2009 Water Quality Assessment Report for the Blackwater and Ivy Creek Watershed
Analysis of Chemical, Biological, and Physical Indices

2009 ENVS 375 Freshwater Ecology Class
Friday, May 8, 2009

Group Members

Project Manager: Dr. Thomas Shahady
Assistant Project Manager: Adam Bonaventura, Senior, Environmental Science

Chemical Analysis
Buddy Dailey, Junior, Environmental Science
Kaitlin Marvin, Junior, Biology

Macroinvertebrates Analysis
Stephen Armstrong, Sophomore, Environmental Science
Rebecca Evans, Junior, Environmental Studies
Rachel Roozen, Junior, Environmental Studies

Fish Analysis
Ryan Enoch, Sophomore, Environmental Science
Bradley Puffenbarger, Junior, Environmental Science

Physical Analysis
Thomas “Ford” Kerns, Sophomore, Environmental Science
Brandon Schneider, Junior, Environmental Science

Introduction, Discussion, and Editing
Molly Galloway, Sophomore, Environmental Science
Caitlin Gibb, Sophomore, Environmental Science
Sabrina Ripperger, Sophomore, Biology

Table of Contents

Abstract

The Blackwater Creek Watershed has a drainage area within three governmental jurisdictions including the City of Lynchburg, Bedford County, and Campbell County. The objective of the study is to determine to what effect urbanization influences water quality within the watershed. Seven different sites throughout Blackwater Creek's tributaries are currently being tested, with each location involving various combinations of urbanization, suburban development, and land use practices that all consequentially alter water quality. The land uses within the Blackwater Creek watershed include agricultural, forested/pasture, urban, suburban, recovery, and restoration (Shahady 2009) The samplings involve the use of numerous indices including chemical, physical, and biological in order to obtain a higher level of accuracy when evaluating the health of the stream. Biological assessments incorporate both macroinvertebrate and fish examination. Through the study of both current and previous years' data, the continuous monitoring of changes within the watershed can be achieved. The current hypothesis states that as the quantity of rural land decreases, urbanization increases and as urbanization increases, overall water quality will continuously decrease. As the percent of rural land declines, water quality indicators including conductivity and Index of Biological Integrity both on a spatial and temporal scale reflect a reduction in scores. This report reflects a comprehensive process of compiling and analyzing existing watershed data, determining and documenting trends, and providing potential improvements to promote a the restoration and future preservation of the ecological integrity within the Blackwater Creek Watershed.

Introduction

Urbanization: Effects on Stream Health

Urbanization refers to development within a watershed, such as the construction of roads, buildings, and other land use changes from rural to residential and industrial that result in an increase of impervious surface, accumulation of polluting substances, increase of domestic wastewater load, and a greater water demand due to increased human population (Kemp and Spotila, 1997). It is a pervasive and rapidly increasing form of land use of both the public and private sector including construction sites, parking lots and roads, commercial developments, industries, and residential communities (Shahady and Fitzsimmons, 2008). Sources of pollution attributed to urbanization are from both point and non-point sources, with non-point sources of pollution being difficult to regulate.

One of the major components of urbanization is the increase in impervious surfaces, which causes a decrease in infiltration of precipitation and an increase in surface runoff (Dunne and Leopold, 1978). As the percent of impervious surface cover increases to 10-20%, runoff increases twofold; 35-50% imperious surface cover increases threefold; and 75-100% impervious surface cover increases surface runoff more than fivefold in comparison to forested lands (Arnold and Gibbons, 1996).

The increase and contamination of run-off from both point and non-point sources negatively effects stream health in a myriad of ways. An increase in the amount of runoff often causes eutrophication, the overabundance of nutrients. Eutrophication, in conjunction with the increased amount of light, usually favors increased algal biomass, a characteristic of urban streams where nutrients do not seem to be the limiting factor of algae (Meyer and Paul, 2001). The increase in algal blooms causes the breakdown of dissolved oxygen essential for the metabolic processes of invertebrates and fish, causing a loss of biodiversity.

In addition to the rapid increase in runoff caused by urbanization, water that falls on impervious surface is unable to infiltrate into the ground at that spot and therefore must travel to porous ground, where it is able to infiltrate. The inability of water to infiltrate impervious surfaces leads to an increased discharge from a given location, causing erosion from the rate and amount of water being released (Arnold and Gibbons, 1996). The effects of impervious surface are exacerbated with rainfall in a curb-and-gutter system because the water is diverted into a sewer system, where it travels until it drains into a stream. The water increases in speed and temperature as it moves through the sewer system and empties from a specific location, causing the discharge of more water than what would naturally enter the stream (Meyer and Paul, 2001).

Sedimentation, the process by which suspended solids settle at the bottom of a stream, is the number one pollutant and master factor impacting streams (Meyer and Paul, 2001). Although sedimentation occurs naturally as part of the dynamic ecosystem, human influence exacerbates the problem, especially during construction because the exposed soil may be released into a stream with run off. Sedimentation disrupts in-stream habitat by increasing stream embeddedness, thus reducing available habitat, which is vital to invertebrates that are susceptible to drift. Invertebrates that inhabit pools are especially affected by the accumulation of sedimentation in urban streams (Arnold and Gibbons, 1996). Stream embeddedness is difficult to control, yet it is one of the worst problems affecting streams because it causes a loss of habitat and thus a loss of biodiversity. Increased embeddedness also causes an increased water flow rate due to the channelized-like conditions of the stream. A faster water flow increases turbidity, the clearness of the water impacted by suspended solids. Turbid water may clog the gills of fish and prevent sunlight from penetrating the water where phytoplankton depends on it for the essential process of photosynthesis.

Channelization is the process by which physical alterations of in-stream habitat by humans drastically alters the natural sinuosity and meandering of a stream. Channelization results in a confined floodplain where there is an increase of flooding, the loss of riparian buffers, and an overall change in stream habitat, which is also due to the increased rate at which water flows. Studies demonstrate that riparian deforestation resulting from urbanization reduces food availability, affects stream temperature, and disrupts sediment uptake, suggesting the crucial role that riparian forests play in buffering a stream from the detrimental effects of urbanization (Meyer and Paul, 2001). The physical manipulation of channelization also triggers a change in the composition of a stream favoring the survival of tolerant fish and invertebrate species (Kemp and Spotila, 1997).

Previous studies of the Blackwater Creek Watershed from 2004, 2005, 2006, and 2008 indicate that urbanization degrades water quality. In the preceding studies, water quality was assessed chemically, biologically, and physically using many different parameters in each category. Results overtime signify that as development and land disturbing activities increase within the Blackwater Creek watershed, the stream ecosystem changes chemically, biologically, and physically (Shahady and Fitzsimmons, 2008).

The objective of this study was to determine the effects of urbanization on water quality. We hypothesized that as the quantity of rural land decreases, urbanization increases. As urbanization increases, overall water quality decreases.

Blackwater and Ivy Creek Watershed

The Blackwater Creek Watershed is a tributary of the James River, encompassing about 42,000 acres of the Piedmont region of Central Virginia (Figure 1). Located in the foothills of the Blue Ridge Mountains with the James River bordering it to the north, it presents an area of transition between mountains and lowlands (Shahady and Fitzsimmons, 2008). Large portions of the watershed are within the municipal authority of the City of Lynchburg while Bedford and Campbell County comprise the remainder of the watershed. Each of the two counties adjacent to the City of Lynchburg are urbanizing and expanding into the undeveloped portions of the watershed.

The Ivy Creek segment of the watershed originates in rural Bedford County, which includes a majority of the Ivy Creek drainage. Although the Ivy Creek portion of the watershed is primarily surrounded by wooded forest and farmland, the lower areas of the watershed in proximity to the City of Lynchburg are urbanized and experiencing increased development pressure from suburban sprawl (Shahady and Fitzsimmons, 2008).

