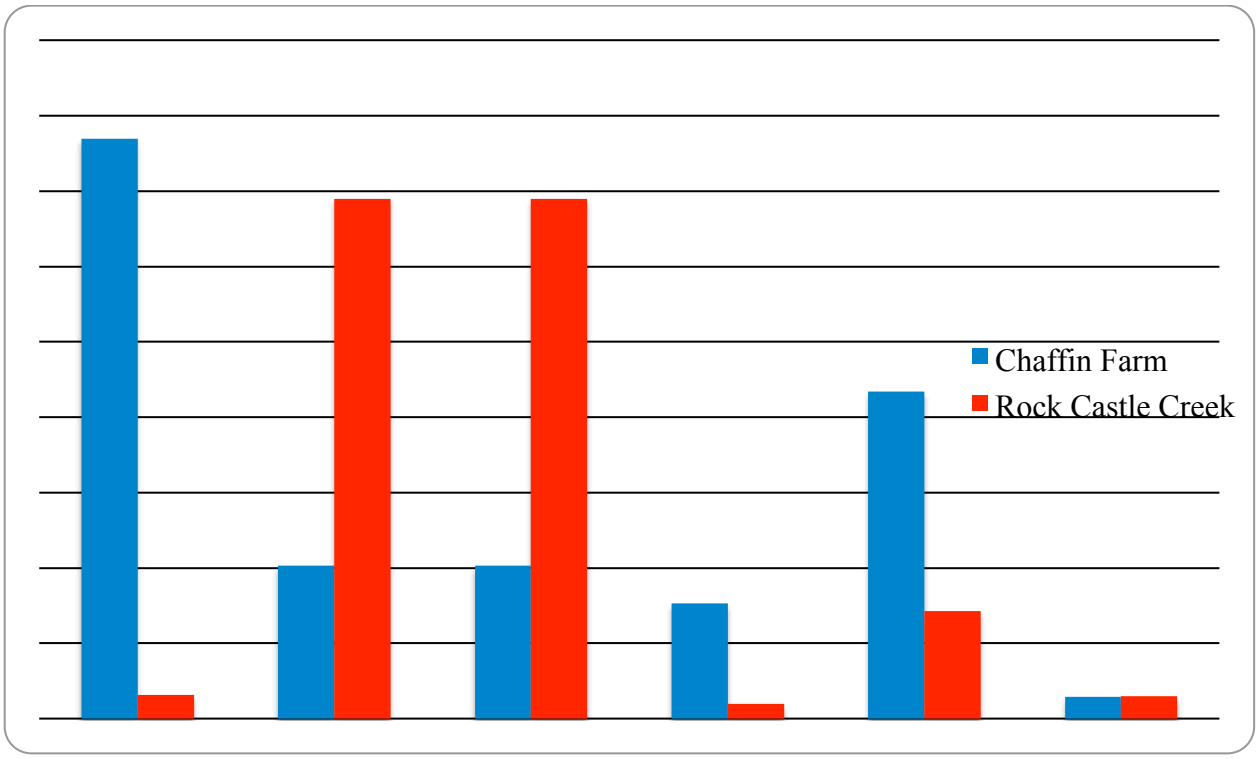



**Figure 29. Phosphorous Level 2003-2010: Richard Chaffin Farm and Rock Castle Creek**

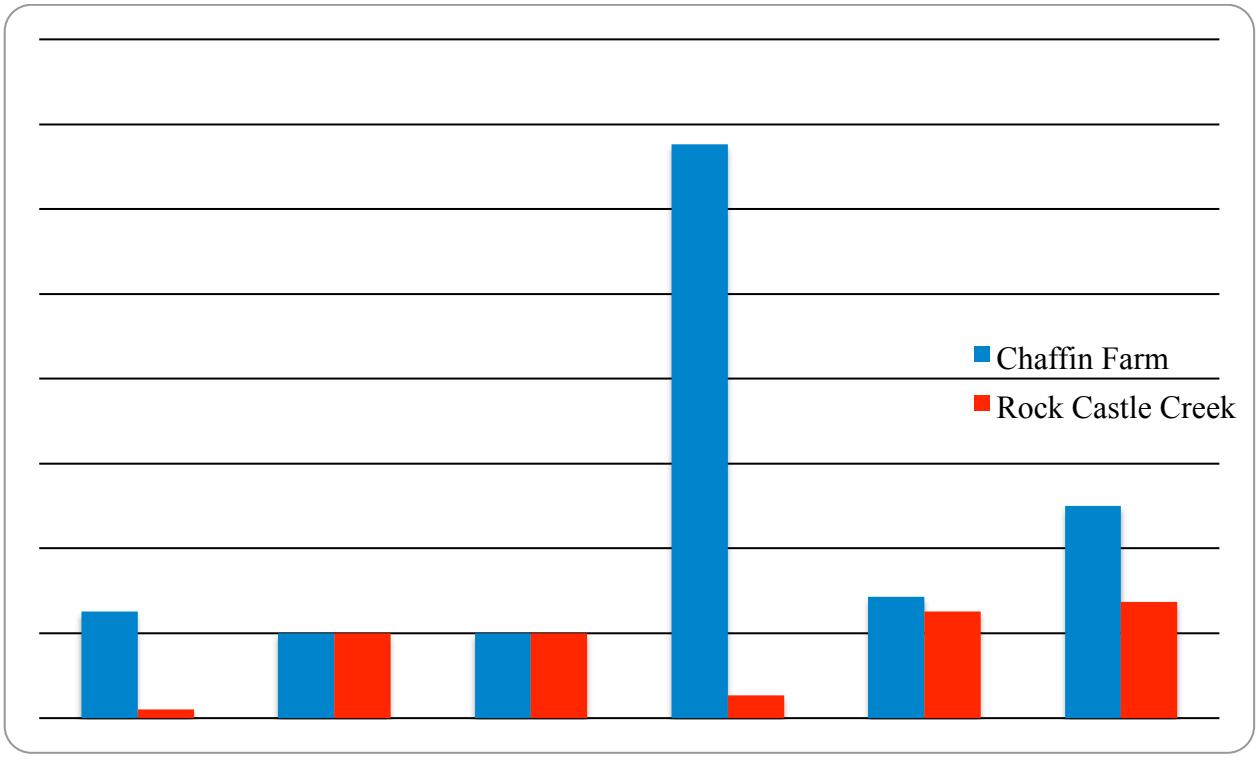



**Figure 30. Conductivity Level 2003-2010: Richard Chaffin