2008 Blackwater Creek Watershed Water Quality Assessment

Freshwater Ecology 375 A

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INTRODUCTION

Purpose:

Our hypothesis is that urbanization degrades water quality within the watershed by introducing many problems such as erosion, sediment, overflow, and organic and inorganic pollutants. We will test chemical, biological, and physical assessments of six streams, to assess the impact of urbanization. Our hypothesis includes tests on spatial and temporal analyses; streams farthest from the urbanized sites show less impact over time, than the streams within the heart of city development.

Urbanization:

Urbanization is the destruction of the environment and natural habitat in order to create a city or similar developments in place of the natural habitat. Humans are constantly developing natural areas and causing the environment to change drastically in order to keep up with all the new changes. The problem with urbanization is exactly the fact that humans are changing the environment in an unfavorable way and there are many consequences that come from these changes in the environment. Humans must realize the detrimental effects that they are causing on the environment and must find ways to slow urbanization to allow the environment time to rebound.

Some of the problems that come out of urbanization are increased sedimentation, channelization, incised banks, increased water velocity, increased impervious surfaces, increased runoff, increased pollutants, and problems with controlling stormwater. As a site becomes developed the largest problem is in the construction phase because there is so much exposed soil that can be carried away very quickly, even in a small storm system. This increases the amount of sedimentation that will end up in the stream system. Sedimentation will destroy instream habitat for fish and other aquatic organisms, it will alter the water flow of a system, which also limits the different types of habitats that are present in the system, and sedimentation will fill in a stream very quickly to a point where the channel completely changes because of large sediment bars located in the stream channel.

Channelization is another problem that must be addressed when dealing with rapid urbanization. Channelization is really a result of many different factors that all lead back to the development of undisturbed areas. It all begins with an increase in the amount of impervious surfaces, which is simply any surface that does not absorb water. As a result of increased impervious surfaces there becomes a larger amount of runoff in a system and a higher velocity of water flow in a system. Runoff is all the materials that stormwater collects and carries down into the stream channel. Materials that are gathered by stormwater include sediment, pollutants, fertilizers, debris, and other wastes that are not properly maintained. Once all of these items reach the stream they begin to degrade the value of the stream immediately upon impact.

Impervious surfaces also have a tendency to channel all the water into one concentrated location before entering the stream system. One main method for channeling this water is through the curb-and-gutter system, where the water will land on the road or in a parking lot and then move to the curb until it runs underground to travel towards the stream. This is a very large problem because the water never slows down in the type of system so the amount of speed that is gained by the time the water reaches the stream channel is far greater than what the speed would be if the water was not channeled to one location. In result of the fast moving waters the banks in the stream channel become deteriorated very quickly. The banks are not built to control water that moves so quickly and the amount of water that moves through the stream channel is also far greater than without impervious surfaces. Increased impervious surfaces are the main cause of channelization in a stream channel because of how the water enters the channel. The amount of water is greater than what the natural environment would allow in and the speed the water is traveling is greater than what the stream channels are built to handle.

The amount of impervious surfaces would not be such a large problem if it was not for the amount of stormwater that each region receives. The stormwater is what really does the damage to the stream systems because that is where all the excess water comes from. Having proper stormwater systems set up throughout a city is very important in minimizing the amount of damage caused within the watershed. Some different examples of stormwater systems that could be used in an area are, ponds, wetlands, infiltration, filtering, and open channels (SMRC 2007). Any natural systems such as ponds or wetlands will definitely be better for the environment compared to open channels but the natural systems also have disadvantages because they do not relief the surface of the stormwater as well as other systems (SMRC 2007). Just like with anything else in the environment, there are many trade-offs that must be weighed before taking action, the only problem is most people do not see the negative effects of simple things such as stormwater until it is too late to fix.

The only way to get people to understand how valuable the environment is, is to set some type of grade or value to the environment. This is why keeping the environment healthy is so difficult because being able to set a value on the natural environment is almost impossible to do. People do not understand how valuable the environment is and unfortunately the majority of people only understand values through financial values and cannot understand any other type of value set on an object. So until there becomes a system that has set values on the environment, conservation and preservation projects will continue to become difficult to increase.

Table 1: Land Use Percentage in each Sub-watershed

#	Site Location	% Impervious	% Forest	% Ag	% Commercial	% Residential	% Total Urbanization = % Commercial + % Residential
1	Ivy Creek at Chaffin's Farm	1.52	53.3	42.1	4.6	0	4.6
2	Ivy Creek at Hooper Road	3.6	45.2	34.7	14.2	5.9	20.1
3	Dreaming Creek at McConville Road	15.45	19.6	16.9	25.2	38.2	63.4
4	Blackwater Creek at Hollins Mill	23.56	33.7	2.1	17.7	46.5	64.2
5	Ivy Creek at Peaksview Park	13.69	28.6	4.7	5.1	61.7	66.8
6	Rock Castle Creek at Cracker Barrell	21.96	23.3	6.9	36.1	33.7	69.8

This table is a perfect example of how humans are disturbing all the natural areas in various watersheds. This table gives definite numbers that refer to the amount of urbanization present in a watershed and as we predicted the larger the amount of urbanization in a watershed, the more the stream will degrade.

Land Use:

Land use is a classification of how the land has been developed and how it is currently being used. Some categories of land uses are forested, agricultural, residential, and commercial. We sampled six sites that represented different types land uses: Richard Chaffin Farm (Ivy Creek), Hooper Road (Ivy Creek), Cracker Barrel (Rock Castle Creek), Peaksview Park (Ivy Creek), Hollins Mill Dam (Blackwater Creek), and Heritage Funeral Home (Dreaming Creek). Each site was chosen based on level of human impacts and stream order. Richard Chaffin Mill presents a pastured/agricultural land use with a stream order of 2. Hooper Road exhibits residential and developing land with a stream order of 3. Heritage Funeral Home exhibits residential/commercial land uses with stream order of 3. Hollins Mill Dam demonstrates forested recreational/residential with a stream order of 5. Peaksview Park is made up of recreational/developing land uses and it is a 4^{th} order stream. Cracker Barrel demonstrates urbanized land with a stream order of 2. Poor land use can mean exposing the subsoil (in Virginia, clay) which is a large product of urbanization. Clay creates problems because it allows storm water to pour into streams without natural filtration by the soil, resulting in overflow and sheet flow (water flowing down the banks without hindrance). Instead, the water that flows into streams brings with it pollution and an overabundance of nutrients from surrounding banks. Clay is nonporous, creating filtration problems within the stream when large quantities are present. Clay competes with surrounding organisms by binding large amounts of phosphorous, an already limited and vital nutrient for animals and plants. Excess sedimentation in a stream, especially clay, greatly increases the amount of embeddedness in the stream channel. Embeddedness is the filling in of the stream substrate with different sediments entering the stream channel.

Physical Stream Assessments:

The Physical Stream Assessment is primarily a visual process where the conductor provides a variety of observations that help give the stream channel a score as to how healthy or stable that stream is. This assessment measures the riparian buffers, instream habitat, bank conditions, channel alterations, and channel conditions. The riparian buffers are measured on both banks, 100 feet out from the bank full mark. The bank full is the point where the water would rise to fill the stream channel but not overflow into the floodplain. The buffers are measured by the percentage of canopy cover present and the land use on each side of the stream channel. The instream habitat measures the amount of suitable habitat in the stream for organisms to live.

This includes different fish species, macroinvertebrate species, reptiles, and amphibians. Some examples of instream habitat are woody debris, leaf packs, riffles, and large pools. The bank conditions measure the stability of the banks on each side of the stream. This basically gives the reviewer a general idea of the cross section of the stream. Stable banks will have a slight slope up and away from the stream channel and have a very small amount of incisions. Unstable banks are severely undercut and in danger of collapsing into the stream channel. Finally the last measurement is the channel alterations, which measures the amount of human interference in the stream channel. This simply focuses on any signs of human impact on the stream channel, for example any stream crossings, sewage pipes, or dams in the stream would be taken into consideration.

These measurements have been standardized and are followed using Unified Stream Methodology (USM) forms. The USM form has these different measurements divided into different categories and gives a description of each score that the scientist can give the stream for that category. In general each category has an optimal grade, suboptimal, marginal, poor, and severe grade (U.S. Army Corps of Engineers 2007). Depending on the description of the score and how the evaluator feels about that particular reach of the stream, a score will be given. Having a standardized stream methodology system helps everyone understand the condition of the stream without even having to see it.

Chemical Assessment:

The easiest and most immediate way to measure water quality in a stream is through chemical assessment. Going out and measuring levels of dissolved oxygen, nitrogen, phosphorus, temperature, turbidity, and pH all provide a snapshot of the condition of the stream at the time of sampling and can yield very important information. The drawback of this technique is that it can only provide information about the health of the stream at that moment and cannot give any clues about the stream's condition in the past. Dissolved oxygen (DO) levels are an important measure of stream conditions. The amount of oxygen dissolved in the water directly affects aquatic organisms. If levels are low, these species will either leave the area if possible or suffer physically from the scarcity, resulting in weakness and eventually death. There are natural fluctuations in dissolved oxygen content found in a stream on a daily basis as well as on a seasonal basis. However, when a stream is impacted, dissolved oxygen levels can diminish rapidly.

Water temperature is also an important abiotic factor when considering stream health and goes hand-in-hand with DO levels. When temperature increases, levels of DO decrease. So temperature has an indirect effect on species through its effect on oxygen levels. Temperature also affects the rate of biological processes in aquatic organisms. Most species can only tolerate a limited range of temperatures in order to survive. While they can adapt to many natural fluctuations in temperature (such as those influenced by weather and diurnal changes), these species have a much harder time adapting to the temperature changes induced by human activities. Destruction of riparian buffers and clearance of canopy cover for streams causes increased exposure to sunlight which in turn causes higher water temperatures. Introduction of cool water sources also impact a stream's temperature.

Measuring the turbidity and pH of a stream is also important. Turbidity is a measure of the amount of sediment (such as silt, clay, or sand) suspended in a stream or other body of water (Closs 2004, 62). When turbidity is high, sediments cause the water to be murky which prevents sunlight from reaching certain depths in a stream and can cause temperatures in a stream to increase. Sediments such as clay tend to stay suspended in water for longer periods of time because of the small particle size of the sediment (Swackhammer 2003). In geographic regions where the subsoil is mainly comprised of clay, sedimentation also competes for phosphorus, a limiting nutrient for aquatic organisms. Ranked on a scale from 1 to 14, pH measures the acidity or alkalinity of a stream. A large portion of aquatic organisms prefer and can only survive in an environment between pH levels of 6.5 and 8.0 (where neutral is 7). If waters deviate from this range, many aquatic organisms can't survive. Consequences of deviations in pH are reduced reproductive rates and reduction in biodiversity. Changes in pH can be caused by input of wastewater, acid rain, and rock deposition (leaching minerals into the water).

Two nutrients that have significant effects on stream conditions are nitrogen and phosphorus. Both are essential nutrients for plants and animals, decreasing in the bioavailability of these nutrients can have huge negative impacts on stream health. Excess amounts of these nutrients can also create major problems for plants and animals. Human sources of nutrient input include runoff from fertilizers, sewage overflow, and wastewater discharge. By testing the stream for the presence of these nutrients, we can determine whether levels are out of balance and, if so, try to ascertain what the sources of imbalance are.