The effects of urbanization continue to affect the Blackwater Creek Watershed as a whole. Increased discrepancy between sample sites when compared with earlier data suggests that watershed degradation is accelerating (Shahady and Fitzsimmons, 2008).

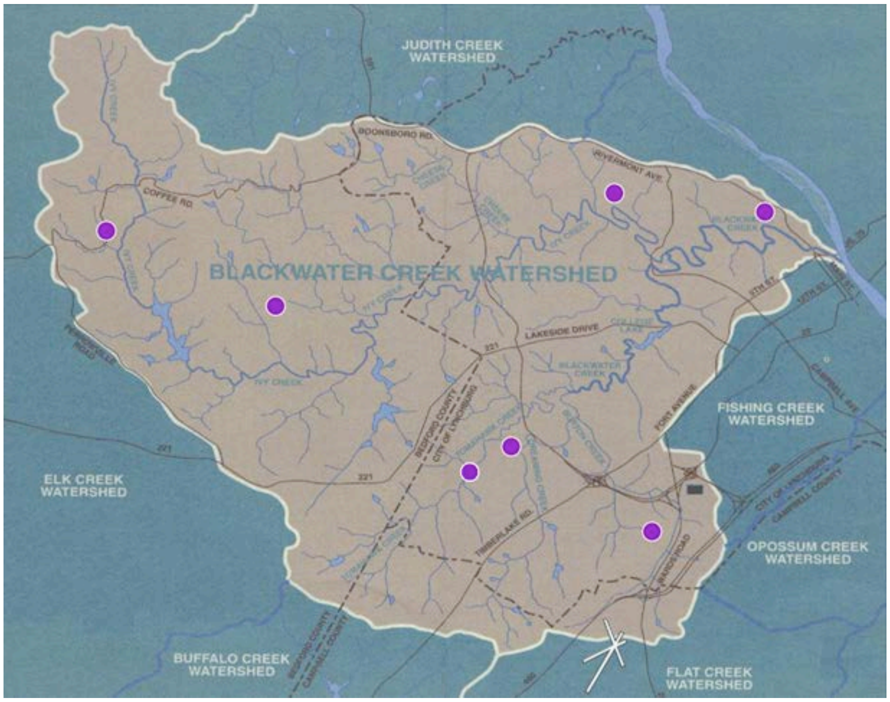

Figure 1. The 42,000 Blackwater Creek Watershed is located in the foothills of the Blue Ridge Mountains

Land Use

Land use is a key component when assessing the effect of urbanization on water quality. The seven sites sampled for this project represented the different uses of land in the Blackwater Creek Watershed, which include agriculture, forest, pasture, restoration, residential, suburban, commercial, urban, or a combination of the different land uses (Figure 2). Generally, the further down in the watershed, the poorer the water quality of the streams (Shahady and Fitzsimmons, 2008). Ivy Creek at Chaffin's Farm, the reference stream for the project that was predicted to have the best overall water quality, is located in the upper portion of the Blackwater Creek Watershed and is distinguished by agricultural land use. Ivy Creek at Hooper Road has both forest and pasture land and was expected to have good water quality. Blackwater Creek at Hollins Mill Dam is a restoration site anticipated to have fair water quality that is improving steadily. In an effort to better support our hypothesis that urbanization degrades water quality, the addition of a new sampling site at Tomahawk Creek was added to the study. Land use at Tomahawk Creek is characterized by residential and commercial land use. It was estimated that Tomahawk Creek would have fair water quality that was likely comparable to that of Peaks View Park, a site comprised of suburban and residential land use. The predicted water quality of Dreaming Creek, a former restoration site, was poor due to the current commercial land use of the site. Rock Castle Creek at Cracker Barrel is heavily developed and urbanized and was expected to have very poor water quality.

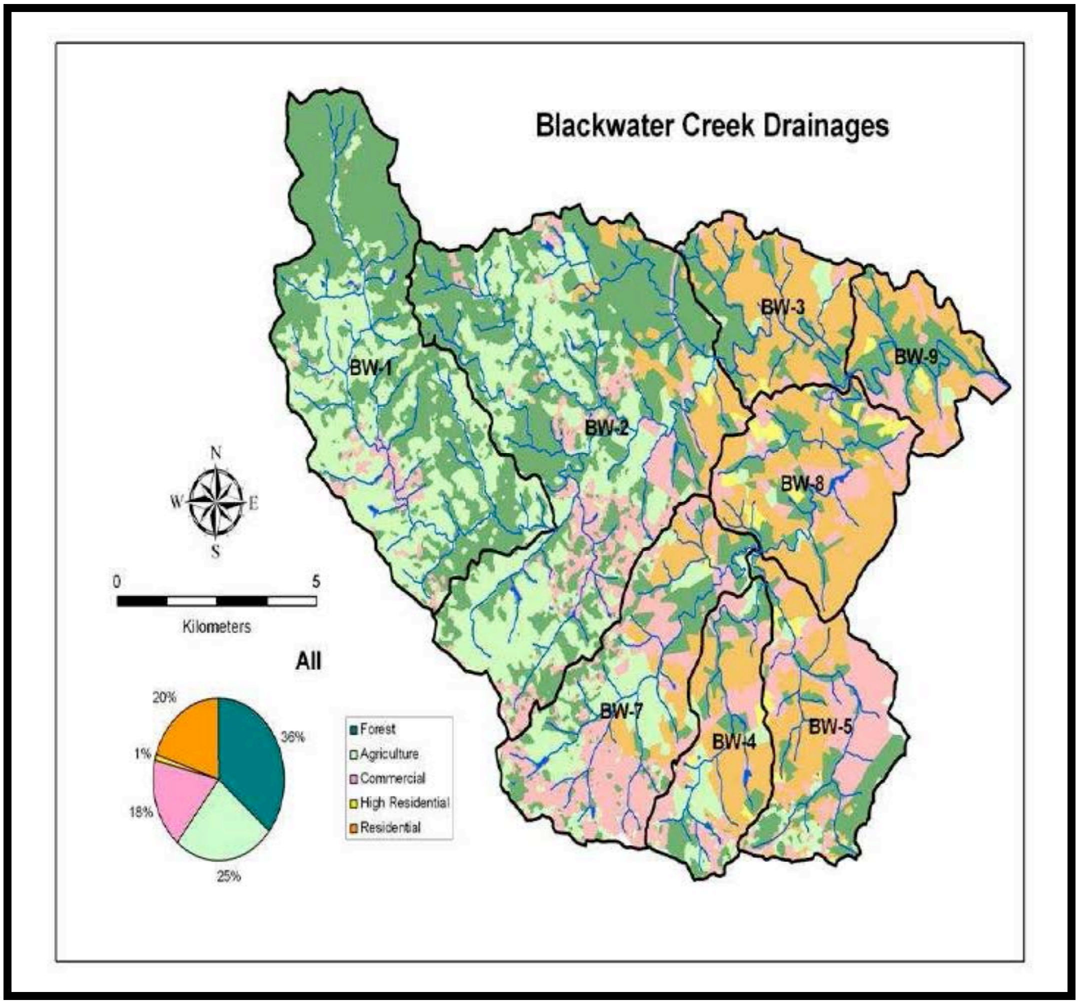

Figure 2. Land use in the Blackwater Creek Watershed

Table 1. Sample sites were ranked based on the percentage of rural land use, determined by multiplying the percentage of forested land use by a value of 1.2 and percentage of agricultural land use by a value of 0.5