Farm and Rock Castle Creek**

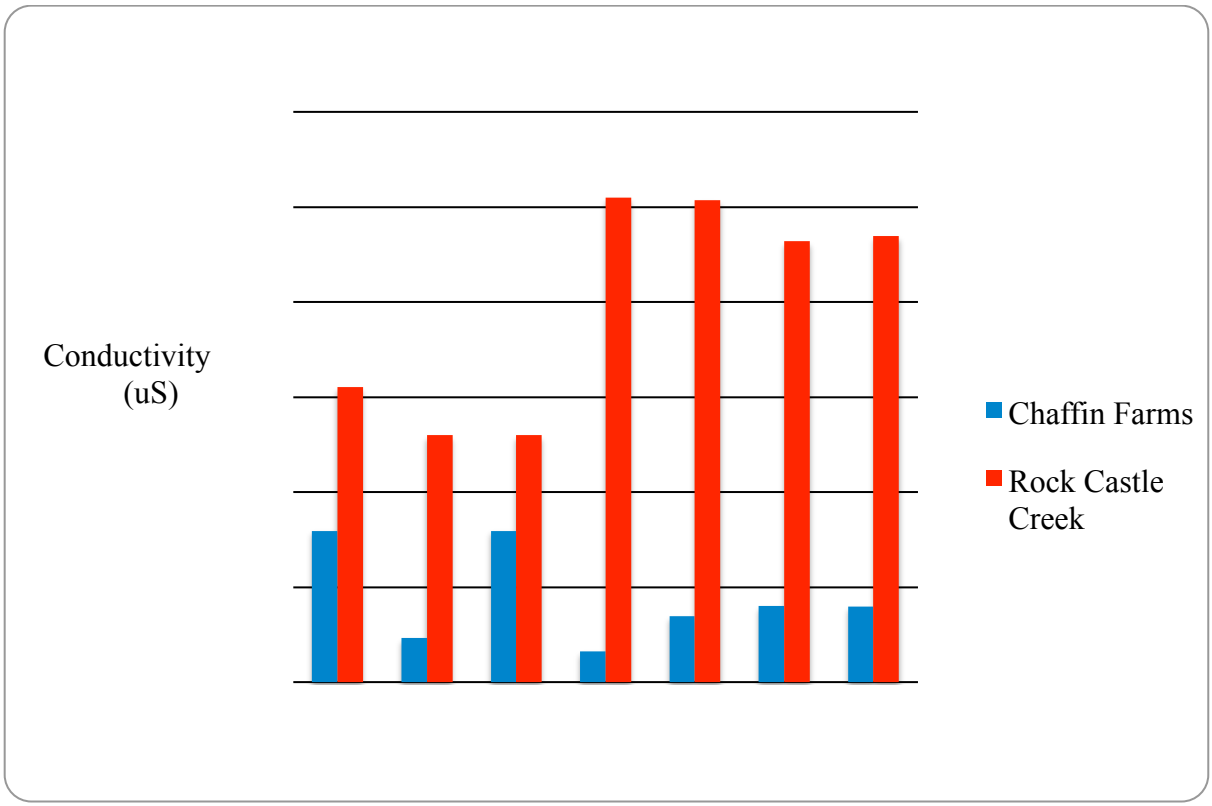



**Figure 31. Conductivity Levels 2010: Seven Water Sampling Sites**

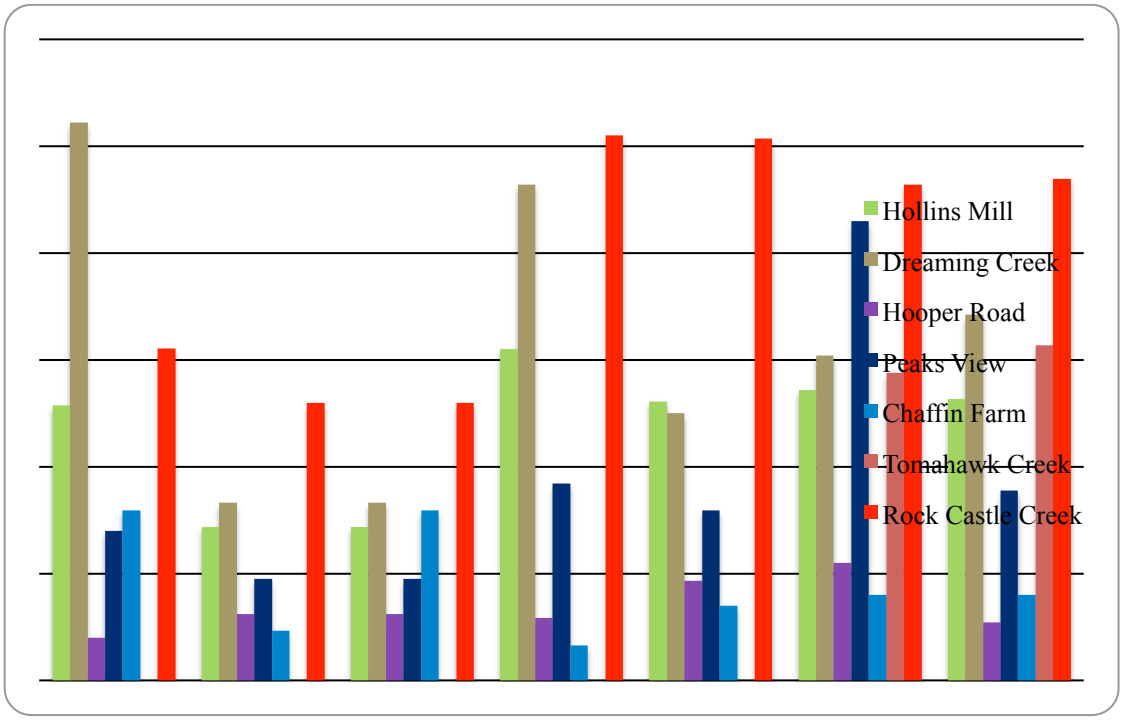
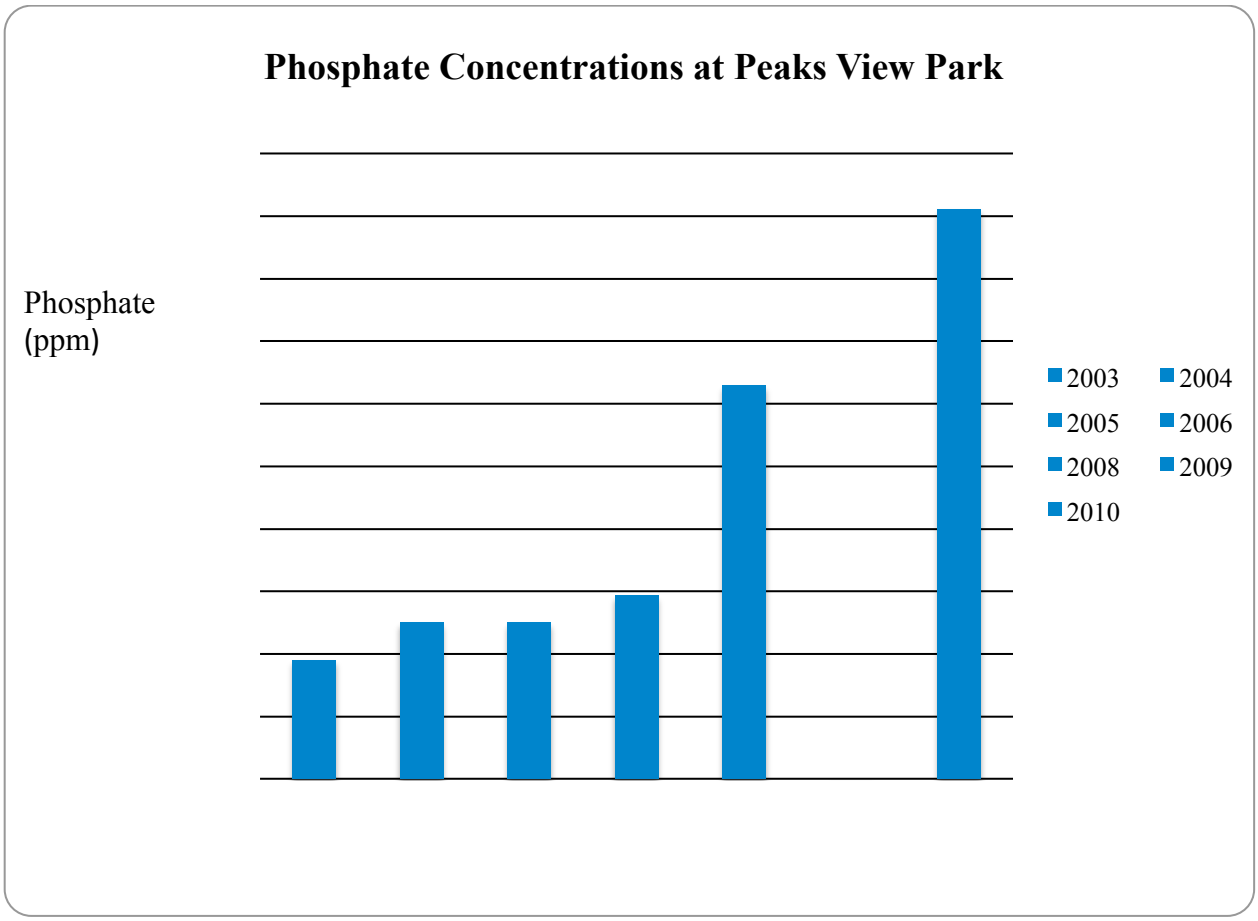