Biological Assessment:

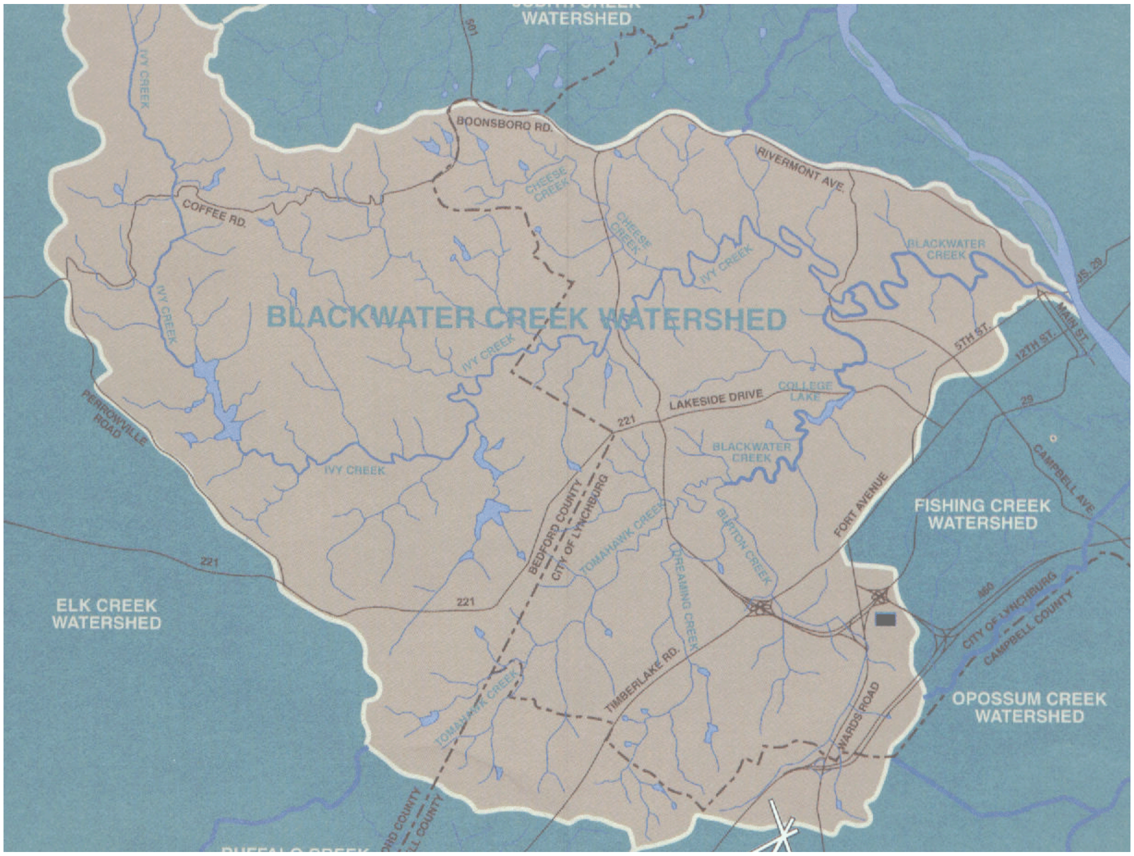
A good indicator of a stream's health is the amount and diversity of aquatic life present. In particular, the presence or absence of certain macro invertebrates and fish tells us what kind of conditions (i.e., how much pollution) has persisted in streams. Biological surveying of these species provides us with information that chemical assessment of a stream cannot. Chemical assessment can only supply us with information about the condition of the stream at the moment we test it; whereas biological assessment of a stream can tell us about the levels of pollution that have been present over a longer period of time (i.e. months to years). This is because organisms such as fish and macroinvertebrates spend their whole lives in a stream and cannot escape the pollution introduced into it. Therefore, their presence and level of health can tell us what kind of environmental conditions they have experienced in their lifetimes.

Biologists have created four different metrics to measure water quality in terms of the biological organisms found: (1) Family Biotic Index (FBI), (2) Species Richness, (3) EPT Index, and (4) Percent Model Affinity (PMA). We use all these indices to assess the health of the six streams we sampled. Family Biotic Index (FBI) is a measure of the sensitivity of specific macroinvertebrates to pollution. Sensitivity values have been assigned to each macroinvertebrate species or family based on their level of sensitivity, ranging from 0 (extremely sensitive) to 10 (very tolerant). Based on the number and variety of species found during sampling, the FBI index value can be determined for the stream to rate its level of pollution. Species Richness simply measures the total number of species or families in a stream. The greater the diversity of species, the healthier the stream. EPT is a measure of the number of families of Ephemeroptera (Mayflies), Plecoptera (Stoneflies), and Trichoptera (Caddisflies) in a stream. As with species richness, the greater the number of families present, the better the health of the stream. Finally, Percent Model Affinity (PMA) is a comparison of the proportions of species found in a sampled stream to the proportions known to be found in an unimpacted, healthy stream. The higher the PMA value, the more similar the proportions (calculated as percentages) are to a healthy stream. By using all four of these indices, we are able to assess stream quality from slightly different angles and can therefore more accurately judge the true health of a stream.

Like macroinvertebrates, fish are known as integrators of their environment. But because fish can travel so much further than macroinvertebrates in a stream, they can tell us more about the water quality of a stream over a longer period of time. Essentially, they provide us with a broader picture of the impacts a stream is experiencing. When making an analysis of our data collected during fish sampling, we use what is called the Index of Biological Integrity (IBI) to describe the condition of a stream. This index includes a total of nine measurements of fish species in a stream: (1) The total number of fish species present, (2) total number (or relative percent) of darter species to the total, (3) total number (or relative percent) of water column insectivores present, (4) total number (or relative percent) of pool-benthic insectivores, (5) total number (or relative percent) of intolerant species, (6) relative abundance of tolerant species, (7) relative abundance of omnivores or generalist feeders, (8) relative abundance of top carnivores, and (9) deviation from ideal (or number of individuals in a sample). These nine measurements provide enough information about the fish population within the streams to accurately assess the water quality.

Watershed:

Our study consisted of the Blackwater Creek watershed located in Lynchburg City, as well as the surrounding counties of Campbell and Bedford, Virginia (Figure 1.). The Blackwater Creek watershed empties into the James River, and ultimately the Chesapeake Bay. The Blackwater Creek watershed spans 42,000 acres (170 km2) (Shahady, 2006). Within the watershed, four main rivers were analyzed: Ivy Creek, Rock Castle Creek, Blackwater Creek, and Dreaming Creek. Dreaming Creek flows throughout the urbanized portions of Lynchburg City, forming a 3rd order stream (Shahady, 2006). Blackwater Creek, first merges with Dreaming, Tomahawk, and Burton Creek, which forms a 4th order stream before flowing into College Lake (Shahady and Fitzsimmons, 2008). Ivy Creek flows throughout Bedford County, starting out with 1st to 2nd orders and merges with Blackwater Creek eventually forming a 5th order stream just before draining into the James River (Shahady and Fitzsimmons, 2008).



METHODS

Physical Assessment:

A physical stream assessment is a great way to start to determine what the health of the stream you are analyzing is. 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 decreasing.

Upon performing the stream walks we implemented a new method of analyzing the streams. The Unified Stream Methodology (USM) is a new format that is becoming universally used throughout Virginia. Upon completing the USM you are able to see how all of the different parameters are affected and you can determine the overall health of the stream.

So upon performing the physical stream assessment there are four main parameters that were noted, Channel Condition, Riparian Buffers, In-stream Habitat, and Channel Alteration. Upon arriving at each of the six different stream sites a GPS reading was taken at both the top or bottom of the reach and the width of the stream channel was measured. When measuring the width one end of the tape measure was placed on the top of the stream bank at the bankfull mark and measured across to the other bankfull mark. Once the width was determined it was then multiplied by 30 to determine the reach that we were going to sample. For example at stream that is 20 feet wide would have a reach of 600 feet long because this gives the correct ratio between the reach length and the size of the stream.

The next step was to perform the stream walk and take note of the Channel Condition, Riparian Buffers, In-stream Habitat, and Channel Alteration. Upon noting the conditions of these criteria we completed the USM form that had been provided and each of these criteria received 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, the 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 herbaceous 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 habitat dealt with things such as the pools, runs, and riffles, in the stream as well as types of substrate, woody and leaf debris, the velocity and depth of the water, root mats, the shade, and the embeddedness of the substrate. Channel alteration is the assessment of how the channel has been altered by bridges, pipes, livestock, riprap, etc. 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 us a visual record of the streams physical conditions. 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 reflects the health of the stream.

Chemical Sampling:

Before we began sampling, we calibrated each instrument according to the tests each piece of equipment could perform. For the YSI 60, which read pH and temperature, we allowed the temperature to stabilize and then using known pH buffers we calibrated the equipment to read properly. We used Hach Singlet pH buffer solution of 7.0 and 4.01 and Orion Application Solution 910110 pH 10.01. For the YSI 85, we allowed the meter to stabilize and then used a known conductivity solution, Hach Sodium Chloride Standard Solution, to calibrate conductivity. To calibrate dissolved oxygen we entered the altitude, 600 meters, into the meter and allowed it to stabilize. For the Turbidity meter, HI 93703 Microprocessor Turbidity Meter, we filled the vial with deionized water, placed it into the meter and allowed it to run. The reading would come up as 0.000.

On March 27, 2008, we sampled four sites starting at 14:00 to 16:00. For sampling on the first day, we measured the temperature and pH first using an YSI 60 meter. The YSI 85 meter is used by placing the probe completely in the water and allowing the temperature and pH to stabilize on the screen. Once the measurements stabilized, we recorded the data. Following measuring temperate and pH, we measured, dissolved oxygen (DO) in percentage and in mg/L and conductivity (μS) using an YSI 85 meter. The YSI 85 meter is used by placing the probe completely in the water and allowing the current screen to stabilize. We then recorded the data. We also measured turbidity using a HI 93703 Microprocessor Turbidity Meter. To measure turbidity, we rinsed a small vial with deionized water and then placed it into the water to collect a 10 mL sample. We then wiped the vial to make it completely dry and remove all fingerprints. We then placed the vial into the meter and covered it and allowed it to read. Finally, we collected two water samples per site using aseptic method in order to prevent contamination. Each bottle was labeled with the following information: date and time, location and our names. An accurate weather forecast was also obtained before each site was sampled in order to assure that each creek was similar in weather conditions when we sampled. We collected the four samples from Heritage Funeral Home (Dreaming Creek), Peaks View Park (Ivy Creek), Hollins Mill Dam (Blackwater Creek) and Cracker Barrel (Rock Castle Creek). We placed one bottle of water from each sample into the refrigerator for further analysis. The second sample bottle was placed in the freezer in case more sample was needed. Upon reflection with the team, we discovered that we sampled the wrong section of Dreaming Creek. Due to this, we collected another correct sample from Dreaming Creek on April 3, 2008.

On March 31, 2008, we sampled the remaining two sites from 13:50 and 15:30. We followed the same procedure used on March 27, 2008. Samples were collected from: Hooper Road (Ivy Creek) and Chaffin Farm (Ivy Creek).

On April 3, samples were collected from the correct location in Dreaming Creek at 10:15. We followed the same procedure used on March 27, 2008.

After sampling, we used the Phosphorus, Total, Test ‘N Tube Reagent Set Hach Method 8190 to determine the concentration of phosphate in the water samples. Also after sampling, we used the Hach Method 10020, Chromotropic Acid Method, Test `N Tube to analyze nitrate.

Macroinvertebrates Sampling:

In an effort to collect and provide comprehensive macroinvertebrate data for the 2008 Blackwater Creek Watershed Study, samples were taken at specific sites chosen for the purposes of consistency with studies conducted in previous years. The following areas were sampled on Friday, March 21, 2008: Rock Castle Creek at Cracker Barrel, Ivy Creek at Peaksview Park, and Blackwater Creek at Hollins Mill Dam. The following areas were sampled on Saturday, March 22, 2008: Ivy Creek at Richard Chaffin Farm and Ivy Creek at Hooper Road. The following area was sampled on Monday, March 31, 2008: Dreaming Creek at McConville Road.