	Site Location	% Impervious	% Forest	% Ag	% Commercial	% Residential	% TOTAL RURAL= (1.2)%Forest+ (0.5)%Ag
1	Ivy Creek at Chaffin's Farm	1.52	53.3	42.1	4.6	0	**85.01**
2	Ivy Creek at Hooper Road	3.6	45.2	34.7	14.2	5.9	**71.59**
3	Blackwater Creek at Hollins Mill	23.56	33.7	2.1	17.7	46.5	**41.49**
4	Tomahawk**	35.90	21.4	26.7	36.6	15.3	**39.03**
5	Ivy Creek at Peaks View Park	13.69	28.6	4.7	5.1	61.7	**36.67**
6	Dreaming Creek at McConville Road	15.45	19.6	16.9	25.2	38.2	**31.97**
7	Rock Castle Creek at Cracker Barrel	21.96	23.3	6.9	36.1	33.7	**31.41**

Quantifying Urbanization

In order to accurately analyze the effects of urbanization on water quality, urbanization was quantified based on land use and sites were rated based on the percent of rural land (Table 1). The calculations to quantify land use were based on vegetative cover (undisturbed woods vs. cultivated/grazing land) and infiltration (imperviousness). Land was rated based on rural land use and assigned a value based on its vegetative cover and imperviousness, which is a better indicator of land that is not urbanized. Studies estimate that urbanization and construction may equal or exceed all other contributing factors of the problem of sedimentation (Shahady and Fitzsimmons, 2008). Forest is the best indicator of a rural area because of its high amount of vegetative cover and the ability for water to infiltrate into its soil. Although less rural than forest, agriculture was assigned a value of 0.5 for rural land use because it allows for infiltration and is less developed than commercial and industrial land. The value for agricultural land use was determined to be 0.5 because urbanization is better quantified by commercial, residential, or impervious land uses.

Chemical Analysis

Methods and Materials

Samples were collected from seven sample sites as follows: Dreaming Creek, Tomahawk Creek, Rock Castle Creek, Chaffin Farm (Ivy Creek), Peaks View Park (Ivy Creek), Hooper Road (Ivy Creek), and Hollins Mill Dam (Ivy Creek). Each site was visited and water was collected in acid washed half liter bottles. The bottles were labeled with the name of the sample site and the date sampled. Dissolved oxygen and conductivity were obtained using a calibrated conductivity meter. The pH was obtained using a pH meter. The pH meter was placed in the water for at least five minutes to receive a proper reading.

The water samples were brought back to the lab and stored in the freezer to keep the phosphorus from diffusing in the water. Later a phosphorus test was run using the HACH DR/4000 Procedure Total Phosphorus Kit. Method 8190 with test'n tube vials was used. First the COD was set to 150 °C. 5 standards were prepared containing .5, 1, 1.5, 2, and 2.5 mg/L of phosphate standard and 5ml were then added to the test tubes. The water samples from each of the sites were prepared the same way by adding 5 ml of each sample to separate test tubes. One Packet of Potassium Persulfate was added to each test tube. The test tubes were transferred to the COD Reactor and digested for 30 minutes. After digestion the test tubes were taken out and cooled for approximately 20 minutes. One packet of PhosVer 3 Powder Pillow was added to each test tube. The test tubes were capped and inverted for approximately 15-20 seconds. Each sample was poured into a cuvette and placed in the spectrometer at 890nm. We conducted this phosphorus test several times and still had problems with the results so no phosphorus data will be included in this report.

Results

- Spatial

.

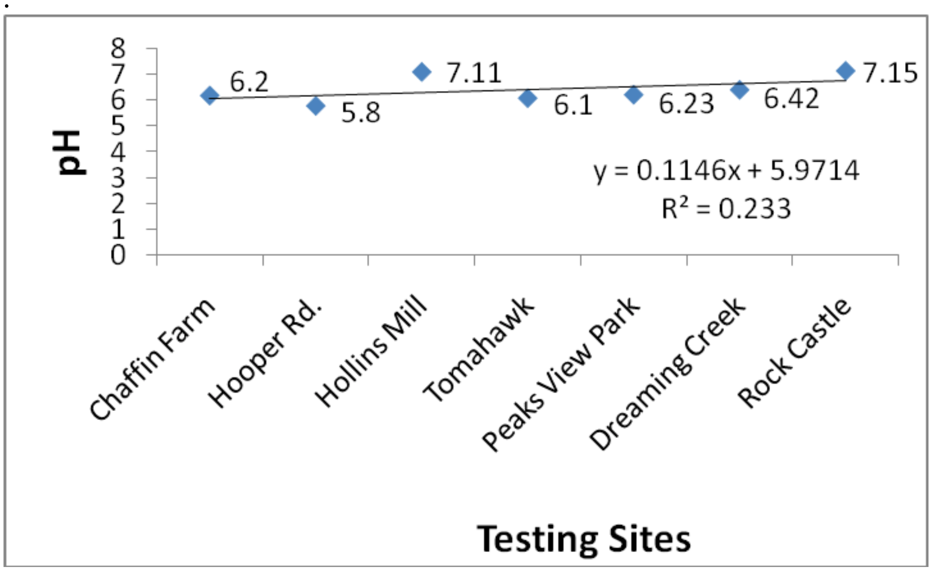

Figure 1. Shows relationship between urbanization and pH

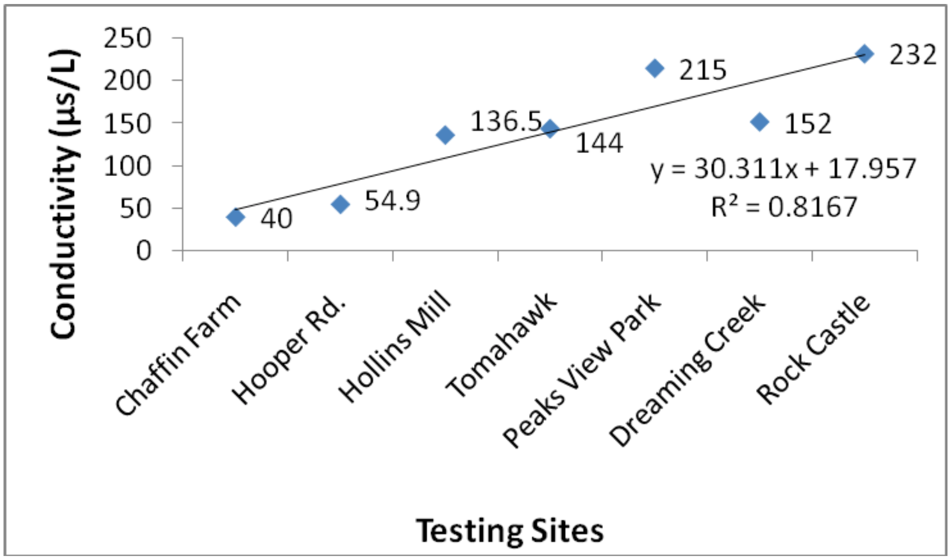

Figure 2. Shows relationship between urbanization and conductivity.