**Figure 32. Phosphate concentrations 2003-2010 at Peaks View Park**




**Chemical Analysis Discussion**

From the chemical analysis it was difficult to come to conclusions on water quality based on chemistry, however some of the data showed trends over the years and at certain locations. One trend that was found was an increase in phosphorus levels at Peaks View Park (Figure 32), and higher conductivity levels at Rock Castle Creek (Figure 30). In terms of pH, temperature, D.O, and nitrate, the data did not show any significant trend over the years.

The increasing levels of phosphorus over the years at Peaks View Park may be the result of increased runoff carrying organic material and or an increase of sedimentation in the stream. In addition, the rise in conductivity levels at Rock Castle Creek may be the result of a rise in runoff or increased sedimentation in the water. Rock Castle Creek had the highest level of

conductivity of all the streams (Figure 31), and this may be due to location of the stream, which is in a highly urbanized area with minimal buffer stream. In addition, Rock Castle Creek also had the highest pH, (Figure 25) of all of the streams sampled. The chemistry analysis results including conductivity, suggest that Rock Castle Creek is the most impacted stream and may be the result of increased runoff and sedimentation.

**Macroinvertebrate Analysis Results**

**Table 8. FBI, EPT and PMA Scores for Subwatershed BW-1 Upper Ivy: Richard Chaffin Farm**

| Water Quality | FBI | EPT | PMA |
|---|---|---|---|
| Excellent | .00-3.75 | >10 | >64 |
| Very Good | 3.76-4.25 | - | - |
| Good | 4.26-5.00 | 6.0 - 9 | 50-64 |
| Fair | 5.01-5.75 | 2.0 - 5 | 35-49 |
| Fairly Poor | 5.76-6.5 | - | - |
| Poor | 6.51-7.25 | 0-1 | <35 |
| Very Poor | 7.26-10 | - | - |

**Table 9. FBI, EPT and PMA Scores for Subwatershed BW-2 Middle Ivy: Hooper Road**

| Water Quality | FBI | EPT | PMA |
|---|---|---|---|
| Excellent | .00-3.75 | >10 | >64 |
| Very Good | 3.76-4.25 | - | - |
| Good | 4.26-5.00 | 6.0 - 9 | 50-64 |
| Fair | 5.01-5.75 | 2.0 - 5 | 35-49 |
| Fairly Poor | 5.76-6.5 | - | - |
| Poor | 6.51-7.25 | 0-1 | <35 |
| Very Poor | 7.26-10 | - | - |

**Table 10. FBI, EPT and PMA Scores for Subwatershed BW-3 Lower Ivy: Peaks View Park**

| Water Quality | FBI | EPT | PMA |
|---|---|---|---|
| Excellent | .00-3.75 | >10 | >64 |
| Very Good | 3.76-4.25 | - | - |
| Good | 4.26-5.00 | 6.0 - 9 | 50-64 |
| Fair | 5.01-5.75 | 2.0 - 5 | 35-49 |
| Fairly Poor | 5.76-6.5 | - | - |
| Poor | 6.51-7.25 | 0-1 | <35 |
| Very Poor | 7.26-10 | - | - |

**Table 11. FBI, EPT and PMA Scores for Subwatershed BW-9 Lower Blackwater: Hollins Mill Dam**

| Water Quality | FBI | EPT | PMA |
|---|---|---|---|
| Excellent | .00-3.75 | >10 | >64 |
| Very Good | 3.76-4.25 | - | - |
| Good | 4.26-5.00 | 6.0 - 9 | 50-64 |
| Fair | 5.01-5.75 | 2.0 - 5 | 35-49 |
| Fairly Poor | 5.76-6.5 | - | - |
| Poor | 6.51-7.25 | 0-1 | <35 |
| Very Poor | 7.26-10 | - | - |

**Table 12. FBI, EPT and PMA Scores for Subwatershed BW-5 Burton: Cracker Barrel**

| Water Quality | FBI | EPT | PMA |
|---|---|---|---|
| Excellent | .00-3.75 | >10 | >64 |
| Very Good | 3.76-4.25 | - | - |
| Good | 4.26-5.00 | 6.0 - 9 | 50-64 |
| Fair | 5.01-5.75 | 2.0 - 5 | 35-49 |
| Fairly Poor | 5.76-6.5 | - | - |
| Poor | 6.51-7.25 | 0-1 | <35 |
| Very Poor | 7.26-10 | - | - |

**Table 13. FBI, EPT and PMA Scores for Subwatershed BW-4 Dreaming: Heritage Funeral Home**

| Water Quality | FBI | EPT | PMA |
|---|---|---|---|
| Excellent | .00-3.75 | >10 | >64 |
| Very Good | 3.76-4.25 | - | - |
| Good | 4.26-5.00 | 6.0 - 9 | 50-64 |
| Fair | 5.01-5.75 | 2.0 - 5 | 35-49 |
| Fairly Poor | 5.76-6.5 | - | - |
| Poor | 6.51-7.25 | 0-1 | <35 |
| Very Poor | 7.26-10 | - | - |

**Table 14. FBI, EPT and PMA Scores for Subwatershed BW-7 Tomahawk: McConville Road**

| Water Quality | FBI | EPT | PMA |
|---|---|---|---|
| Excellent | .00-3.75 | >10 | >64 |
| Very Good | 3.76-4.25 | - | - |
| Good | 4.26-5.00 | 6.0 - 9 | 50-64 |
| Fair | 5.01-5.75 | 2.0 - 5 | 35-49 |
| Fairly Poor | 5.76-6.5 | - | - |
| Poor | 6.51-7.25 | 0-1 | <35 |
| Very Poor | 7.26-10 | - | - |