Within each of the areas named above, one sample was taken from three different riffle habitats within each reach in order to maximize diversity of the macroinvertebrates. Each sample was taken using a Hess Sampler because it offers a constant surface area of 0.1 m^2 per sample. A kick screen may have allowed for collecting a sample that might have possibly been richer in species, yet consistent Hess sampling was the logical choice given the scope and time constraints of the project. The specimens collected were preserved in 70% ethanol for later identification.

Identification of the macroinvertebrates contained in each sample was conducted (Voshell 2002). Once identified, data collected was entered into spreadsheets. The metrics calculated were Family Biotic Index (FBI), Ephemeroptera Plecoptera Trichoptera (EPT) Index, and Percent Model Affinity (PMA). Each type of metric has advantages and disadvantages.

The Family Biotic Index (FBI) is an index (0-10 scale) that was developed based on the sensitivities of specific macroinvertebrates to organic pollution (Hilsenhoff 1988). In the FBI, the lower the number means the better the water quality. "Excellent" water quality suggests that "organic pollution is unlikely"; a "very good" water quality suggests that there is "possible slight organic pollution"; a "good" water quality suggests that there is "some organic pollution"; a "fair" water quality suggests that "fairly substantial pollution is likely"; a "fairly poor" water quality suggest that "substantial pollution is likely"; a "poor" water quality suggests that "very substantial pollution is likely"; and a "very poor" water quality suggests that there is "severe organic pollution" (Hilsenhoff 1988). Yet the FBI does not distinguish well and tends to be too absolute assigning a "good" value for present species and a "bad" value if species are not present.

The Ephemeroptera Plectoptera Tricoptera (EPT) Index uses three pollution intolerant families to assess the water quality. The EPT measurement has expected ranges where greater than 10 indicates that the water quality is "excellent and non-impacted", 6-9 indicates "good water quality that is slightly impacted", 2-5 indicates "fair water quality with moderate impacts", and 0-1 suggests the water quality is "poor with severe impacts" (Lenat 1988). A problem with the EPT Index is it provides a measure for only three families and some species within each family are not necessarily good indicators, such as the burrowing mayfly with lives within the sediment.

The final measurement, the Percentage Model Affinity (PMA) measures similarities to a non-impacted stream community but is limited in theory. The PMA measurement has expected ranges where greater than 64 indicates that the water quality is "excellent and non-impacted", 50-64 indicates "good water quality that is slightly impacted", 35-49 indicates "fair water quality with moderate impacts", and less than 35 suggests the water quality is "poor with severe impacts" (Novak and Bode 1992).

Fish Sampling:

The freshwater fish assessment was conducted on three different days. On March 22, 2008, samples were taken from Ivy Creek at Hooper Road and Ivy Creek at Chaffin farm. On March 27, 2008, samples were taken from Rock Castle Creek and Dreaming Creek. The last two samples were taken on April 4, 2008, from Ivy Creek at Peaksview Park and Blackwater Creek. Samples were taken using a Smith-Root backpack electrofisher and a team of 4 or 5 people. The person with the electrofisher should slowly wade upstream, moving from bank to bank as they shock. The four people netting the fish should position themselves to not interfere with the shocking, but be able to efficiently collect all the fish. Two people will follow along with the head end of the electrofisher, while the other two people will watch the tail end for floating fish as well as carry the buckets for containing netted fish. Time of shock should be watched and recorded for approximately 30 minutes, or until there is a sufficient amount of fish to adequately make a judgment of water quality. Once the shock was completed, the fish were identified using the *Freshwater Fishes of the Carolinas, Virginia, Maryland, and Delaware* by Rhode et. al. The specific species and quantity of fish collected were recorded at each site.

After all the fish were recorded and totaled, the data was entered into a spreadsheet that calculated specific numbers used to determine the Index of Biological Integrity (IBI). This test consists of nine different measurements including: total number of fish species, relative percent of darter species to the total, number/relative percent of water column insectivores, total number/relative percent of pool-benthic insectivores, total number/relative percent of intolerant species, relative abundance of tolerant species, relative abundance of omnivores or generalist feeders, relative abundance of top carnivores, and the total number of fish. Each measurement will be graded between zero and five. Zero depicts a stream that is significantly impacted and a five signifies a stream that has very little human impact.

Catch per unit effort was used to standardize the quantity of fish that were caught between all six stream sites. This is done by multiplying the length of time the shock occurred by a number that will give an even sixty minutes. The same number will then be multiplied by the total amount of fish that were caught.

RESULTS

Physical Assessment:

Table 1: Overall Scores for Physical Assessment

Site	Channel condition	Riparian Buffer	Instream Habitat	Channel Alteration	Over all Score
Chaffin Farm	Fair	Fair	Good	Good	Fair
Hooper Road	Poor	Excellent	Good	Fair	Fair
Dreaming Creek	Fair	Good	Good	Fair	Fair
Hollins Mill	Fair	Fair	Good	Fair	Fair
Peaks view	Poor	Poor	Bad	Poor	Poor
Rock Castle	Poor	Poor	Fair	Poor	Poor

The data in Table 1 shows how each stream site scored based on the completion of the USM form. The data we gathered showed us that Chaffin Farm, Hooper Road, Dreaming Creek, and Hollins Mill all had an overall score of Fair while Peaks View (Ivy Creek) and Rock Castle had overall scores of Poor.

Figure 1: Overall Scores for Physical Assessment

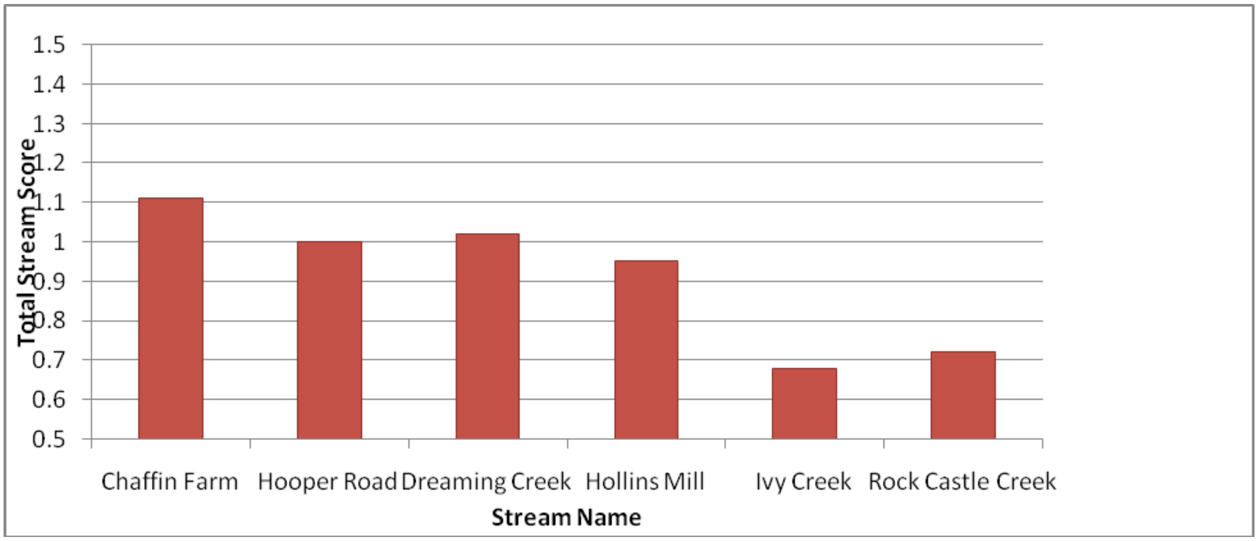


Figure 1 shows the numeric score that each stream received from the USM results.

Figure 2: Stream Characteristic Scores

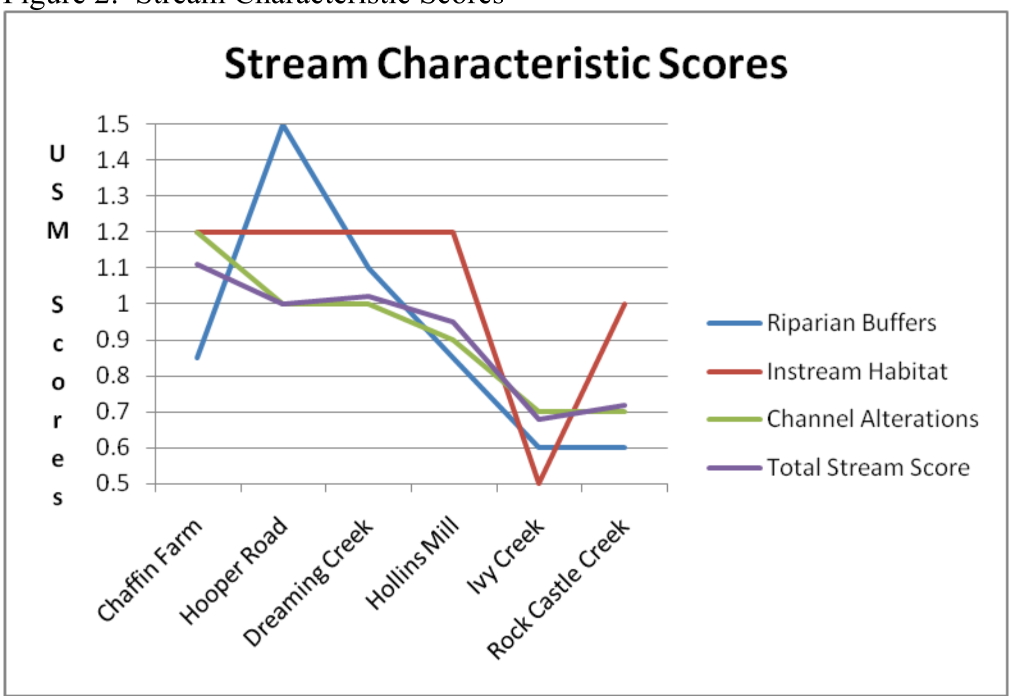


Figure 2 shows how each site scored on the USM form for Riparian Buffer, Instream Habitat, and Channel Alteration and well as showing the overall score.

Figure 3: Channel Condition

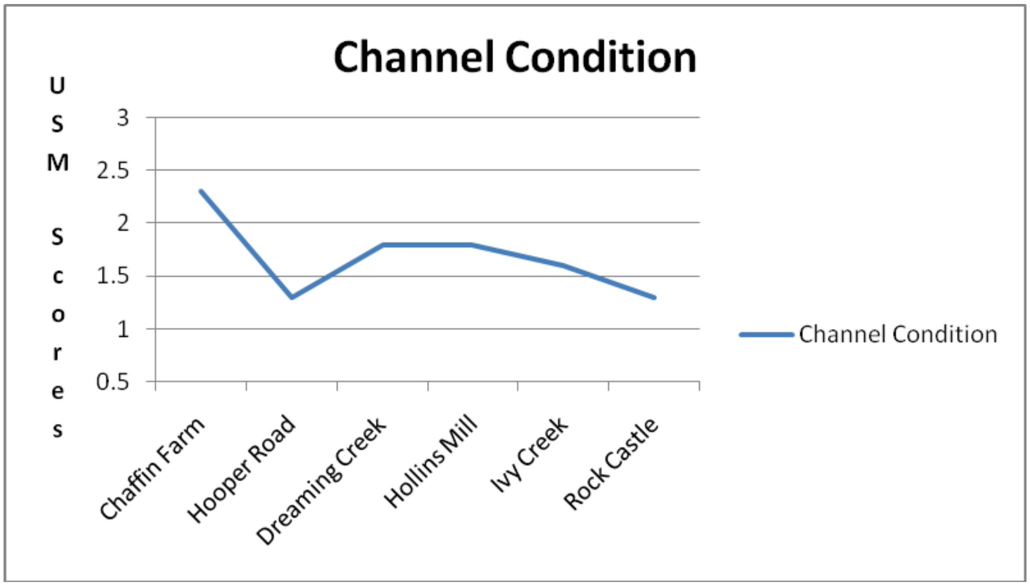


Figure 3 shows how each Stream scored on Channel Condition for the USM form.