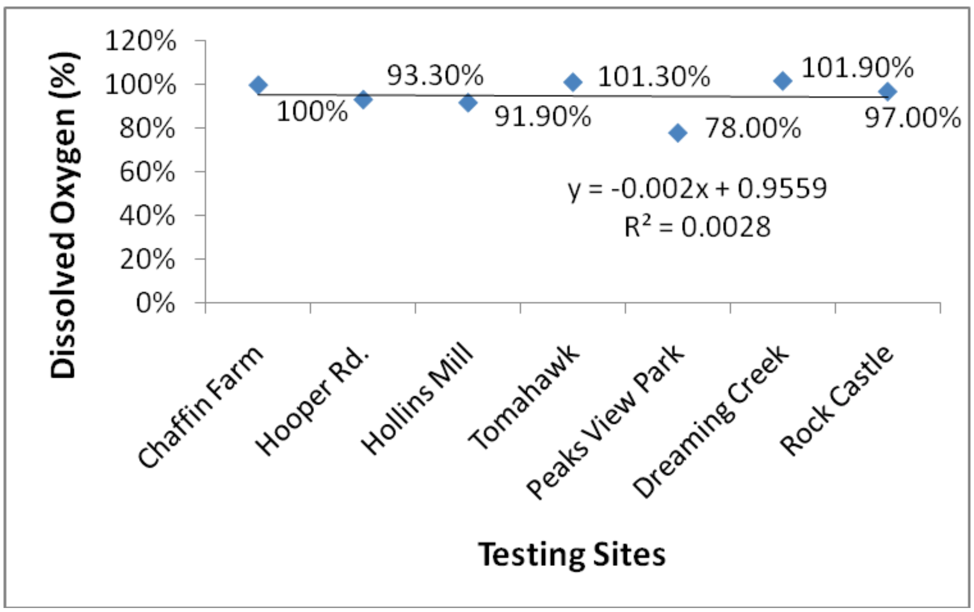

Figure 3. Shows relationship between urbanization and dissolved oxygen.

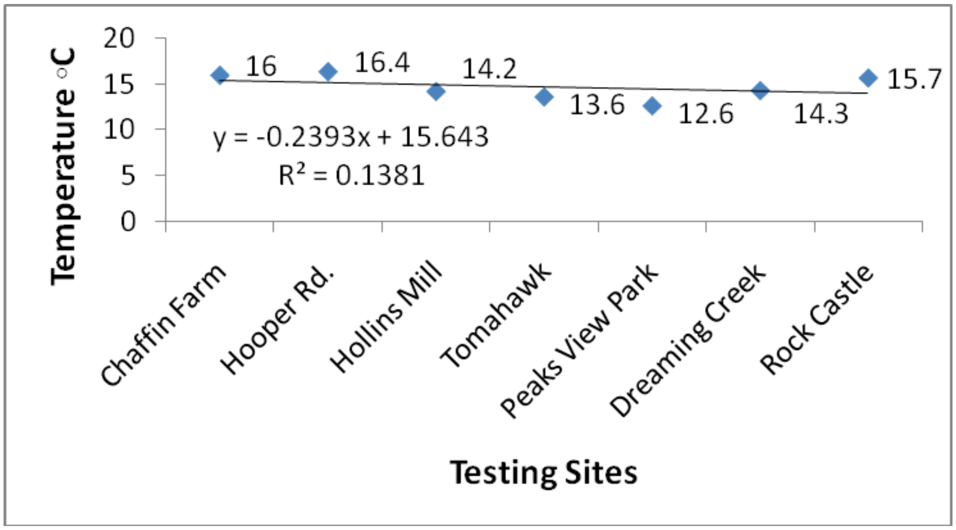

Figure 4. Shows relationship between urbanization and temperature.

- Temporal

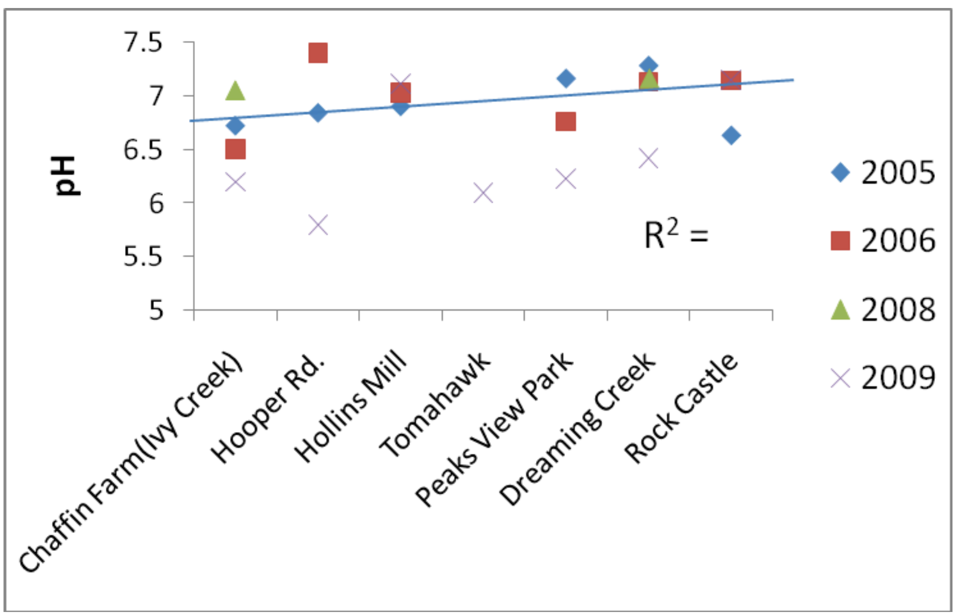

Figure 5. Shows relationship between urbanization and pH over time.

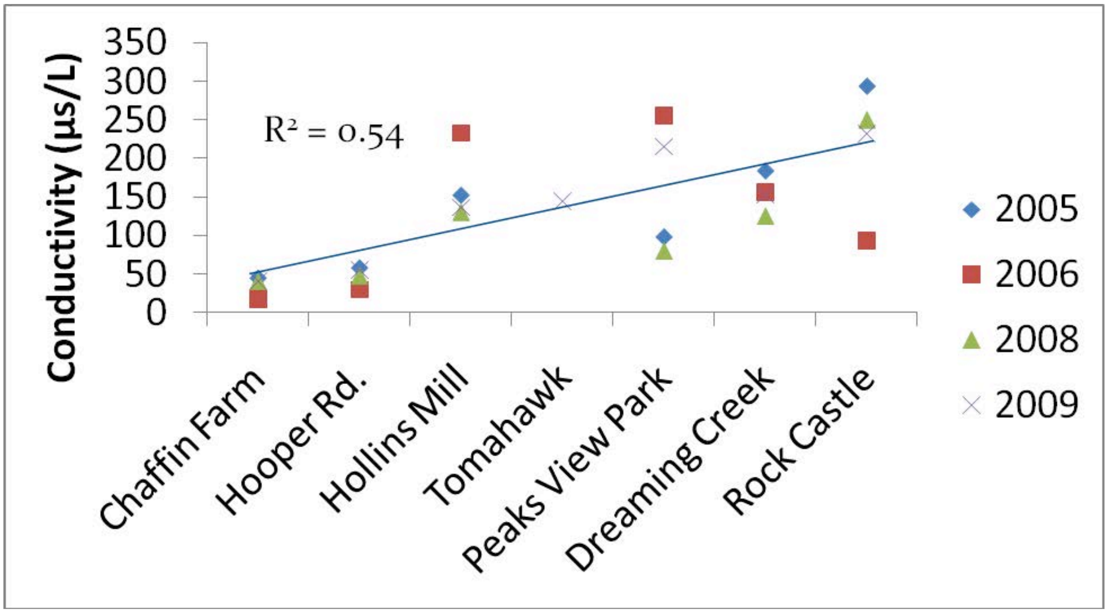

Figure 6. Shows relationship between urbanization and conductivity over time.