**Figure 33. Overall Stream Health Based on FBI, EPT and PMA Scores**

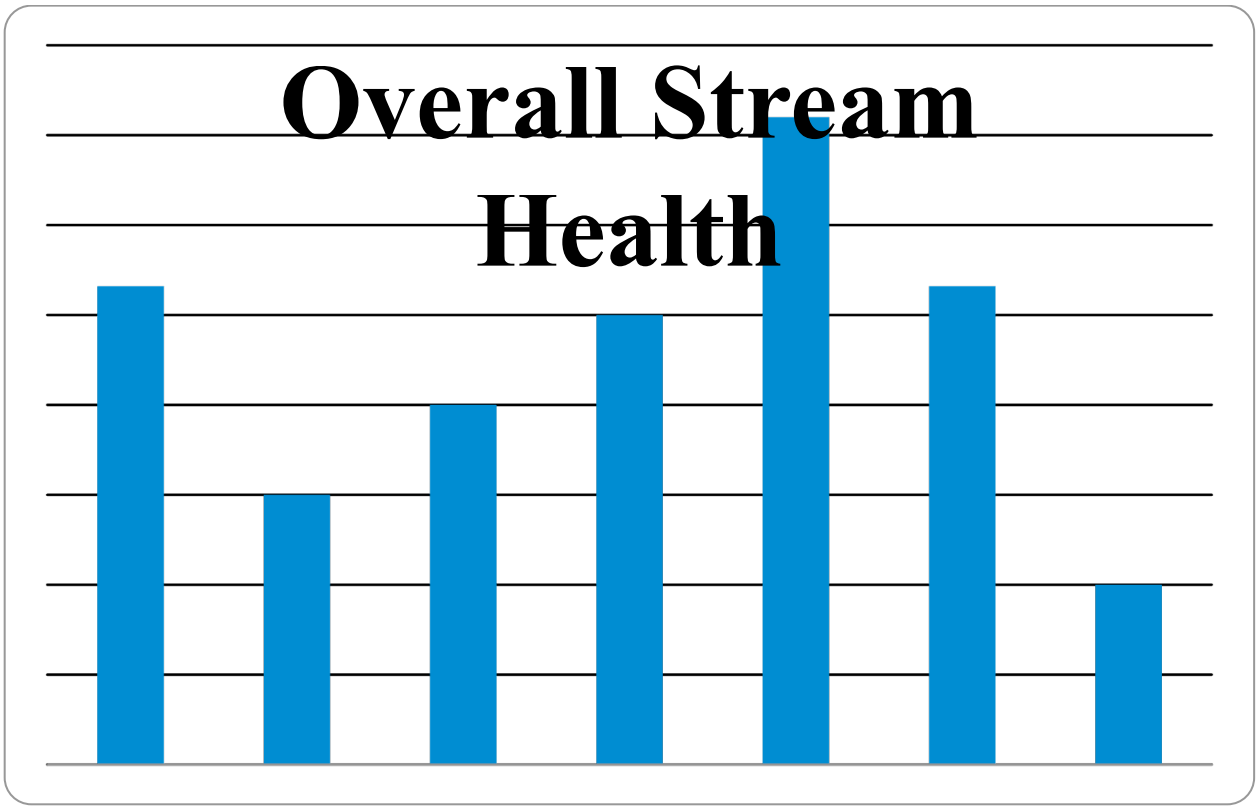



Figure 33. Stream sampling sites were given a number 1-4 representing poor (1) , excellent (4) and average (2-3) of the three Indices, EPT, FBI, and PMA, in order to score overall water quality of the streams.