Chemical :

Chaffin's Farm (Ivy Creek)-Agricultural

Chaffin's Farm is an agriculture area located off Tabernacle Lane, Route 781. The pH was recorded as 7.06, which indicates an excellent overall assessment (Table 5). Conductivity was 34.8 µS, which also indicated excellent water quality (Table 6). Turbidity for the site was fair which was readings of 35.47 NTU (Table 3). The stream had a temperature of 9.1 C. This should have a DO range (in mg/L) between 11.55 and 11.27 (Laboratory Manuel 18). Our site had a DO (in mg/L) of 12.7, this indicates more oxygen is being produced than consumed. The overall DO percentage was 109.6, which did indicate excellent water quality (Table 1). After returning to the lab, both the nitrate and phosphate testing came to the conclusion the water quality for Chaffin's Farm was good. Nitrate was 0.86782 ppm and phosphate was 0.14326 ppm (Table 7). Both nitrate and phosphate indicated good water quality (Table 2, Table 4).

Hooper Road (Ivy Creek) – Residential/Developing

Hooper Road is a forested/pasture area, however, it is located near a residential area. The pH was measured to be 8.36, which indicated good water quality (Table 5). This stream had a temperature of 10.5˚C. This should have a DO range (in mg/L) between 11.27 and 11.01 (Laboratory Manuel 18). Our site had a DO (in mg/L) of 12.81, which indicates good water quality (Table 1). Conductivity was measured at 46.6 µS, which indicated excellent water quality (Table 6). Turbidity for this site was measured at 27.85 NTU, which indicated fair water quality (Table 3). Nitrate was measured to be 0.8230789 ppm, which indicated good water quality (Table 2). Phosphate was measured to be 0.14326 ppm, which indicated good water quality (Table 4).

Dreaming Creek- Residential/Commercial/Urbanizing

Dreaming Creek is located near the Heritage Funeral Home. The pH was measured to be 7.16, which indicated excellent water quality (Table 5). This stream had a temperature of 10.15˚C. This should have a DO range (in mg/L) between 11.27 and 11.01 (Laboratory Manuel 18). Our site had a DO (in mg/L) of 10.99, which indicated excellent water quality (Table 1). Conductivity was measured at 125.0 µS, which indicated fair water quality (Table 6). Turbidity was measured to be 45.98 NTU, which indicated fair water quality (Table 3). Nitrate levels were measured to be 0.42051 ppm, which indicated excellent water quality (Table 2). Phosphate was measured at 0.05556 ppm, which indicates excellent water quality (Table 4).

Hollins Mill Dam (Blackwater Creek)-Forested Recreational/Residential

Hollins Mill Dam is located in downtown Lynchburg, off Hollins Mill road. Temperature was measured to be 13.8 C. The pH was measured to be 7.96, which indicates good water quality (Table 5). The DO (in mg/L) for a temperature of 13.8 should be in a range of 10.52 and 10.29 (Laboratory Manuel 18). Our actual DO was recorded as 10.72 mg/L, and the percentage was 103.7, which indicates excellent water quality in this specific area (Table 1). Conductivity was recorded at 130.6 µS, which indicated fair water quality (Table 6). Turbidity was recorded at

45.77 NTU, which indicated fair water quality (Table 3). Nitrate levels were measured to be 0.4428755 ppm, which indicated excellent water quality (Table 2). Phosphate was measured to be 0.06433 ppm, which indicated excellent water quality (Table 4).

Peaks View Park (Ivy Creek)-Recreational/Developing

Peaks View Park is a suburban area located off Wiggington Road in Lynchburg. Temperature was recorded at 15.0 C, and a pH of 7.81, which indicates good water quality (Table 5). For this recorded temperature range, we could expect a dissolved oxygen level of 10.07 mg/L (Laboratory Manuel 18). Our actual DO was recorded as 11.58mg/L, and a percentage of 114.0, which indicated good water quality (Table 1). Conductivity was measured at 79.7 μS, which indicates good water quality (Table 6). The turbidity was measured to be 38.99 NTU, which indicated fair water quality (Table 3). Nitrate for Peaks View Park was measured at 1.538785 ppm which indicates a poor level (Table 2). Phosphate was measured to be 0.12572 ppm which indicated good water quality (Table 4).

Cracker Barrel (Rock Castle Creek) - Urbanized

Rock Castle Creek is located at the edge of the Cracker Barrel, Wal-mart and Sam's Club parking lots. The stream had a pH of 7.8, which indicated good water quality (Table 5). The temperature was recorded at 18.8˚C. This should have a DO range (in mg/L) between 9.45 and 9.26 (Laboratory Manuel 18). Our site had a DO (in mg/L) of 9.57 and 66.1 % DO, which indicated poor water quality (Table 1). Conductivity was measured to be 253.6 μS, which indicated poor water quality (Table 6). Turbidity was measured at 32.5 NTU, which indicated fair water quality (Table 3). Nitrate levels were measured at 0.286317 ppm, which indicated excellent water quality (Table 2). Phosphate was measured to be 0.12572 ppm, which indicated good water quality (Table 4).

Table 1: Percent Dissolved Oxygen (2008)

Rating	Excellent 90-110	Good 110-120	Fair 120+	Poor <70
	Sufficient Oxygen	80-90 Fairly Sufficient oxygen	70-80 Too much oxygen	Insufficient amount to support biological respiration

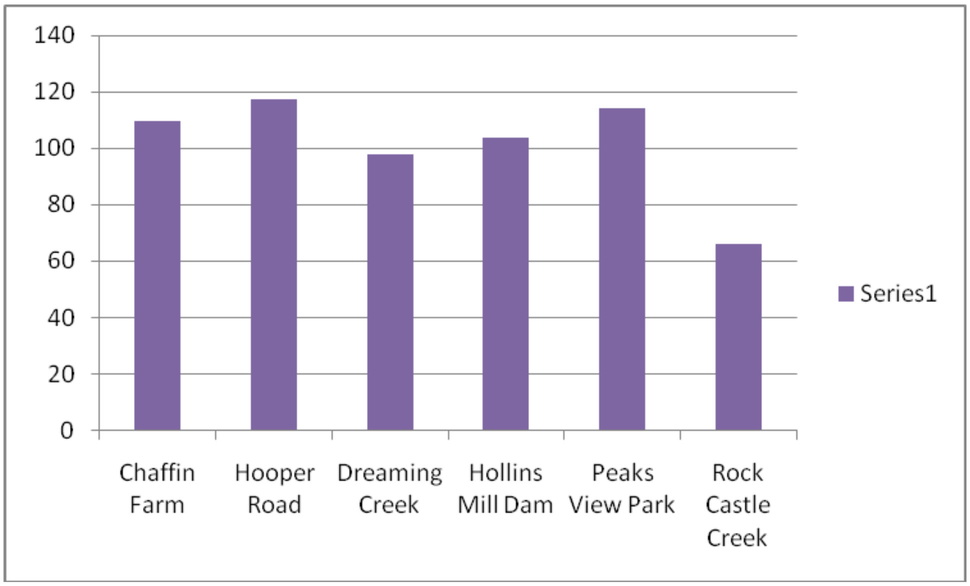


Figure 1: Dissolved oxygen in percent. The x axis shows the sites. The y axis shows the percent dissolved oxygen.

Table 2: Total Nitrate (ppm) (2008)

0.00-0.7 mg/L	Excellent
0.7-0.9 mg/L	Good
0.9-1.0 mg/L	Fair
greater than 1.0 mg/L	Poor

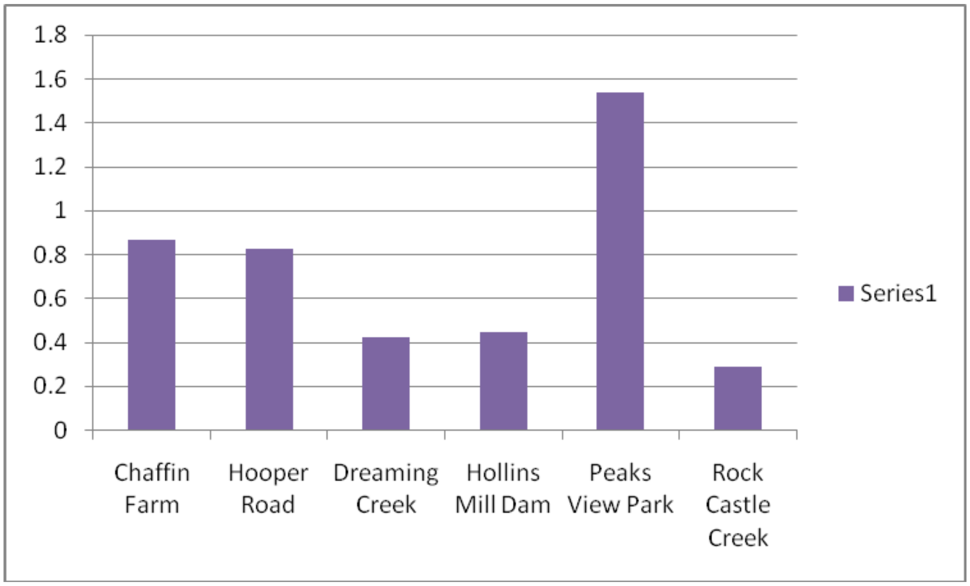


Figure 2: Nitrate levels (ppm). The x axis shows the sites. The y axis shows the concentration of nitrate in ppm.

Table 3: Turbidity (NTU) (2008)

0-10.0	Excellent
11.0-25.0	Good
26.0-50.0	Fair
> 50.0	Poor

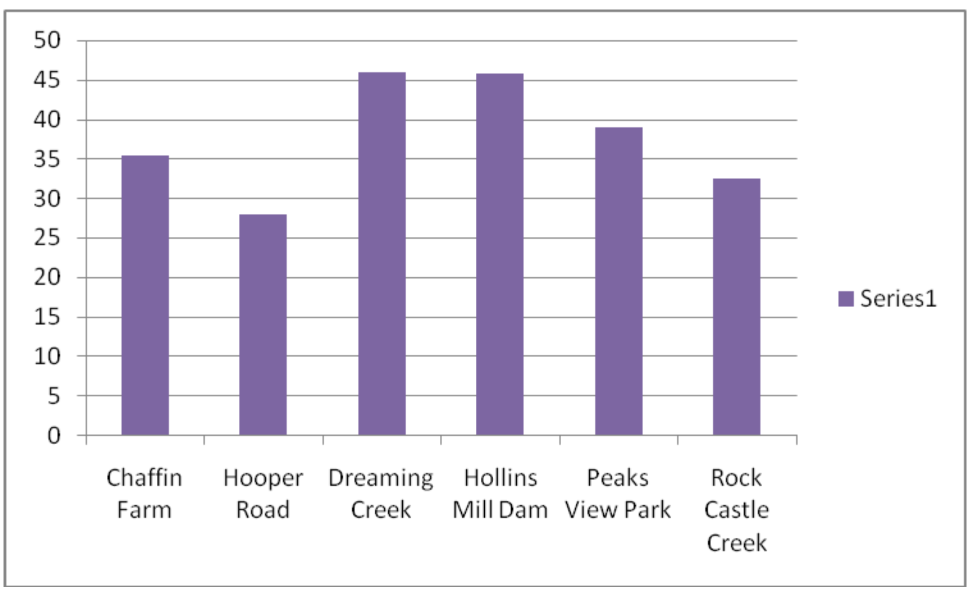


Figure 3: Turbidity (NTU). The x axis shows the sites. The y axis shows the turbidity level in NTU.