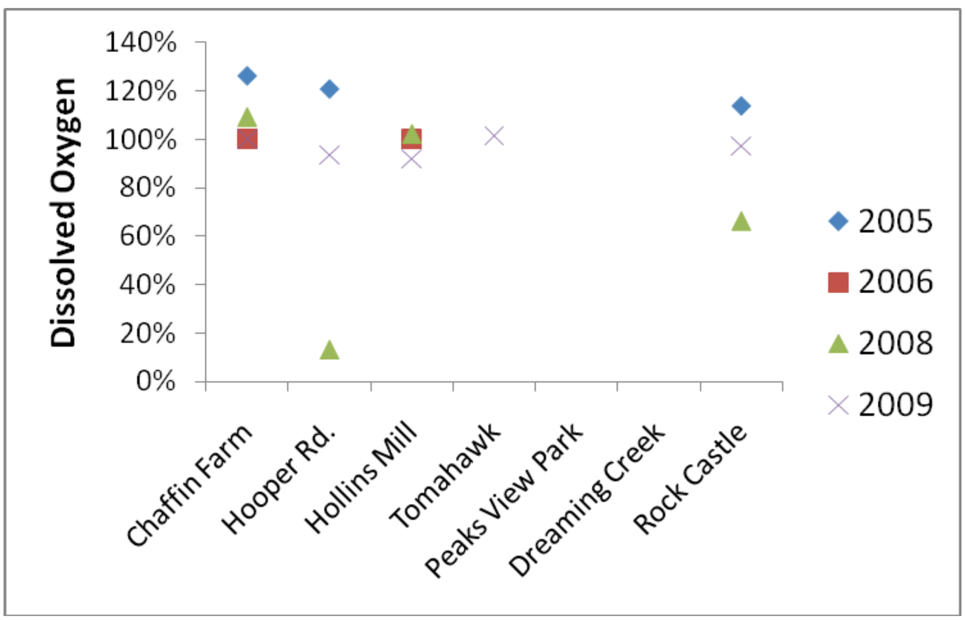

Figure 7. Shows relationship between urbanization and dissolved oxygen over time; DO data was missing for several sites and years

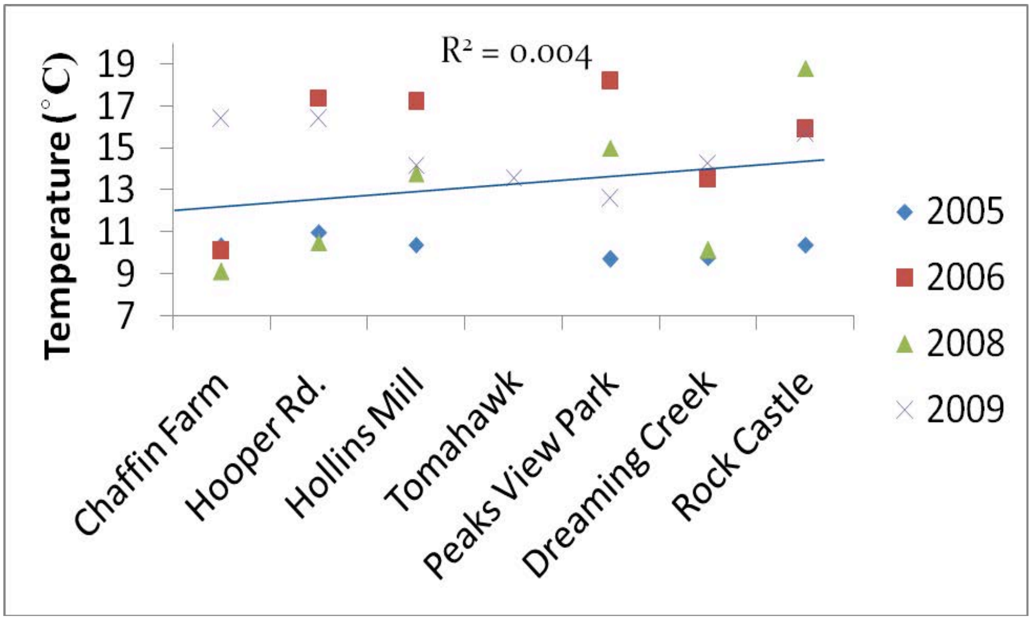

Figure 8. Shows relationship between urbanization and temperature over time

Discussion

The spatial data for 2009 shows an overall correlation with our hypothesis that urbanization decreases water quality. The pH shows a slight increase in pH ($R^2 = 0.233$) as urbanization increases this could be due to the lack of vegetation. If vegetation was present it would produce acid byproducts decreasing the pH of the water. Conductivity shows the strongest correlation ($R^2 = 0.8167$) relating to our hypothesis. High conductivity indicates pollution could be present. This pollution could be from dumping chemicals or runoff from storage drains and holding tanks or high sedimentation deposits. Dissolved oxygen showed no correlation with the above hypothesis. This is because dissolved oxygen is based on how much oxygen water can hold and is based more on the physical aspects of the stream such as riffles and pools. Temperature also had no correlation between our hypotheses. This is due to weather; if it rains the temperature of the water may be cooler. The water may be warmer on a sunny day than a cloudy day and water may be cooler in a more shaded area than an open area.

While the temperature is the most widely varying (temporally), its linear progression is disturbing due to the increased biomass. Collecting electrons penetrating the waters surface However, its range has the least amount of importance when it comes to local water quality because: 1 all the temperatures were within acceptable limits and 2 the amount of sun light, and local weather control the relative temperature of the water. The more pressing metric is the variation of pH. The pH across the board has been lowered. The lowest was a 5.8, which can be unhealthy for stream life. While the recent rain fall at the time of the testing has a major impact on the reading of the pH meter(all but one site at record lows) the correlation of the readings through time has shown us the relative pH at all of the sites has risen with a $R^2 = .036$.

Dissolved oxygen was for the most part good. Peaks View Park was lower than expected but still within reason. The conductivity for the creeks increased in values as urbanization increased. However, the temporal data shows that areas that have finished developing have shown a decrease in materials in the water column. Areas starting to urbanize, such as Peaks View Park, have been showing a dramatic increase in conductivity.

The over all result of the water quality based on chemical analysis does support the initial hypothesis based on the temporal data of pH and conductivity. Through the comparison of figures 5, and 6 both pH and conductivity are increasing over time in urbanized areas indicating degrading water quality.

Macroinvertebrates Analysis

Methods and Materials

We sampled Dreaming Creek, Tomahawk, Hollins Mill Dam, and Rock Castle Creek (Cracker Barrel) on April 9th, 2009. On the following Monday, April 13th, 2009, we sampled the other 3 sites which included Ivy Creek at Chaffin Farm, Ivy Creek at Hooper Road, and Ivy Creek at Peaks View Park. After sampling these sites, we realized that we had collected a bad sample at Peaks View Park and re-sampled the site on April 16th. At each site, we selected suitable riffles in which to sample. We looked for riffles that had small to medium rocks (because the Hess sample would not fit around larger rocks), and also had fast water flow. We used a Hess sample to sample each riffle. We selected this sampling method because it gives an exact meter^2 value. This keeps the measurements precise and consistent. We would place the Hess sampler in the water and place it firmly into the ground. This would eliminate macroinvertebrates from going under the Hess sampler. After the Hess was securely in the ground, one person would then use their hands to dislodge macroinvertebrates by shifting rocks and debris inside the Hess. We would do this three times at each site, with one sample from downstream, midstream, and upstream based on the stream reach. Upon returning to the lab we would put the entire sample on alcohol until the macroinvertebrates in each sample could be identified.

We choose to identify what was in each sample on various days. In order to do this we would drain the alcohol out of the bottle into a separate bottle. Then we would put the sample into a dissecting dish with water. We would pick out the individual macroinvertebrates using a probe and tweezers. We would then identify the macroinvertebrates using A Guide To Freshwater Invertebrates of North America, J. Reese Voshell, Jr. This book contained comprehensive information regarding the larvae form of each macroinvertebrate and also contained information about habits and preferred living situations. After we identified each macroinvertebrate we placed them in a bottle of alcohol together in order to save them for our records. We then would use the lists acquired from identifying the macroinvertebrates and fill out spreadsheets which would give us the EPT (Ephemeroptera, Plecoptera, and Tricoptera), FBI (Family Biotic Index), and PMA (Percent Model Affinity).