**Figure 34. FBI Score for Seven Sampling Sites: 2004-2010**

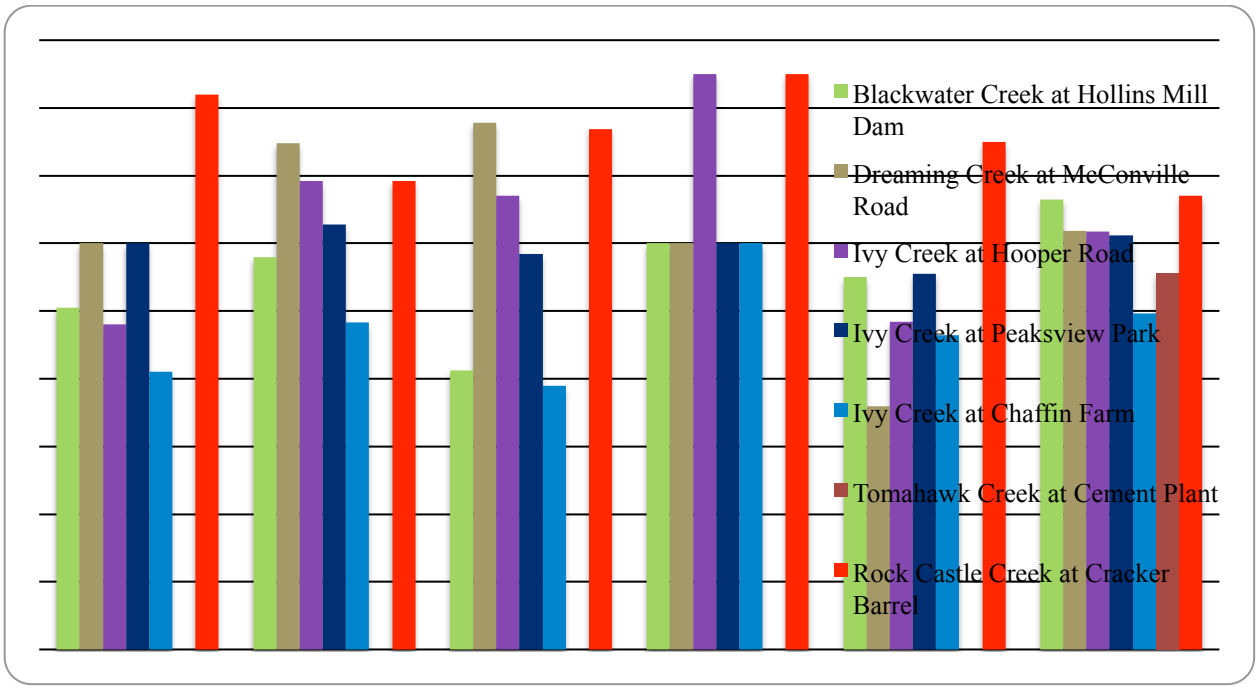



**Figure 35. PMA Score for Seven Sampling Sites: 2004-2010**

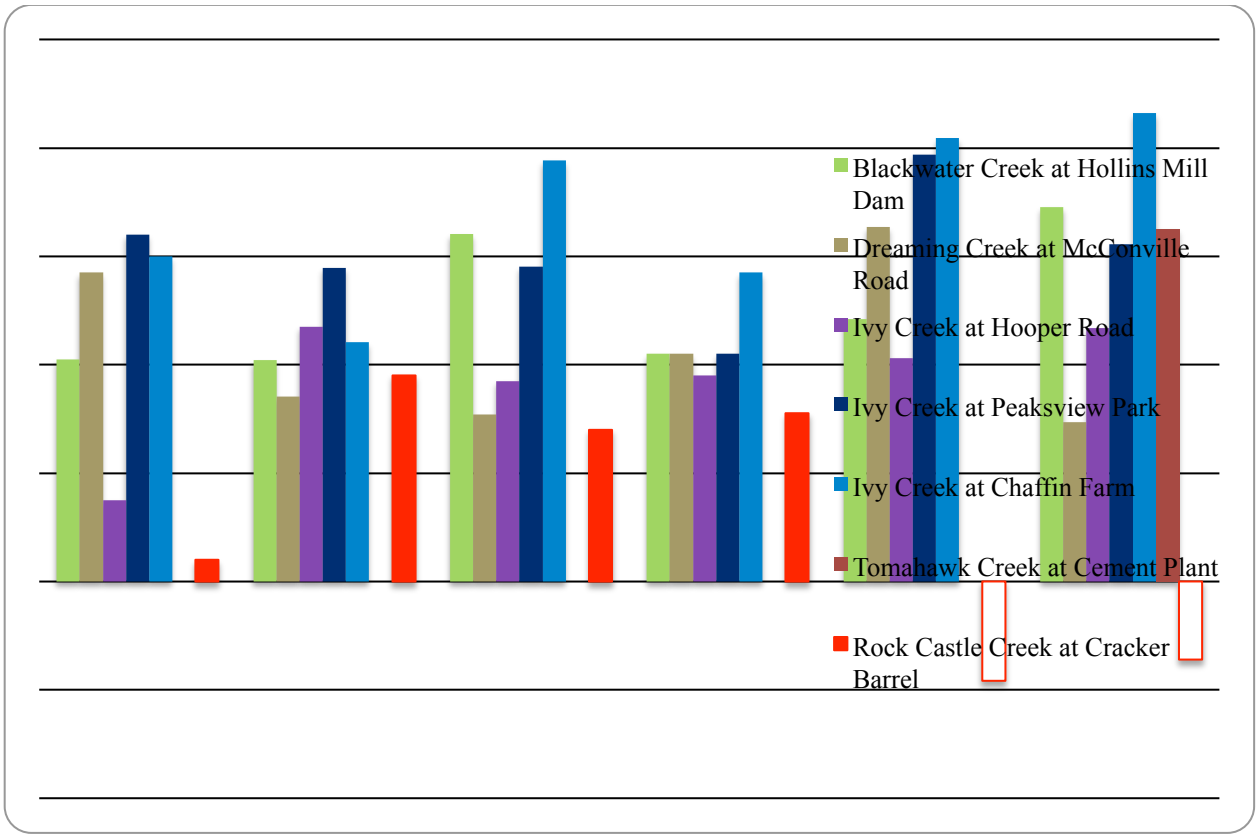
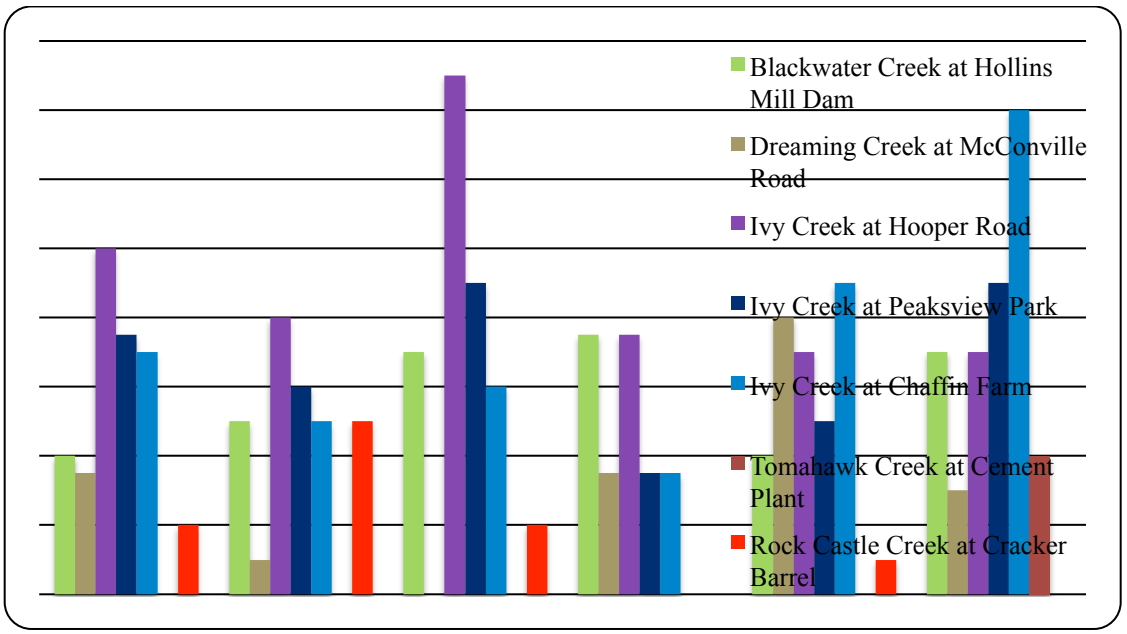



**Figure 36. EPT Score for Seven Sampling Sites: 2004-2010**




**Macroinvertebrate Analysis Discussion**

For Figure 33. streams were scored by assigning a number 1-4 representing poor to excellent to average of the three Indices, EPT, FBI, and PMA, to give a score for overall water quality of the streams. The results from Figure 33 show that the Chaffin Farm location was the healthiest and that Rock Castle Creek at Cracker Barrel was the least healthy. The tables show individual FBI, EPT and PMA score for each site, and then Figures 33-36 shows one index per figure for each stream to compare the streams to one another over a six year period.

For the Cracker Barrel, Rock Castle Creek sampling site (Table 12), FBI, EPT, and PMA were all in poor conditions. The main species present were aquatic worms and midges which both have high FBI values and are tolerant to pollution. No organisms from EPT were found at all. This site is in poor condition, and has been declining in an overall trend since the first study with the exception of FBI improving.

The Heritage Funeral Home, Dreaming Creek location (Table 13), had many aquatic worms and midges as well as one stonefly, mayfly, and caddisfly. The FBI is fairly poor due to the presence of pollution tolerant organisms, although some organisms that indicate good water quality were present. Looking at all three indices overall at this stream, Dreaming Creek has been maintaining its health although the quality is not very high.

At the Hollins Mill Dam, Blackwater Creek location (Table 11), the low FBI and high PMA scores indicate that there are a lot of organisms of many different pollution tolerances. There were many midges with high FBI numbers which can tolerate pollution along with a good amount of mayflies and stoneflies. The large biodiversity in this stream is healthy and contributes to the excellent PMA level. This stream overall has been increasing in health under the EPT and PMA indices since the study was begun.

The Hooper Road, Ivy Creek location (Table 9) had good levels of EPT and PMA indicate that this stream is in good health while the FBI indicates that the stream is poor. This difference is due to the large amount of midges that have a large FBI number. This stream has moderate health due to the presence of mayflies, stoneflies and caddisflies. Under the FBI and EPT indices the stream has been declining while the PMA has increased greatly since 2004. This stream is moderately healthy although it has been declining slowly for the most part.

At the Ivy Creek, Peaks View Park location (Table 10) there were many organisms with high FBI scores that contributed to the fairly poor rating, while there were organisms that indicate good water quality as well. This stream contains good biodiversity, the EPT, FBI, and PMA levels have maintained themselves around the same level since 2004. The steady levels of these organisms indicate that this stream is resistant and can maintain good health.

The Ivy Creek at Chaffin Farm site (Table 8), was very healthy, with excellent EPT and PMA scores indicate many organisms that there are many pristine organisms present. The FBI score of good indicates that there are some organisms that can tolerate pollution. The FBI has slowly been rising since the study begun although it is still tolerable. EPT and PMA levels have been improving since 2004 which indicate very good water quality. This was the most healthy stream we sampled.

For the Tomahawk Creek location there was no data present from previous studies on macroinvertebrates in this stream. Looking at Table 14, the PMA was excellent, although the FBI and EPT were fair. There were some stoneflies and mayflies present which indicates that there is not very much pollution present. The presence of midges and worms make the FBI score go up. This stream is of moderate health containing both pollution tolerant and intolerant species.

The macroinvertebrate analysis indicated that the streams with the best health were located in more rural areas. The streams located closer to the urbanized area of Lynchburg have indicated lower health than those located in the less developed areas surrounding Lynchburg. The ability for some of these streams to maintain the levels that were found during the first study indicates that these streams are somewhat resistant to change.

**Fish Analysis: Results**

The tolerant species found in streams have the ability to withstand large or sudden changes in their environment, while intolerant species are incredibly sensitive to any change. This variation in characteristics of fish species helps to determine the health of the stream they are found in. Abundance in omnivorous species which are tolerant to change shows that the stream's intolerant species which consume specific organisms have declined. For example, a decrease in the health of a stream will decrease the EPT insect species which will directly affect the insectivore fish species.