Table 4: Total Phosphate (ppm) (2008)

0.0-0.1	Excellent
0.11-0.2	Good
0.21-0.5	Fair
>0.5	Poor

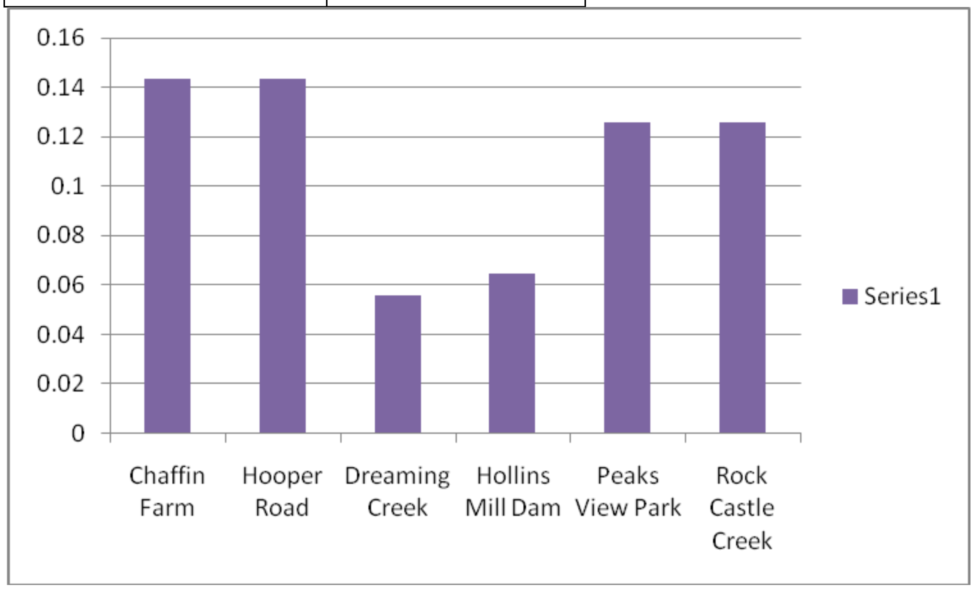


Figure 4: Phosphate levels (ppm). The x axis shows the sites. The y axis shows the total concentration of phosphate in ppm.

Table 5: pH (2008)				
	Excellent	Good	Fair	Poor
Ratings	6-7.5	5-6 or 7.6-8.6	4.5-4.9 or 8.7-9.1	<4.4 or 9.27

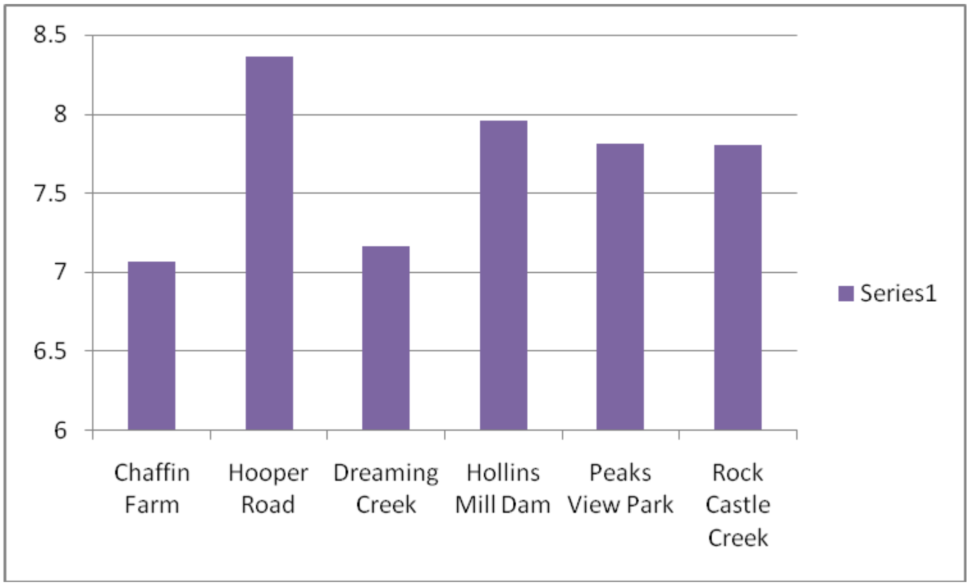


Figure 5: pH. The x axis shows the sites. The y axis shows the pH.

Table 6: Conductivity (µS)(2008)				
	Excellent	Good	Fair	Poor
Ratings	0-50	50-100	101-200	>201

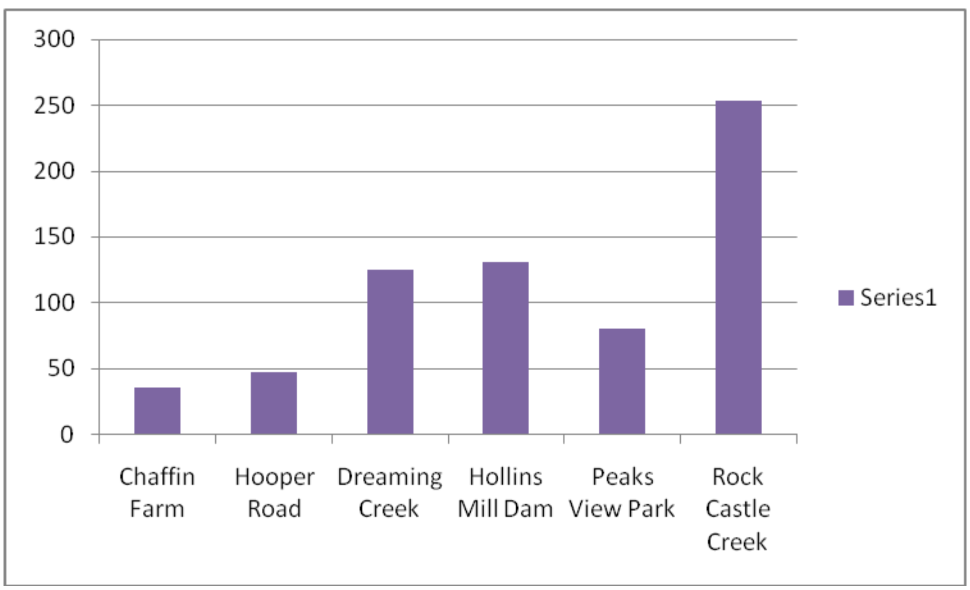


Figure 6: Conductivity (µS). The x axis shows the sites. The y axis shows the conductivity in µS.

Table 7: Measurements of Water Quality (2008)

	pH	Conductivity (µS)	Turbidity (NTU)	% Dissolved Oxygen	Nitrate (ppm)	Phosphate (ppm)
Chaffin Farm	7.06	34.8	35.47	109.6	0.86782	0.14326
Hooper Road	8.36	46.6	27.85	117.2	0.823089	0.14326
Dreaming Creek	7.16	125.0	45.98	97.9	0.42051	0.05556
Hollins Mill Dam	7.96	130.6	45.77	103.7	0.4428755	0.06433
Peaks View Park	7.81	79.7	38.99	114.0	1.538785	0.12572
Rock Castle Creek	7.8	253.6	32.5	66.1	0.286317	0.12572

To determine actual health, a scale and averages were used:
Excellent = 4
Good = 3
Fair = 2
Poor = 1
0.0-0.49 rounded down, 0.5-0.99 rounded up.

Table 8: Ranges of Water Quality (2008)

	pH	Conductivity (µS)	Turbidity (NTU)	% Dissolved Oxygen	Nitrate (ppm)	Phosphate (ppm)
Chaffin Farm	Excellent	Excellent	Fair	Excellent	Good	Good
Hooper Road	Good	Excellent	Fair	Good	Good	Good
Dreaming Creek	Excellent	Fair	Fair	Excellent	Excellent	Excellent
Hollins Mill Dam	Good	Fair	Fair	Excellent	Excellent	Excellent
Peaks View Park	Good	Good	Fair	Good	Poor	Good
Rock Castle Creek	Good	Poor	Fair	Poor	Excellent	Good

Table 9: Expected vs. Actual Stream Health (2008)

Site	Land Use	Expected Stream Health	Actual Steam Health (2008)
Chaffin Farm	Pastured	Excellent	Good
Hooper Road	Residential (Developing)	Good	Good

Dreaming Creek	Residential/Commercial (Urbanizing)	Poor	Good
Hollins Mill Dam	Forested recreational/Residential	Good	Good
Peaks View Park	Recreational/Developing	Fair	Good
Rock Castle Creek	Urbanized	Poor	Fair

Table 10: Average Measurements of Water Quality (Over the Past 5 Years)

	pH	Conductivity (µS)	% Dissolved Oxygen	Nitrate (ppm)	Phosphate (ppm)
Chaffin Farm	7.16	29.1	101.7	0.147817	0.482464
Hooper Road	7.63	38.5	104.8	0.385913	0.058554
Dreaming Creek	7.45	157.0	100.3	0.693452	-0.00244
Hollins Mill Dam	7.65	138.3	108.7	0.098214	0.012809
Peaks View Park	7.18	76.4	98.4	-0.25893	0.058554
Rock Castle Creek	7.56	178.0	104.2	0.058532	0.018908

To determine actual health, a scale and averages were used for Table 11 and Table 12:
Excellent = 4
Good = 3
Fair = 2
Poor = 1
0.0-0.49 rounded down, 0.5-0.99 rounded up.

Table 11: Ranges of Water Quality (Over the Past 5 Years)

	pH	Conductivity (µS)	% Dissolved Oxygen	Nitrate (ppm)	Phosphate (ppm)
Chaffin Farm	Excellent	Excellent	Excellent	Good	Fair
Hooper Road	Good	Excellent	Excellent	Excellent	Excellent
Dreaming Creek	Excellent	Fair	Excellent	Excellent	Excellent
Hollins Mill Dam	Good	Fair	Excellent	Excellent	Excellent
Peaks View Park	Excellent	Good	Excellent	Excellent	Excellent
Rock Castle Creek	Good	Fair	Excellent	Excellent	Excellent

Table 12: Actual Stream Health (Over the Past 5 Years)

Site	Land Use	Actual Steam Health Average
Chaffin Farm	Pasture	Excellent
Hooper Road	Forest/Pasture	Excellent
Dreaming Creek	Restoration	Excellent
Hollins Mill Dam	Recovery	Good
Peaks View Park	Suburban	Excellent
Rock Castle Creek	Urban	Good

Macroinvertebrates:

Table 1: FBI, EPT, and PMA values. The highlighted areas correspond to the scores received for the FBI, EPT, and PMA values for each of the sampled areas in 2008.