Indices

- EPT

EPT measures the number of Ephemeroptera (mayflies), Plecoptera (stoneflies), and Tricoptera (caddisflies) in each stream. Each of these species are good indicators of pollution and are specimens found in clean-water (Lenat 1988). EPT is measured on scale 0 to 10, 10 being the best. A score of 10 would indicate excellent water quality, a score of 6 to 10 would indicate a slightly impacted stream, 2 to 5 moderately impacted and a stream with a score 1 or lower would indicate a severely impacted stream. The EPT score is determined by adding together the total number of EPT families found in the sample. EPT can be a good measurement of because these families have quick reaction time to change in the water and the measurement is consistent at all sites sampled. Some of the drawbacks of using EPT as the sole measurement is that it does only include three families.

- PMA

The Percent Model Affinity (PMA) measures the similarities of a stream to an ideal or non impacted stream. The non impacted stream is based on its percent abundance in seven major groups (Novak and Bode 1992), these groups being, Ephemeroptera, Plecoptera, Tricoptera, Coleoptera, Chironomidae, Oligochaeta, and other. PMA is measured on a scale from >64 to <35, 64 and above being the best indicating excellent water quality. 50 to 64 would indicate good water quality with slight impacts, a measurement of 35 to 49 would indicate fair quality with moderate impacts, and a score of 35 or below would show poor quality and severely impacted water.

- FBI

The Family Biotic Index (FBI) is an index that assigns macro invertebrate species or families a score based on their sensitivity of organic pollution. FBI is on a scale of 1 to 10, meaning very sensitive to organic pollution and 10 being the least sensitive to organic pollution. The FBI is calculated by multiplying the tolerance value of each species by the number of individuals, then dividing by the total number of individuals. If a stream has a score ranging from 0.00-3.75 it would indicate excellent water quality with low organic pollution, 3.76 to 5.00 would indicate very good to good water quality with some organic pollution, 5.01 to 6.5 would indicate fair- fairly poor water quality with substantial pollution likely and a score of 6.51 to 10 would indicate poor to very poor water quality and severe organic pollution likely. A good reason for using FBI to measure water quality is that it uses all macroinvertebrate families' but it tends to over estimates problems in moderately impacted streams and underestimates pollution problems in severely impacted streams.

Results

Dreaming Creek at McConville Road had the best water quality of all seven streams according to our FBI measurements receiving a score of "excellent" (Table 3). Ivy Creek and Chaffin's Farm and Ivy Creek at Hooper Road have an FBI score of "good" (Table 2). Meanwhile, Blackwater Creek at Hollins Mill Dam, Ivy Creek at Peaks View Park, and Tomahawk at cement plant all had an FBI score of "fair" (Table 1). Rock Castle Creek at Cracker Barrel had the lowest FBI score of "very poor."

Ivy Creek at Chaffin's Farm, Ivy Creek at Hooper Road, and Dreaming Creek received the highest EPT scores all of which received a score of "good." Blackwater Creek at Hollins Mill, Ivy Creek at Peaks View Park, and Tomahawk at cement plant all had an EPT score of "fair". Rock Castle Creek at Cracker Barrel continues to have the worst water quality including EPT score which was "poor".

Chaffin's Farm and Dreaming Creek again have the best water quality regarding PMA scores along with Peaks View Park. All three got a PMA score of "excellent." Hooper Road and Hollins Mill Dam all received a score of "fair" while Tomahawk received a "poor". Rock Castle once again had the worst water quality receiving a score of "very poor".

Based on macroinvertebrate assessment Dreaming Creek at McConville Road had the best overall water quality closely followed by Ivy Creek at Chaffin's Farm and Ivy Creek at Hooper Road. The majority of the other streams fell into the "good" or "fair" category with the exception of Rock Castle Creek at Cracker Barrel. This site had consistently bad scores for EPT, PMA, and FBI. Every measurement had a score of "poor" or "very poor". Figure 1 ranks the streams in order of water quality from best to worst based on their EPT, PMA, and FBI scores. The scores were averaged for each stream in order to obtain this number. According to the macroinvertebrate data the ranking of each stream is different from the ranking of streams based on land use. Ivy Creek at Peaks View Park and Dreaming Creek at McConville Road stand out the most receiving biological scores much higher than we expected based on land use. Generally, however, our data supports the hypothesis that urbanization degrades water quality. Rock Castle Creek at Cracker Barrel, our most urbanized site, continuously received very poor biological scores.

Discussion

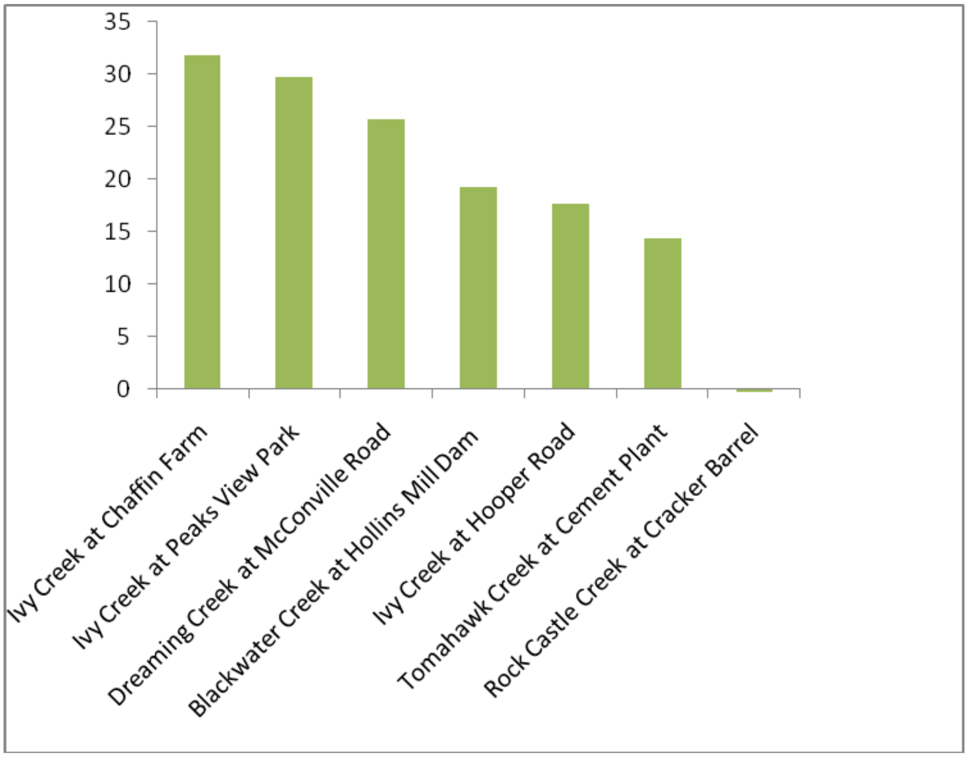

Figure 1. Ranking of Streams Based on Average of Macro Data

- Spatial

With a few exceptions, macroinvertebrate data was supportive of the hypothesis that urbanization degrades water quality. Peaks View Park turned out to be one of the better sites that we sampled, especially considering the area that it was located in. Part of this comes from the high PMA that was found. This could be due to a variety of reasons. One reason is that the PMA works off looking for proportions of key species and comparing them to a pristine stream (Figure 1). Other than that, the EPT and FBI came out to be significantly lower. There are many reasons that these could have been lower as well. One reason is that the site was difficult to sample because the riffles were deep and contained large rocks that made it difficult to get the Hess sample into the ground. This could have caused user interference in the data.

Table 1. Spatial Data for Ivy Creek at 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	-	-

Another site that turned out to be much different than we expected was Ivy Creek at Hooper Road. This site was supposed to be one of our better sites due to the location upstream in the Ivy Creek system and the presence of a densely wooded area around the stream. The EPT, FBI and PMA all came out significantly lower than they were expected to come out (Figure 2, 3). A reason that these could have come out lower than they were expected to could be urbanization. Recently the area has been urbanizing and this could be having a detrimental effect on the stream.