Health depletion in a stream may be the result of things. An over abundance in phosphorus can cause eutrophication and the rapid decline of the stream's ecosystem. Urbanization in a watershed has time and again proved fatal to the environment surrounding and inside of a stream. The increase in sediment and foreign toxic chemicals from the surrounding area called "runoff" enters the stream and wreaks havoc on its organisms.

Through electro-shocking fish in a stream, we observe patterns in population numbers and species diversity. Fish, being high in the food chain, are involved in the food chain on a more complex level. Having to rely on other living organisms in a stream, fish are more affected by pollution and stream health. The ability of fish to travel farther and faster than other organisms, tells us that they interact with large stretches of stream which gives us a better idea of the level of impact. Sampling fish from spring through late summer is optimal as temperatures are higher and fish are more active. By avoiding sampling after rainstorms, we were able to manage the waters turbidity and see the fish as clearly as possible.

**Table 15. IBI Measurements**

| | |
|---|---|
| Measurement 1 | Total number of fish species |
| Measurement 2 | Total number of darter species/Relative percent of darter species to the total |
| Measurement 3 | Total number/relative percent of water column insectivores |
| Measurement 4 | number/relative percent of pool-benthic insectivores. |
| Measurement 5 | Total number/relative percent of intolerant species. |
| Measurement 6 | Relative abundance of tolerant species. |
| Measurement 7 | Relative abundance of omnivores or generalist feeders |
| Measurement 8 | Relative abundance of top carnivores. |
| Measurement 9 | Deviation from ideal or number of individuals in sample. |

Table 1 is an overall list of the data found in 2010 at each site. It lists total numbers of fish sampled as well as percentages of different classifications of fish and niches that they occupy in their environment. These data provide us with the values needed to calculate IBI values.

## Table 16. Total/relative Percent of Different Fish Categories at Each Site Sampled

| | Dreaming Creek | Rock Castle Creek | Peaks View Creek | Hollins Mill Creek | Chaffin Farms | Hooper Road | Tomahawk |
|---|---|---|---|---|---|---|---|
| **Total Fish Species** | 13 | 10 | 8 | 7 | 11 | 11 | 11 |
| **Total # Fish Caught** | 70 | 90 | 46 | 46 | 135 | 97 | 55 |
| **Percent Percids** | 7.14 | 8.89 | 4.34 | 43.47 | 13.33 | 21.64 | 5.45 |
| **Percent Suckers** | 12.86 | 1.11 | 0 | 0 | 2.96 | 0 | 23.63 |
| **Percent Cyprinidae** | 78.57 | 72.22 | 6.52 | 2.17 | 79.25 | 70.10 | 54.54 |
| **Percent Catfishes** | 0 | 0 | 2.17 | 2.17 | 0 | 3.09 | 14.54 |
| **Percent Sunfish** | 1.43 | 17.78 | 84.78 | 47.82 | 4.44 | 4.12 | 1.81 |
| **Percent WC Insectivores** | 2.86 | 20 | 82.60 | 47.82 | 4.44 | 4.12 | 7.27 |
| **Percent Pool Insectivores** | 32.86 | 23.33 | 6.52 | 47.82 | 17.77 | 26.80 | 32.72 |
| **Percent Omnivores** | 50 | 52.22 | 8.69 | 4.34 | 75.55 | 69.07 | 40 |
| **Percent Carnivores** | 0 | 0 | 2.17 | 0 | 0 | 0 | 0 |
| **Total # WC Insectivores** | 2 | 18 | 38 | 22 | 6 | 4 | 4 |
| **Total # Pool Insectivores** | 32 | 22 | 3 | 22 | 27 | 26 | 29 |
| **Percent Tolerant** | 44.29 | 51.11 | 91.30 | 50 | 26.66 | 50.51 | 52.72 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Percent Intolerant** | 55.71 | 48.89 | 8.69 | 50 | 73.33 | 49.48 | 47.27 |

IBI Score Key: Score = 1-2, Score = 3, Score = 4-5

**Table 17. IBI Measurements for 2010 Sampling**

| **Index of Biological Integrity (IBI)** | | | | | | | |
|---|---|---|---|---|---|---|---|
| Measurements | **Dreaming Creek** | **Rock Castle Creek** | **Peaksview** | **Hollins Mill Creek** | **Chaffin Farms** | **Hooper Road** | **Tomahawk** |
| Total Number of Species | 3 | 2 | 2 | 2 | 3 | 3 | 3 |
| Total Number / Relative percent of Darter Species | 1 | 2 | 1 | 5 | 3 | 4 | 1 |
| Total Number / Relative percent of Water Column Insectivores | 1 | 4 | 5 | 5 | 1 | 1 | 1 |
| Total Number / Relative percent of Pool-Benthic Insectivores | 5 | 5 | 3 | 5 | 5 | 5 | 5 |
| Total Number / Relative percent of Intolerant Species | 3 | 3 | 2 | 3 | 5 | 3 | 3 |
| Relative abundance of Tolerant Species | 2 | 1 | 1 | 2 | 4 | 2 | 2 |
| Relative abundance of Omnivores or Generalist Feeders | 3 | 3 | 5 | 5 | 2 | 2 | 2 |
| Relative abundance of Top Carnivores | 0 | 0 | 1 | 0 | 0 | 0 | 0 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Deviation from ideal or number of individuals in sample | 3 | 3 | 2 | 2 | 5 | 4 | 2 |
| **Totals for each site ►** | 21 | 23 | 22 | 29 | 28 | 24 | 19 |
| **Grade ►** | Poor | Fair | Poor | Good | Fair | Fair | Poor |

Table 2 displays the IBI values for each site sampled. The IBI scores on a scale of 9-45, with 45 being the highest score representing superior stream quality. In our results we found that Hollins Mill had the best water quality with an IBI score of only 29. Next behind that was Chaffin Farms with a score of 28. We found that the stream with the poorest quality was Tomahawk with an IBI score of 19.