Ivy Creek at Chaffin Farm

Water Quality	FBI	EPT Index	PMA
Excellent	.00-3.75	>10	>64
Very Good	3.76-4.25	-	-
Good	4.26-5.00	6-9	50-64
Fair	5.01-5.75	2-5	35-49
Fairly Poor	5.76-6.5	-	-
Poor	6.51-7.25	0-1	<35
Very Poor	7.26-10	-	-

Ivy Creek at Hooper Road

Water Quality	FBI	EPT Index	PMA
Excellent	.00-3.75	>10	>64
Very Good	3.76-4.25	-	-
Good	4.26-5.00	6-9	50-64
Fair	5.01-5.75	2-5	35-49
Fairly Poor	5.76-6.5	-	-
Poor	6.51-7.25	0-1	<35
Very Poor	7.26-10	-	-

Dreaming Creek at McConville Road

Water Quality	FBI	EPT Index	PMA
Excellent	.00-3.75	>10	>64
Very Good	3.76-4.25	-	-
Good	4.26-5.00	6-9	50-64
Fair	5.01-5.75	2-5	35-49
Fairly Poor	5.76-6.5	-	-
Poor	6.51-7.25	0-1	<35
Very Poor	7.26-10	-	-

Blackwater Creek at Hollins Mill Dam

Water Quality	FBI	EPT Index	PMA
Excellent	.00-3.75	>10	>64
Very Good	3.76-4.25	-	-
Good	4.26-5.00	6-9	50-64
Fair	5.01-5.75	2-5	35-49
Fairly Poor	5.76-6.5	-	-
Poor	6.51-7.25	0-1	<35
Very Poor	7.26-10	-	-

Ivy Creek at Peaksview Park

Water Quality	FBI	EPT Index	PMA
Excellent	.00-3.75	>10	>64
Very Good	3.76-4.25	-	-
Good	4.26-5.00	6-9	50-64
Fair	5.01-5.75	2-5	35-49
Fairly Poor	5.76-6.5	-	-
Poor	6.51-7.25	0-1	<35
Very Poor	7.26-10	-	-

Rock Castle Creek at Cracker Barrel

Water Quality	FBI	EPT Index	PMA
Excellent	.00-3.75	>10	>64
Very Good	3.76-4.25	-	-
Good	4.26-5.00	6-9	50-64
Fair	5.01-5.75	2-5	35-49
Fairly Poor	5.76-6.5	-	-
Poor	6.51-7.25	0-1	<35
Very Poor	7.26-10	-	-

In Table 1, the data from the FBI for our locations shows that Rock Castle Creek at Cracker Barrel and Ivy Creek at Hooper Road have a “very poor” quality while Blackwater Creek at Hollins Mill Dam and Ivy Creek at Chaffin Farm have the highest quality. Data from the EPT measurement for our locations shows that Blackwater Creek at Hollins Mill Dam and Chaffin Farm have “good” water quality while Rock Castle Creek at Cracker Barrel has “poor” water quality. Most of other sites were in the “fair” classification. The PMA measurement data for our locations shows that Ivy Creek at Chaffin Farm has "good" water quality while Rock Castle Creek at Cracker Barrel has "poor" water quality. For the most part the other sites were in the "fair" classification.

Overall assessment based only on macroinvertebrate collections and analysis shows that Ivy Creek at Chaffin Farm has the best overall water quality with a ranking of "good", followed by Blackwater Creek at Hollins Mill Dam, Ivy Creek at Hooper Road and Peaksview Park, and Dreaming Creek at McConville Road with "fair" overall water quality, with Rock Castle Creek at Cracker Barrel at the end of the list with "poor" overall water quality as shown in the charts below. Figure (1a) shows a rating measure based on the combined scores of FBI, EPT, and PMA assigning a rating of excellent to very poor. Figure (1b) shows the PMA rating for 2008 supporting the range of excellent to poor as discussed above. This data supports our urbanization model with the exception of Ivy Creek at Hooper Road and Dreaming Creek at McConville Road, unlike the complete model (Figure 1a).

Figure 1a. Average of 2008 FBI, EPT, and PMA ratings. The effects of urbanization on water quality evidenced by macroinvertebrate populations.

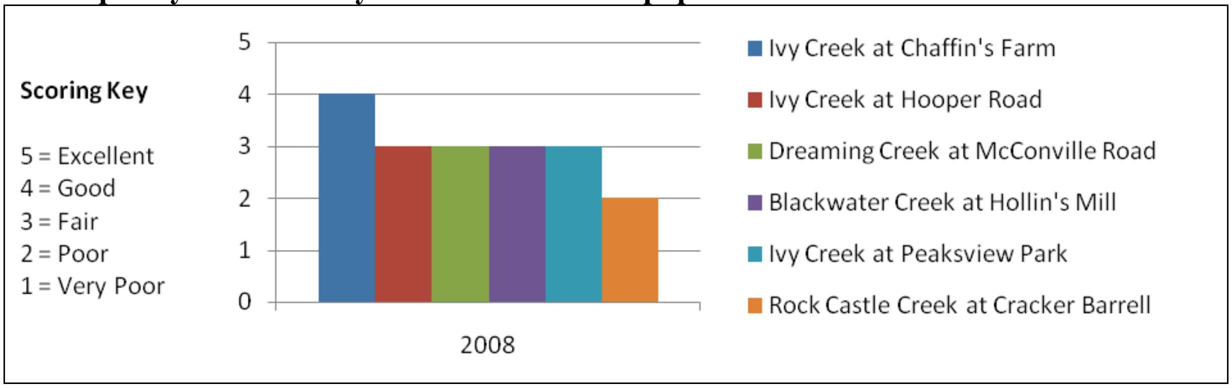
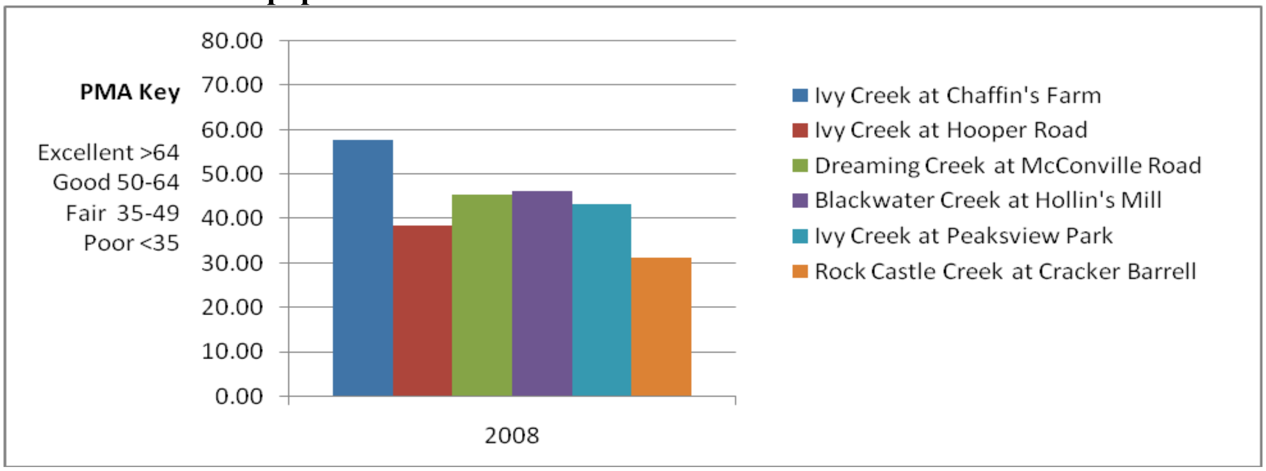


Figure 1b. 2008 PMA score. The effects of urbanization on water quality evidenced by macroinvertebrate populations.



When looking at the results spatially or temporally, data suggests that overall water quality is declining over time when comparing the 2008 data to similar studies conducted in 2005 and 2006. Figure (2a) shows the decrease in the PMA over time with the exception of Dreaming Creek at McConville Road, which actually increased in 2008, and Ivy Creek at Hooper Road, which has stayed at a steady rate. Figure (2b) shows a few different trends. The first is that areas of urbanization cause a downward trend. This is best expressed in the three most urbanized areas, Blackwater Creek at Hollins Mill Dan, Ivy Creek at Peaksview Park, and Rock Castle Creek at Cracker Barrel. While Rock Castle Creek at Cracker Barrel is a 2nd order stream in the Blackwater Creek Watershed, the impacts of urbanization have greatly affected it, when compared to another 2nd order stream such as Ivy Creek at Chaffin Farm. The other two streams in this urbanized area are 4th and 5th order streams in the Blackwater Creek Watershed. Secondly, it also shows us that the areas that are not as urbanized, such as Ivy Creek at Chaffin Farm and Hooper Road, and Dreaming Creek at McConville Road, have water quality that is variable from year to year. This variability may indicate that stressors are present but the steams are able to adapt to the stressors. These streams are either 2nd or 3rd order streams within the Blackwater Creek Watershed.

Figure 2a. Average of PMA Scores from 2005 -2008.

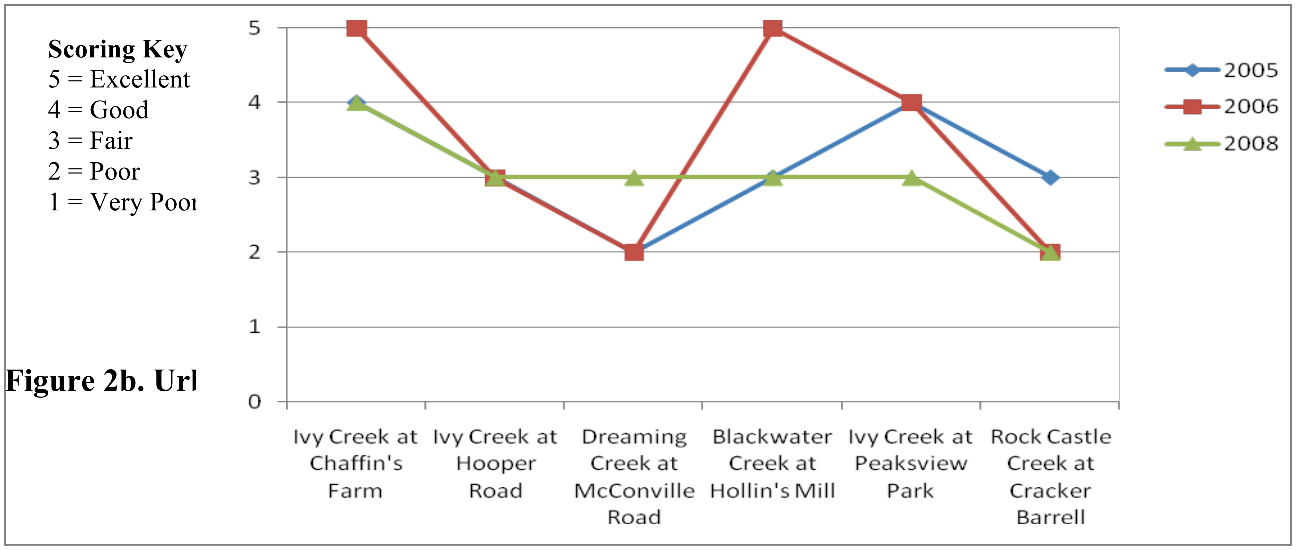
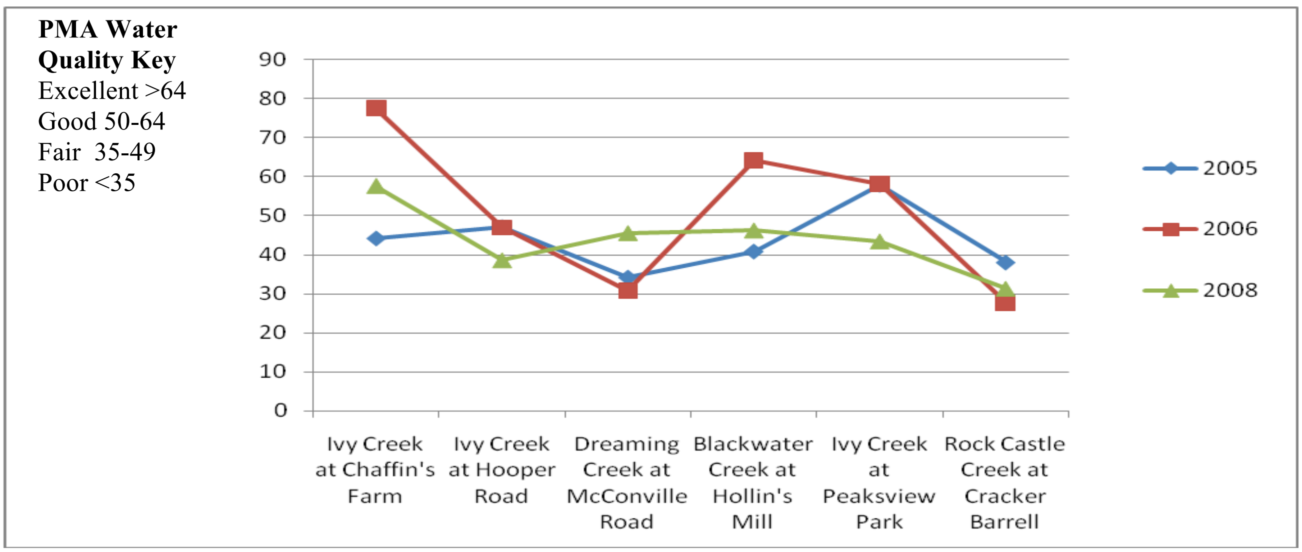


Figure 2b. Url



ANOVA testing was done for areas we would logically expect to see the least amount of impact (Ivy Creek at Chaffin Farm – maximum value) versus the area where we would logically expect to see the greatest degree of impact (Rock Castle Creek at Cracker Barrel – minimum value). This testing was completed for the periods 2005, 2006, and 2008. The testing revealed statistical significance for changes that occurred between 2005 and 2008 (Table 2). With the exception of the PMA Score CF vs. CB (Max vs. Min Values), the ANOVA calculations for the period of 2006, 2008 did demonstrate statistical significance. The data shows that the stronger indicator of statistical change would be for the period 2005-2008.