Table 2. Spatial Data for Ivy Creek at 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	-	-

Our most surprising data for the year of 2009 was Dreaming Creek at McConville Road. Due to urbanization in the past years the stream bed was deeply embedded and appeared to have many problems. However, our data did not those that this stream was suffering. Before sampling Dreaming Creek, we expected to get very few, if any, macroinvertebrates. Our data on the other hand suggested that Dream Creek was doing quite well, with FBI and PMA both being considered "Excellent" quality (Figure 2, 3). The only thing that was not excellent was the EPT. This could be because the EPT populations are still recovering, or they are still suffering from forms of pollution, and since they are some of the most sensitive species, they aren't able to thrive like other families of macroinvertebrates.

Table 3. Spatial Data for Dreaming Creek at 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	-	-

- Temporal

Data was interpreted for six of the seven sites for the years 2004 to 2009 excluding the year 2006: Ivy Creek at Chaffin's Farm, Ivy Creek at Hooper Road, Blackwater Creek at Hollins Mill Dam, Ivy Creek at Peaks View Park, Dreaming Creek at McConville Road, and Rock Castle Creek at Cracker Barrel. FBI was the first parameter that we interpreted and although it shows a weak correlation with an R^2 value of .2 it does support the hypothesis that urbanization degrades water quality. PMA shows an almost identical relationship having a weak correlation but still supporting our theory. Our PMA data has an R^2 value of .31 which is low but still supportive. EPT shows a similar relationship although with a slightly higher R^2 value. This shows that urbanization and the subsequent pollution is having an adverse effect on the existence of Ephemeroptera, Plecoptera, and Tricoptera species. Overall, our temporal data supports our hypothesis that urbanization degrades water quality. Urbanization needs to be mitigated in order to conserve the health of our streams and the diversity of species within those streams.

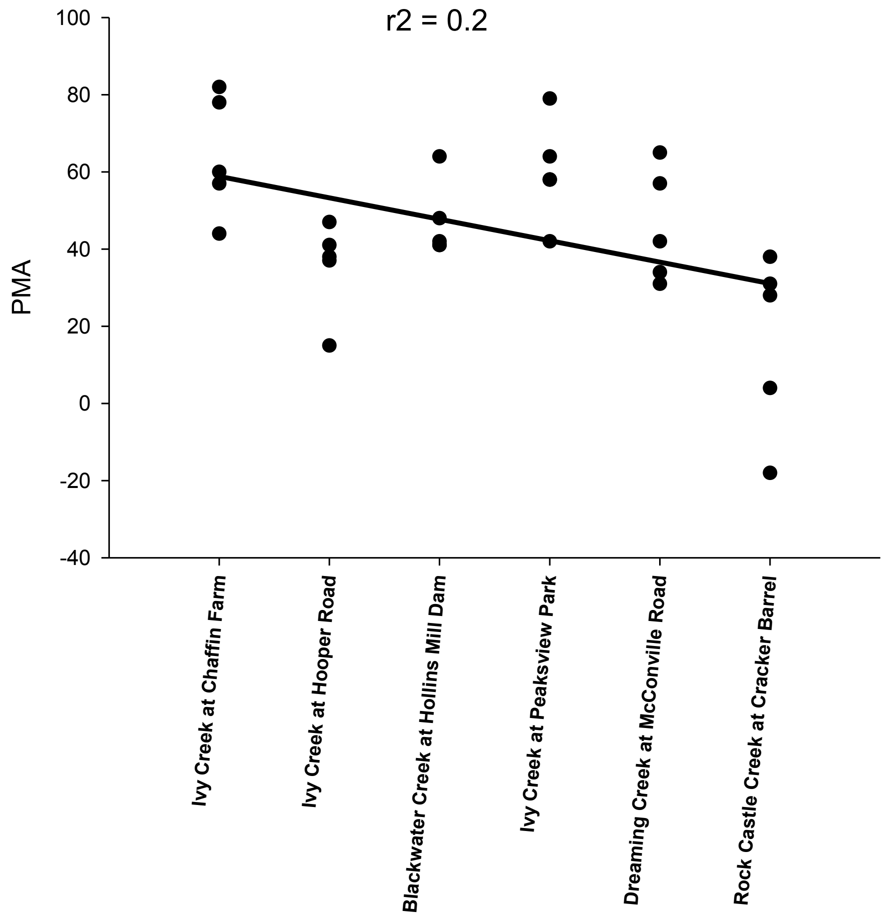

Figure 2. Temporal Graph of PMA from 2004-2009

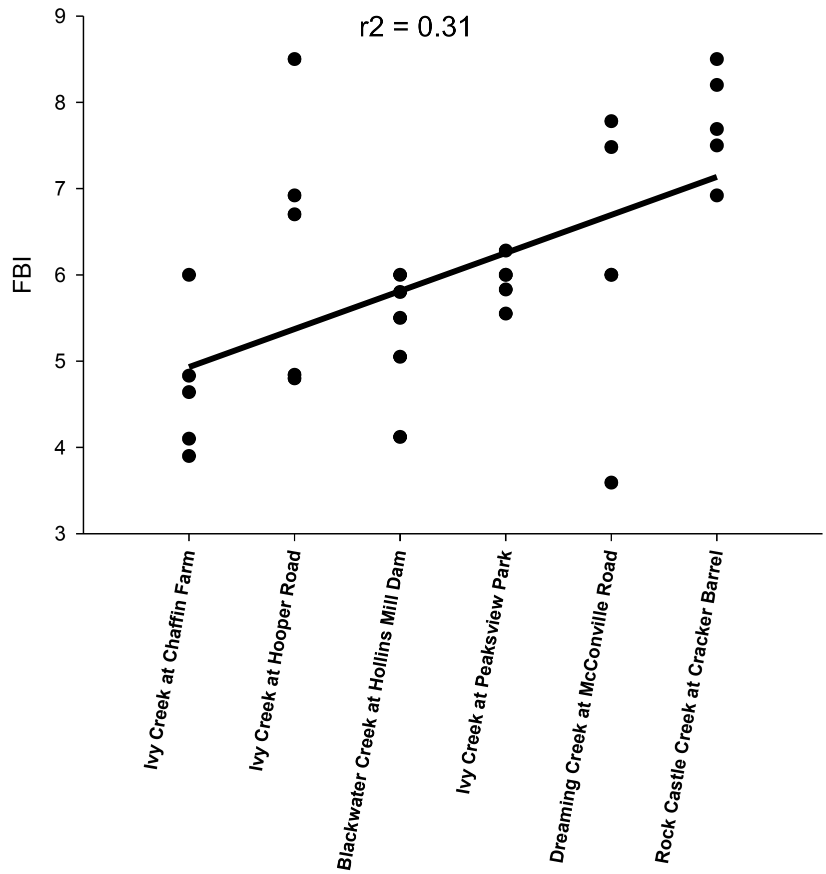

Figure 3. Temporal Graph of FBI from 2004-2009

Fish Analysis

Methods and Materials

Fish sampling was conducted on three different days. On April 9, 2009, Dreaming Creek and Rock Castle Creek were sampled. There had been no rain in the twenty four hours before sampling, and it was sunny with a temperature around 67 degrees Fahrenheit. On April 14, 2009, Ivy Creek at Peaks View and Blackwater Creek at Hollins Mill were sampled. There had been approximately 0.5 inches of rain in the twenty four hours before sampling, and the day was cloudy, around 55 degrees Fahrenheit. On April 16, 2009, Ivy Creek at Chaffin Farms, Ivy Creek at Hooper Road, and Tomahawk Creek were sampled. There had been no rain in the twenty four hours before sampling, and the day was sunny, around 65 degrees Fahrenheit. Fish were collected by using an electro-fish-shocking, Smith-Root backpack. A team of four people were sampling at every site except Dreaming Creek and Rock Castle Creek in which six or seven people helped. The electro-fish-shocking backpack was calibrated when both the probe and the tail were in the water. The person operating the unit waved the probe under water across the stream. Two people were netting fish at the tail and one at the front placing the fish in buckets. Sampling time was 30 minutes at all sites except at Chaffin Farms, which was 20 minutes. After shocking, the fish were identified using the book, Freshwater Fishes of the Carolinas, Virginia, Maryland, & Delaware. Rhode et. al (1994). Numbers and species of fish were recorded in a field journal.