**Figure 37. IBI Score for Each Sample Site: 2005-2010**

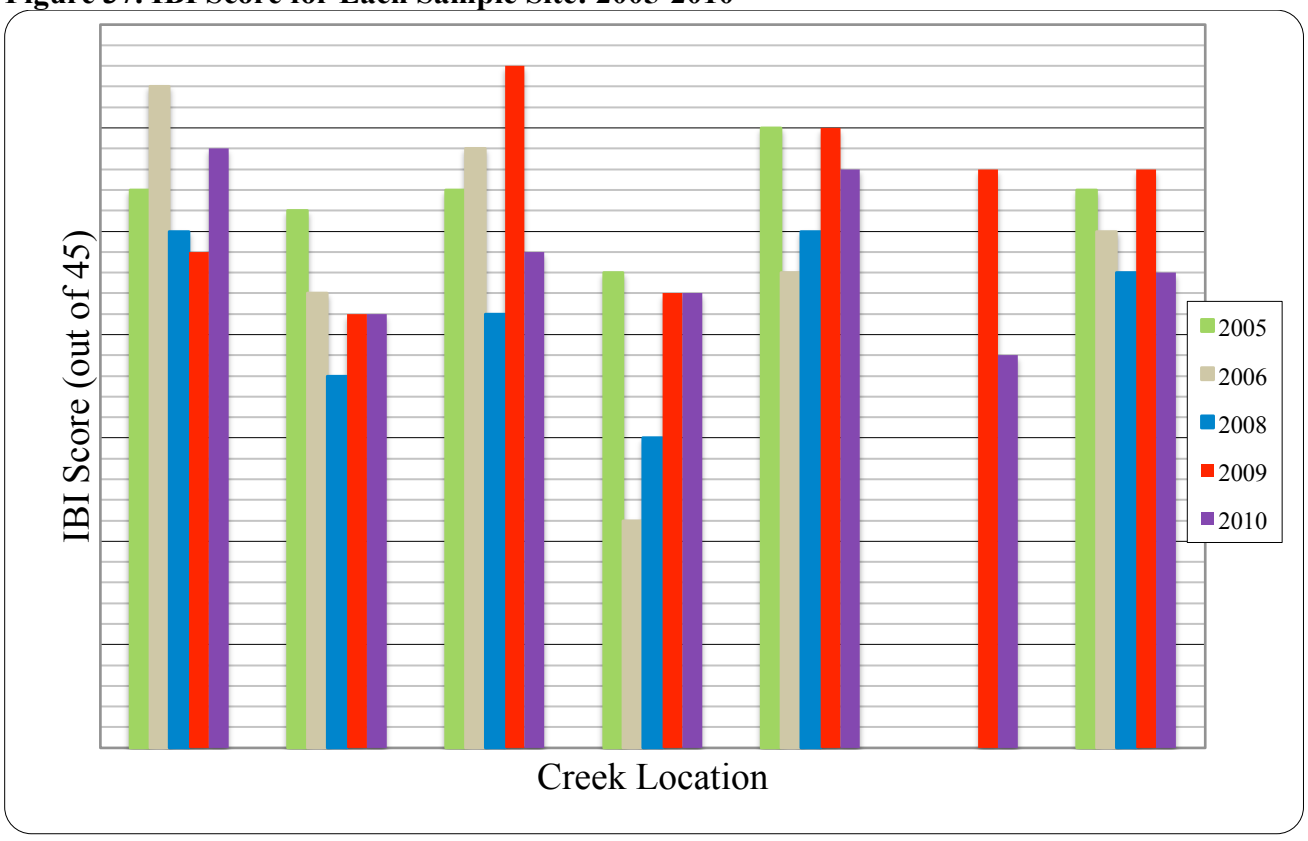
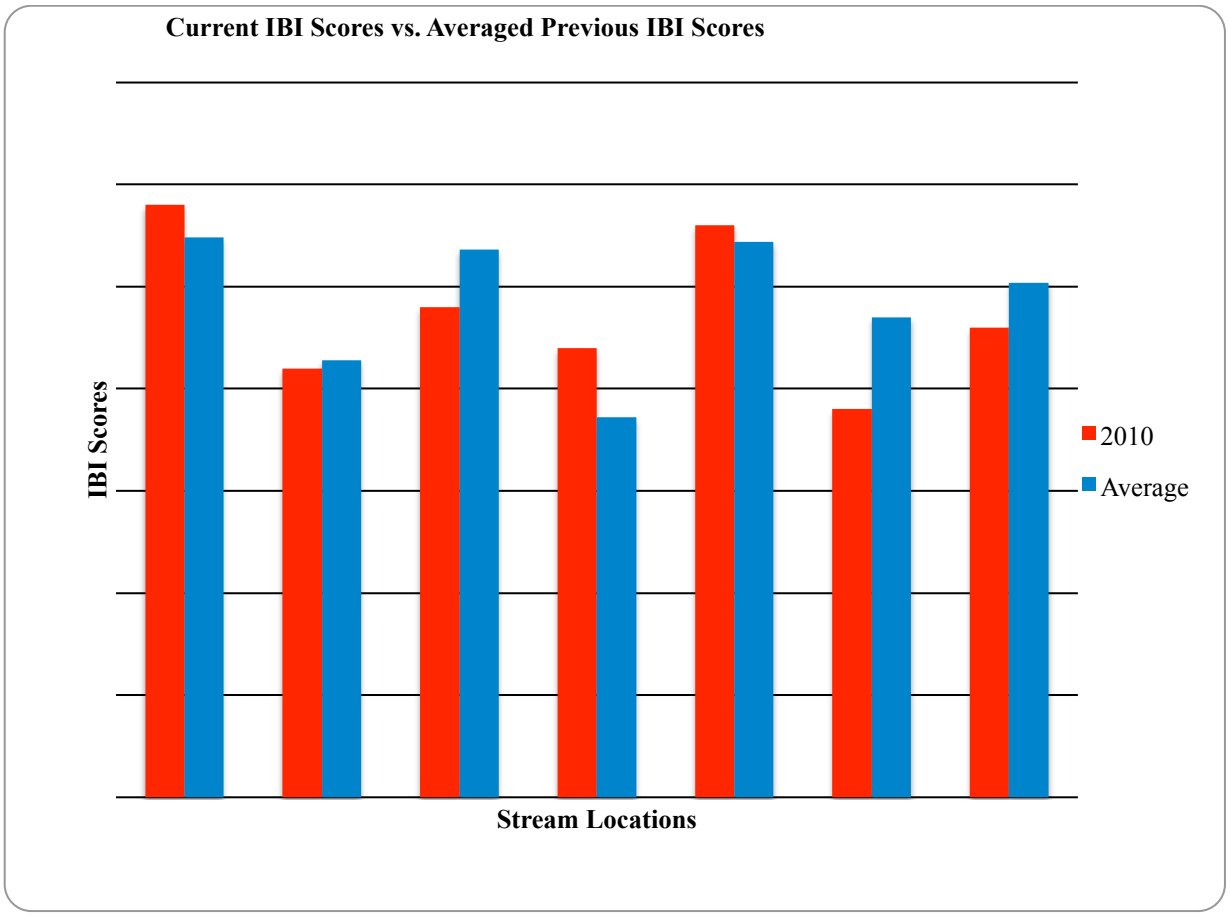



Figure 37. shows that out of the seven sampled creeks in the Blackwater Creek watershed, some have improved biotic integrity in 2010 while others have received lower scores than years prior. Tomahawk Creek was only sampled during the past two years, but its 2010 IBI score was considerably lower than 2009, and was given the lowest score of all sampled creeks for 2010. The Hollins Mill site on Blackwater Creek has shown recent improvent, still 4 points below the site's best score of 33/45 during 2006. Hollins mill was given the highest IBI value for 2010,

and Chaffin Farm on Ivy Creek was also given a good score based on the average score for the watershed (24.3/45). Hooper Road site was closest to the watershed average, and Peaksview Park, labeled on Graph 1 as Ivy Creek, has seen little change from the past year, as well as the Dreaming Creek site, which has received consistently low IBI scores for the past four years.

**Figure 38. 2010 IBI Score vs. Average for All Years Sampled**




Graph 3 shows a comparison of 2010 IBI scores for each site (blue), and the 5-year average for each site (red). The average for Tomahawk Creek is less precise than the other values because it only accounts for two years of sampling, rather than the five years with all six other sites. Dreaming Creek and Chaffin farm show the most stability (smallest deviation from average), while the Hooper Road site and Rockcastle Creek have lower 2010 scores than average. Hollins Mill on Blackwater Creek and Peaksview Park on Ivy Creek show improvement from the average score for each site.