Table 2: ANOVA testing for statistical differences from 2005, 2006, and 2008. Areas of statistical significance are highlighted.

Category	**Timeframe**	**P-Value**
Overall Score – CF vs. CB (Max vs. Min values)	2005, 2006, 2008	0.01
PMA Rating – CF vs. CB (Max vs. Min values)	2005, 2006, 2008	0.01
PMA Score – CF vs. CB (Max vs. Min values)	2005, 2006, 2008	0.05
Overall Score – CF vs. CB (Max vs. Min values)	2006, 2008	0.04
PMA Rating – CF vs. CB (Max vs. Min values)	2006, 2008	0.04
PMA Score – CF vs. CB (Max vs. Min values)	2006, 2008	0.06

The biological data and trends supports that escalating urbanization increases impacts to macroinvertebrates in the streams. Streams that did not have much urbanization around them or upstream from them, were able to handle aquatic stressors better than streams that have increased in urbanization and that are further down the stream order. The ANOVA test demonstrates that statistical change has occurred between the time periods 2005 to 2008. All the visible graphs suggest that a downward trend may be occurring. It would be prudent to continue to monitor these sites for such evidence due to the high level of risk present where not only does urbanization impact water quality, but that the water quality within the watershed may be also decreasing over time.

Fish Analysis:

Table 1: Total Fish by Niche for all Sites. The breakdown of the fish into five major classifications then separated into percentages of certain fish found in each stream site during testing.

	Omnivores	Carnivores	Herbivore	Pool Insectivore	Water Column Insectivore
Dreaming Creek	46	0	15	36	3
Rock Castle Creek	86	0	20	102	17
Ivy Creek (Chaffin Farm)	325	0	0	31	6
Ivy Creek (Hooper Road)	123	2	0	27	6
Ivy Creek (Peaks View Park)	4	1	1	5	30
Blackwater Creek	3	0	0	89	11

The data in Table 1 shows the percent of fish present in each of the five major niche categories during the testing on each of the sites. There were high numbers of omnivores present at Dreaming Creek, Rock Castle, and Ivy Creek at both Chaffin Farm and Hooper Road. Very low amounts were found at Ivy Creek at Peaks View Park and Blackwater Creek at Hollins Mill. Carnivores were found at the Hooper Road and Peaks View Park sites. Herbivores were found in Dreaming Creek, Rock Castle, and Peaks View Park. High numbers of pool insectivores were found at all sites except Peaks View Park. Peaks View Park was the only site where high numbers of water column insectivores were found.

Table 2 shows the breakdown of the IBI scores for all six of the sites in 2008. The highest possible score can be a 45 meaning high water quality and the lowest a 9. The IBI in 2008 shows the following scores Chaffin Farm - 25, Hollins Mill – 25, Rock Castle Creek – 23, Hooper Road

– 21, Dreaming Creek – 18, Peaksview Park – 15. Table 3 shows how the sites were given the quality grade. Figure 10 shows the relationship between urbanization and IBI.

Table 2: Index of Biological Integrity 2008

2008 Index of Biological Integrity						
Measurements	Chaffin Farm	Hooper Road	Dreaming Creek	Hollins Mill	Peaksview Park	Rock Castle Creek
Total Number of Species	3	2	3	1	2	3
Total Number / Relative percent of Darter Species	1	2	1	4	1	2
Total Number / Relative percent of Water Column Insectivores	5	4	5	2	0	3
Total Number / Relative percent of Pool-Benthic Insectivores	4	2	2	0	3	0
Total Number / Relative percent of Intolerant Species	4	3	1	5	1	4
Relative abundance of Tolerant Species	1	3	1	5	1	4
Relative abundance of Omnivores or Generalist Feeders	1	1	1	5	5	3
Relative abundance of Top Carnivores	1	1	1	1	1	1
Deviation from ideal or number of individuals in sample	5	3	3	2	1	3
Totals for each site ►	25	21	18	25	15	23
Grade ►	Fair	Poor	Poor	Fair	Very poor	Poor

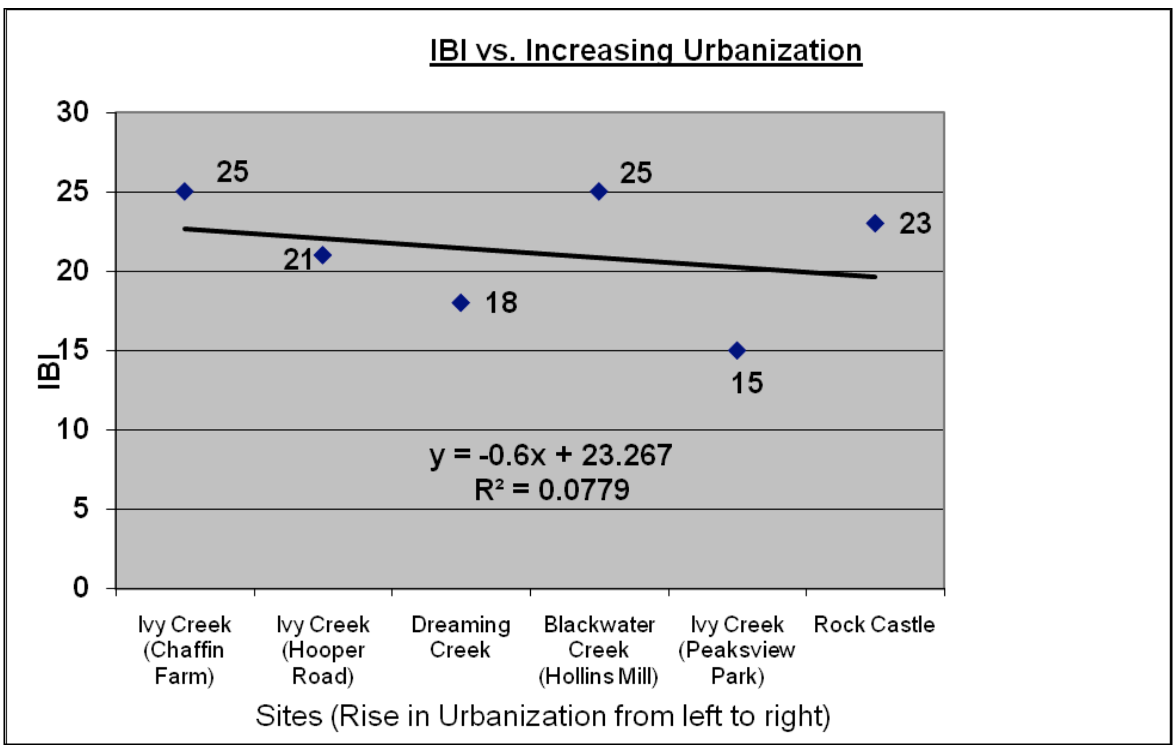


Figure 1: Relation of IBI Score to Urbanization

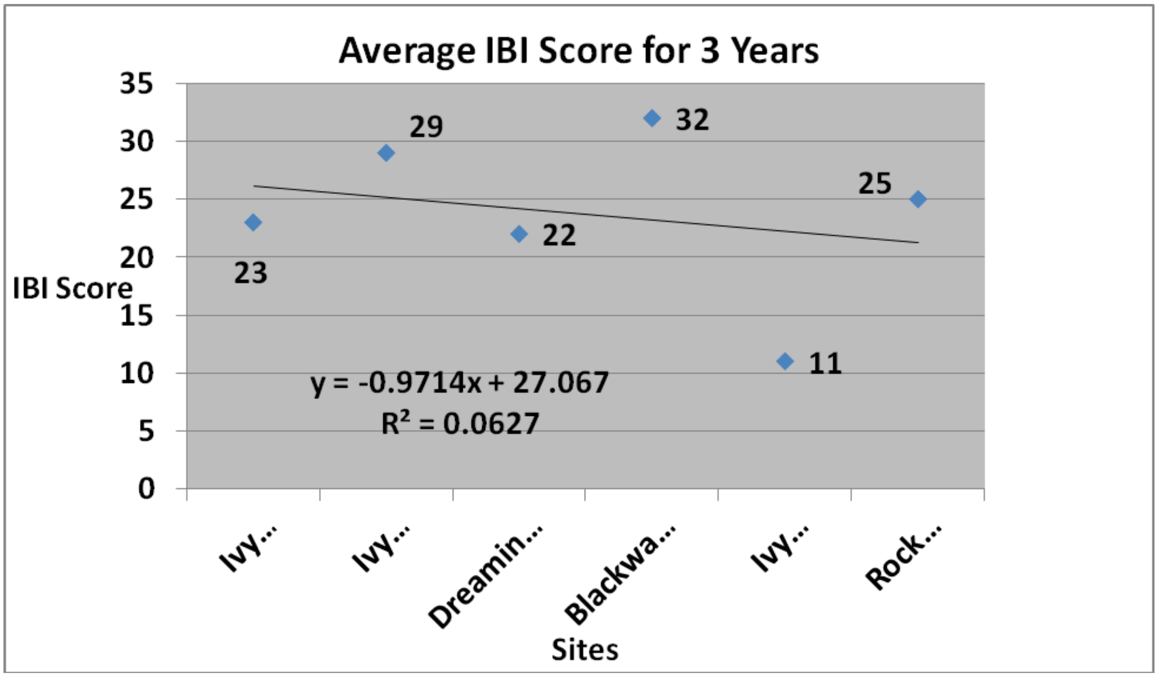


Figure 2: Average IBI Score over past 3 years

Table 3: Quality Grade for each site based on IBI Scores

	Very Poor	Poor	Fair	Good	Excellent
IBI Range	**9-16**	**17-23**	**24-30**	**31-37**	**38-45**