## Fish Analysis Results

Hooper Road's IBI score was the closest to the average for all Lynchburg area streams, indicating stable water quality in the sampled section of the stream. Few darters and water

column insectivores were found in 2009, as well as less tolerant and intolerant species, these factors caused the IBI score to decrease significantly. However, in 2010 Hooper Road's IBI score was still above the 5 year average for this location. Chaffin Farm IBI score proved to be the most stable of all sampled streams when compared with the past averages for Lynchburg area streams. Data collected shows consistent levels of pool benthic insectivores which indicates fair water quality because on average these species are intolerant of change in their environment. Dreaming Creek's IBI score was lower than the average of Lynchburg streams but the stream itself still proved to be stable overall. Hollins Mill was given the highest IBI score of all streams sampled in 2010, it was scored 4.7 points higher than the Lynchburg stream average. This score improved since 2009 due to the abundance of darters and water column insectivores found during sampling this year.

Rock castle creek had an IBI score around the average of past scores. However we did notice a decrease in IBI score from 2009 to 2010. Looking closer at the data we see that there are much fewer darter species in 2010 than 2009 as well. This indicates loss of darter habitat (riffles) caused by sedimentation and erosion. Because Rock Castle creek is surrounded my many impervious surfaces that accompany urbanization, storm-water run-off is highly affecting the quality of Rock Castle Creek.

Peaksview Park also had some interesting data. IBI score from 2009 to 2010 remained the same. Looking back at previous years, we see that the IBI scores have been stable since a drop in 2006. Peaksview Park is also extremely embedded with sediment. Very few riffles were present leading to few little species diversity. Peaksview Park is also very wide relatively straight. This is an ideal place for sediment traveling downstream to settle in the streambed. Because of the streams stable IBI score and low species diversity, we witness that the stream has

been affected in some way but is still able to maintain a stable ecosystem. Thus, Peaksview is a resilient stream.

As far as Tomahawk goes, it received the lowest IBI score in 2010 and represented the biggest drop since 2009. This brings many warnings that this stream is in poor shape. Tomahawk contained many pools, riffles, and runs. Sedimentation and embeddedness were significant in some areas causing darters and water column insectivore numbers decrease from 2009 to 2010. Tomahawk contained improved numbers of pool benthic insectivores. This was largely in part to the large number of turns and meanders in the stream creating habitat suitable to these sunfish etc. Although the IBI score for Tomahawk is low it also shows the ability of streams to be resilient.

**Fish Analysis Conclusion**

The process of urbanization has a direct impact on surrounding creeks and streams. The floodplains of these waterways carry foreign objects and chemicals that drastically change the quality of the water and the health of its ecosystem. We hypothesized that urbanization has a negative effect on surrounding streams and our data as shown supports this.

According to the data our team acquired over three weeks of shock sampling streams; Rockcastle Creek is the most effected stream sampled. The total species number found in this creek was low which may be an indication of poor water quality. This also shows the least diversity of all sampled streams as well as the least populated. Past data collected from Rockcastle Creek shows that its IBI scores fluctuated from fair to poor for the past 5 years. The IBI score in the 2010 sampling of Rockcastle indicated good water conditions. This score was affected by the large number of darters found in the creek.

IBI data for the most part reflects the hypothesis that urbanization impacts biotic integrity negatively. Some of the most urbanized and impacted sites of the seven received very low scores. Such is the case with Tomahawk Creek, Dreaming Creek, and Ivy Creek at Peaksview Park. Hollins Mill on Blackwater Creek is one of the most impacted of the sites (lowest in the watershed, highest order) but suprisingly received a good score based. Possible reasons for this site's high biotic integrity rating could be due to the presence of a dam upstream, blocking the flow of pollutants, and good fish habitat (pools, riffles and runs, and woody debris and organic matter). It is encouraging to see that Blackwater Creek has shown good resilience, given its location low in the watershed, and Ivy Creek shows room for improvement. Agriculture, urbanization and other impacts have covered much of the fish habitat this site, and most of the high order sites (excluding Chaffin Farm) received low values for biotic integrity, and need to have better protection from anthropogenic disturbances and install BMPs.

## Conclusion

Urbanization is the primary factor contributing to the decrease in water quality throughout the Blackwater Creek watershed. Hollins Mill is located in the most urbanized area of the Blackwater Creek watershed yet was ranked as having the best water quality. Further examining the site, Hollins Mill incorporated BMPs (best management practices) which were not present in any of the other sites. The most notable BMP is the immense natural buffer that surrounds the stream. Untouched, forested slopes shield the stream from the majority of urbanization impacts. Therefore, it is essential to implement more BMPs throughout the Blackwater Creek Watershed to further improve water quality by helping to prevent the impacts of urbanization.

Best management practices are essential and can be implemented in a variety of ways. More commonly known techniques are detention ponds, retention ponds, and silt fences. Detention and retention ponds are extremely beneficial when dealing with excess runoff. These ponds are able to store water and then release it back to the aquifer. Detention ponds fluctuate more readily and are typically smaller than retention ponds. Retention ponds typically are surrounded by vegetation and are permanently filled with water. Silt fences are well known but are not necessarily that effective. Silt fences are designed to prevent the movement of sediment by trapping it behind webbed fabric. These are typically installed during construction. Yet, they are often installed incorrectly rendering them ineffective. Also, silt fences are designed to trap soil whose particle size is no smaller than silt. Yet, in Virginia, the soil is predominately clay which contains even smaller particles than silt. Therefore, the silt fences aren't even capable of fully securing sediment. Lesser known BMPs include benching, vanes, and biofiltration. Benching is extremely effective in restoring banks by allowing the stream to access its floodplain. Benching involves digging out the banks at certain intervals to create a stair step pattern than gradually rises to the floodplain. Throughout time, these dramatic steps will be eroded away and cause a natural slope allowing the stream bank to be in optimal condition. Vanes are structures built within the stream that slow the movement of water to prevent damaging effects to the stream bank. They are made out of resistant material such as large rocks and are typically located where the stream bends because of increased vulnerability. Finally, biofiltration is an extremely beneficial technique that utilizes certain plaints to trap sediment and remove harmful materials such as bacteria, metals, nutrients, and total suspended solids. One specific structure involving biofiltration is a filtera box. Filtera boxes are installed where storm drains would usually be put. When the water reaches the filtera box it is absorbed into the soil while the plant engrosses

harmful substances. The combination of these BMPs throughout the Blackwater Creek Watershed would greatly improve water quality by reducing excess runoff, removing harmful substances, and improving stream functionality.

There are two key components to implementing BMPs. The first is government intervention. The majority of the previous mentioned structures would require governmental funds and services. Though this would require excess money, it would also create more jobs to help stimulate the economy. The government is also essential in monitoring these BMPs. Rigorous guidelines must be enforced to ensure that realtors and contractors are up to code which will ensure their use of BMPs. The government should offer tax incentives for the implementation of BMPs as well as sustainable urbanization in general. The second is community awareness. Educating the public about the importance of BMPs and how they can greatly improve water quality is also essential. Encourage the public to do a service project, such as to help install a filtera system, or to help plant trees as buffers. A Blackwater Creek clean up day would be a great way to get the public to do their share in improving water quality throughout the Blackwater Creek watershed.

Finally, the greatest aspect to improving water quality throughout the Blackwater Creek Watershed is to constantly be keeping in mind the long term benefits. Instituting a 50 year plan to improve water quality would set the stage for the greatest benefits by using BMPs most effectively. Examine the possibility of floods, toxic spills, or even sewage bursts. The city needs to take these possibilities into account when deciding what BMPs to initiate. Through the physical, chemical and biological analysis of seven streams in the Blackwater Creek Watershed, it was determined that urbanization has an impact on water quality. However, with the proper use of BMP practices there was an increase in water quality even in an urbanized location.

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