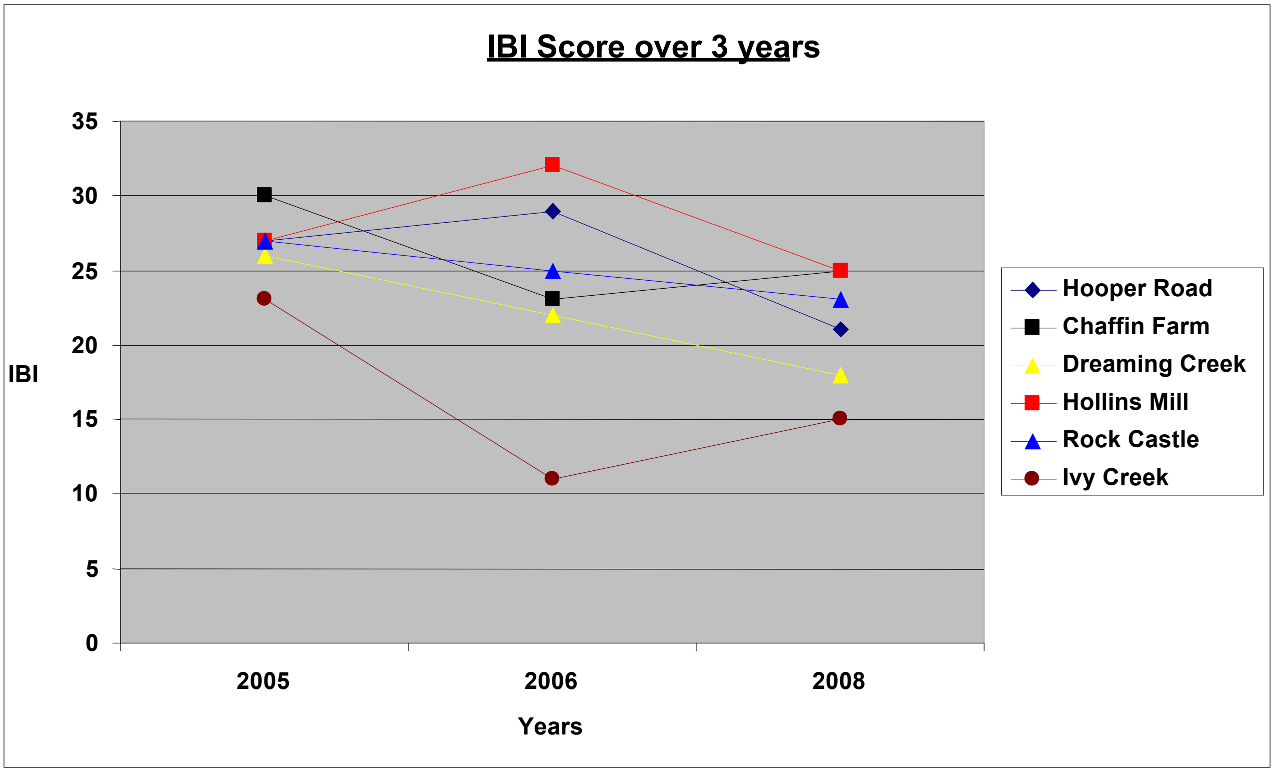


Figure 3: Total IBI Scores over past 3 years

DISCUSSION

Water Quality Based on Chemical Parameters

The chemical make-up of a stream fluctuates on a daily basis, depending on weather conditions, storm events, and other inputs to a stream. Our chemical sampling of the six selected sites within the Blackwater Creek Watershed provides us with a snapshot of the water quality in those streams at the time of sampling. Because these chemical tests provide such an acute short-term diagnosis of water quality, we must consider our results in conjunction with our macroinvertebrate, fish, and physical assessments, which provide evidence for longer-term trends. Chemical assessment nevertheless provides a very valuable piece of the puzzle and can be an excellent indicator of extreme events such as unintended sewage discharge into a stream (increasing conductivity, nitrate, and phosphate levels), industrial discharges, or increased runoff from fertilized land. It can also help us better understand some of our other results, such as low levels of macroinvertebrates or fish in certain streams (as a result of nutrient limitation, increased water temperature, or low DO levels).

A few sites presented extreme (high or low) results. Hooper Road's pH was high (8.36) and out of normal range of 6.5-8.0. There has been recent development upstream of our sample site at Hooper Road, and it is quickly becoming more urbanized. A few years ago, Hooper Road was not yet paved in some places. Macroinvertebrate sampling at Hooper Road indicates a "very poor" rating of the Family Biotic Index (FBI) and only "Fair" ratings using both the EPT index and Percent Model Affinity (PMA). When pH falls outside of the normal range, aquatic organisms experience much greater levels of stress and suffer in numbers and in diversity. The Index of Biological Integrity (IBI) for our fish sampling done at Hooper Road also came out to be poor (Table 2: Index of Biological Integrity 2008).

Rock Castle Creek also had significantly higher conductivity levels than any other site (>120 µS higher) and a correspondingly higher temperature (18.8 C) than any other site. Upon physical assessment of this site, there is a noticeable lack of trees around the stream and consequently little to no canopy cover. Canopy cover and vegetation surrounding the stream have a direct influence on water temperature and in turn conductivity. The result of these conditions are "poor" levels of both macroinvertebrates and fish. All assessments indicate this stream is suffering from the extreme urbanization surrounding it.

Trends: When comparing "Actual Stream Health" Over the Past 5 Years (Table 12 in Chemical Assessment section) with "Actual Stream Health" from 2008 (Table 9 in Chemical Assessment section), we see some negative trends. Five out of six of the sampled sites show a decline in overall water quality according to chemical assessments. Chaffin Farm, Hooper Road, Dreaming Creek, and Peaksview Park all declined from *excellent* overall water quality to *good*.

Rock Castle Creek at Cracker Barrel declined from *good* to *fair*. None of the sites sampled improved in water quality over the last five years and only one (Hollins Mill) remained the same. These results directly support our hypothesis that increasing urbanization is negatively affecting water quality.

Comparing Streams according to similar Stream Order: It should also be noted that Rock Caste Creek and Chaffin Farm are both second order streams. If these two streams are both healthy, we should find the same species diversity and richness in both. However, when we compare the overall assessments of these two streams, we see a very significant difference in water quality, which can be directly attributed to the extreme development of the land surrounding Rock Castle Creek (Wards Road area). The overall stream health of Rock Castle Creek follows: Physical—Poor; Chemical—Fair; Macro—Poor; Fish—Poor.
Chaffin Farm's overall stream health follows: Physical— Fair; Chemical—Good; Macro—Good ; Fish—Fair. Directly comparing the overall water quality assessments of these two second order streams clearly indicates superior water quality in the less impacted stream (Chaffin Farm) where the surrounding land is much less developed, where stream buffers are present, and where infiltration occurs over a much larger percentage of the surrounding land (% Forested: Chaffin Farm—53.3%; Rock Castle Creek—23.3%). This difference in overall stream health also mirrors our urbanization metric. Only 4.6% of the land surrounding Chaffin Farm is considered "urbanized", whereas 69.8% of the land surrounding Rock Caster Creek is "urbanized". These percentages have a huge impact on the overall health of these two streams.

Water Quality Based on Macroinvertebrates

In sum, the visible data supports our hypothesis that urbanization degrades water quality as shown in Tables 1 and 2, and Figures 1a, 1b, 2a and 2b. The statistical data is more compelling because while the visible data on Figures 1 and 2 do indicate a downward trend in water quality, the regression test does not support that this is occurring statistically. In Table 14, the ANOVA shows evidence of significant water quality decline in all the streams between 2005 and 2008 in overall score, PMA score, and comparison of Chaffin's Farm versus Cracker Barrel, showing that the maximum and minimum quality streams support the hypothesis that urbanization degrades water quality. With regard to the regression test, it is quite possible that not enough time has elapsed in order to indicate such a trend from a statistical perspective. Therefore, it would be prudent to continue to monitor these sites for such evidence due to the high level of risk present from urbanization. Not only does urbanization impact water quality, but that the water quality within the watershed may be getting worse over time. Preventing further degradation of these streams is extremely important from what the data shows and following the recommendations set forth is urgent.

Water Quality Based on Fish

The results found through our fish analysis gives a large amount of important information that indicates good or poor water quality. Table 2 gives the IBI scores for each site and our data for the fish analysis supports our hypothesis to an extent. The IBI score for Chaffin Farm was the best because the amount of species diversity in this stream was the highest indicating the best water quality. Table 2 also brings out some interesting points in that Hollins Mill and Rock Castle Creek scored relatively high when compared to the amount of urbanization that is present in those areas. This could mean that there are a couple of different situations that are occurring in the sub-watershed of these creeks. The first scenario is that the amount of urbanization that has occurred around the stream has not affected the fish population yet. All the urbanization in these areas is relatively recent and the time lag for fish to be affected by the urbanization has probably not caught up to the fish population yet. The fish are a part of a stream system that are relatively tolerate to disturbances to an extent. Over time a larger amount of small disturbances will catch up to the fish population and then a noticeable change in the health of the population will become apparent, we just have not see that decrease in health in the fish population at Hollins Mill or Rock Castle Creek yet.

Figure 1 is a good figure because it further supports our hypothesis, in that urbanization has a negative effect on water quality. This figure has the sites of urbanization listed from lowest to highest going from left to right on the x-axis. The treadline indicates that with increasing urbanization the quality of the fish catch decreases. Figure 2 indicates that over the past three years the amount of fish quality has also decreased in each respectable stream. This also has a direct correlation with the amount of urbanization in the area because the urbanization has increased at each site over the past three years as well.

Figure 3 is a very important figure to note because of this is the IBI scores over the past three years for each stream. From this figure, every stream has decreased in its total IBI score from 2005 to 2008. The two important streams that we feel are necessary to focus on are Rock Castle Creek and Dreaming Creek. As previously mentioned the amount of urbanization that has recently been added to these streams has increased greatly and we do not feel like the fish have been impacted yet. While there is a definite decrease in the total IBI score for these two stream, we feel like in the next couple of years we will see an very large decline in the IBI score for these streams. Once the human disturbances finally catch up with the fish population there should be a large drop in the Rock Castle Creek system and the Dreaming Creek system. While not all of the fish analysis supports the hypothesis at this point, we do expect to see changes in the future that support the theory of urbanization decreasing the level of water quality.

Water Quality Based on Physical Parameters

The data from the physical assessment can be used to give an overall grade of a stream and how healthy a stream appears. The data that came out of the physical assessment was right about where we expected all the data to end up with the respected stream. Figure 1 gives the overall stream scores from the USM form and has the streams listed by amount of disturbances present in that stream, with Chaffin Farm having the lowest levels of disturbance and Rock Castle Creek having the highest levels of disturbance. This assessment gave us the best data to support our hypothesis because the data almost goes hand in hand with our hypothesis. From the USM forms we also created Table 1, which shows the condition the stream is in with excellent being the best condition and poor being the worst condition. The majority of the streams scored in the fair range because when the USM scores the total stream score there could be differences in the individual scores but the overall score is not changed very much.

Figure 2 shows the scores given for each parameter at each stream. This is a great figure because it gives a good representation of where each stream stands with each parameter on the stream. The scale on this figure has 1.5 as the highest level possible, so if a stream is perfect then all the categories will reach a score of 1.5. The lowest score possible is 0.5, so if the stream is at the absolute lowest point then the score for all the categories listed would be 0.5. The Total Stream Score is also included in this figure and this is the line that should be looked at the closest. This line shows the general decline in water quality throughout the streams as urbanization increases around each stream.

Overall,

Conclusions and Recommendations:

- Enact stream buffer ordinance throughout city requiring 100 foot buffers on each side of stream channel.
- Encourage conservation easements for private land to further preserve existing undeveloped lands.

- Provide local tax credits for the placement of permanent erosion control structures such as planting trees, shrubs, and other vegetation.
- Prevent stream impacts through green development such as use of green roofs, porous concrete, gravel, (**Ask Shahady about porous blocks for parking lots.)**
- Enforce the Lynchburg City Comprehensive Plan Natural Resource section on all rezoning. **(?? Further Explanation)**
- Secure additional funding and personnel to facilitate stricter enforcement of Erosion & Sedimentation Laws and larger punishment for violations (such as larger fines and/or shutting down a site).

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