To get an indication of the water quality based on the fish data, the Index of Biological Integrity (IBI) was used. After the fish numbers were totaled, the data was entered into a spreadsheet to calculate specific numbers and percentages to determine IBI scores. The test consists of nine different measurements which include: total number of fish species, total number/relative percent of darter species, 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, relative abundance of top carnivores, and the deviation from ideal or number of individuals in sample. Each measurement is scored a five if it reflects very little human impact and a one if it reflects significant human impact. A perfect score is 45 and minimal score is 9.

Since the length of time of each shock was not the same for each site, the amount of fish had to be standardized. Each shock was 30 minutes except at Chaffin farms, which was 20 minutes. We multiplied the quantity of fish at six of the sites by two, and we multiplied the quantity of fish at Chaffin Farms by three so that all the sites would be based on a number of fish for sixty minutes. This standardization is called catch per unit effort (CPUE).

Results

Table 1. Demonstrates the total/relative percent of different fish categories according to each site sampled.

	Chaffin Farms	Hooper Road	Hollins Mill	Tomahawk	Peaksview	Dreaming	Rock Castle
Total Fish Species	11	13	10	13	7	11	13
Total # Fish Caught	774	362	184	198	56	534	334
Percent Percids	7.36	35.91	28.26	14.14	3.57	5.24	34.13
Percent Suckers	0.39	1.11	2.17	11.11	3.57	15.73	1.2
Percent Cyprinidae	88.76	59.12	19.57	72.73	3.57	77.9	62.87
Percent Catfishes	1.55	2.76	0	0	0	0	0
Percent Sunfish	1.94	1.11	50	1.01	82.14	1.12	1.8
Percent WC Insectivores	1.94	1.1	50	1.01	78.57	1.12	1.8
Percent Pool Insectivores	19.77	48.07	30.44	49.49	14.29	25.47	40.12
Percent Omnivores	78.29	49.72	4.35	48.49	3.57	73.41	56.29
Percent Carnivores	0	0	0	0	3.57	0	0
Total # WC Insectivores	15	4	92	2	44	6	6
Total # Pool Insectivores	153	178	84	100	8	136	134
Percent Tolerant	32.95	14.36	56.52	39.39	89.29	62.92	41.32
Percent Intolerant	67.05	85.64	43.48	60.61	10.71	37.08	58.68

•Green = IBI score 4-5
•Yellow = IBI score 3
•Red = IBI score 1-2

Table 2. Index of Biological Integrity (IBI) for 2009

Index of Biological Integrity (IBI)							
Measurements	**Chaffin Farms**	**Hooper Road**	**Hollins Mill**	**Tomahawk**	**Peaksview**	**Dreaming Creek**	**Rock Castle Creek**
Total Number of Species	5	4	4	5	2	3	5
Total Number / Relative percent of Darter Species	2	5	4	3	1	1	5
Total Number / Relative percent of Water Column Insectivores	4	5	2	5	1	5	4
Total Number / Relative percent of Pool-Benthic Insectivores	4	1	2	1	5	3	1
Total Number / Relative percent of Intolerant Species	5	5	2	4	1	2	4
Relative abundance of Tolerant Species	5	5	2	4	1	2	4
Relative abundance of Omnivores or Generalist Feeders	1	3	5	3	5	1	2
Relative abundance of Top Carnivores	1	1	1	1	5	1	1
Deviation from ideal or number of individuals in sample	3	4	2	2	1	2	2
Totals for each site ►	**30**	**33**	**24**	**28**	**22**	**20**	**28**
Grade ►	**Good**	**Good**	**Fair**	**Fair**	**Poor**	**Poor**	**Fair**

Table 1 represents an overall summation of the fish data according to each site sampled. Total numbers and percentages of certain fish categories and fish niches are demonstrated. These totals and percentages gave us the determinants for giving an overall IBI score. This table shows specifically the individual scoring from 1-5 for each of the nine measurements of the Index of Biological Integrity. In looking just at Table 1, the best sites in terms of having IBI scores of four or five in several categories are Ivy Creek at Chaffin Farms, Ivy Creek at Hooper Road, and Rock Castle Creek.

Table 2 shows IBI scores for 2009 at each sampling site. The highest score possible is 45, which indicates excellent water quality and a minimal score is 9, which indicates very poor water quality. Based on IBI scores, Ivy Creek at Hooper Road and Ivy Creek at Chaffin Farms have the best water quality with IBI scores of 33 and 30, and Ivy Creek at Peaksview and Dreaming Creek have the poorest water quality with IBI scores of 22 and 20.

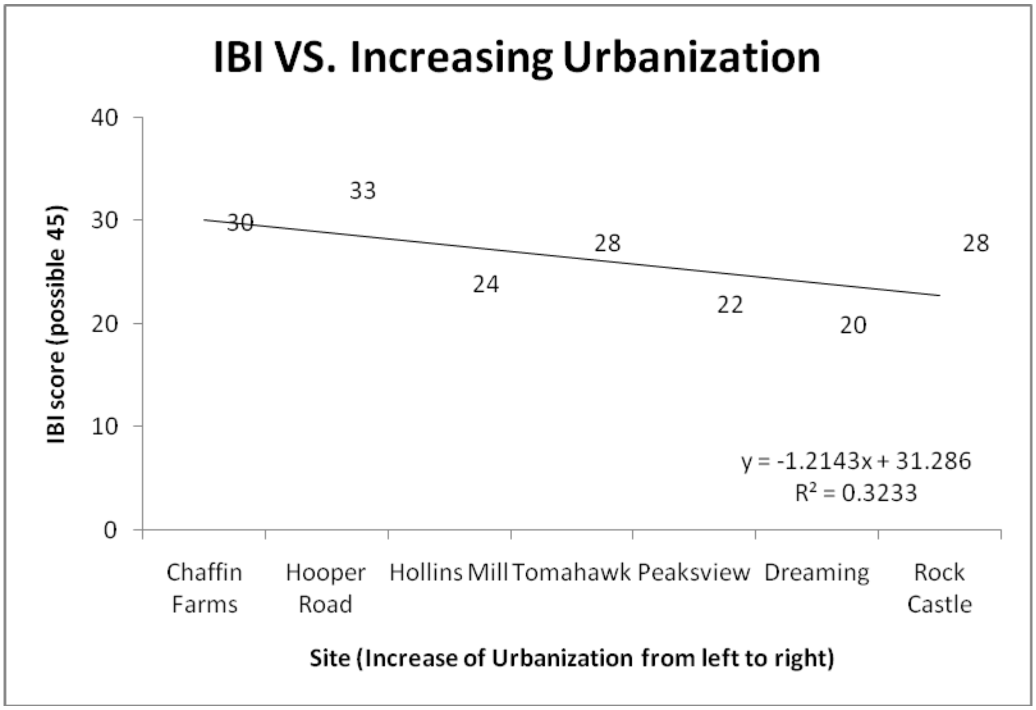

Figure 1. Demonstrates IBI scores compared to increasing urbanization for 2009

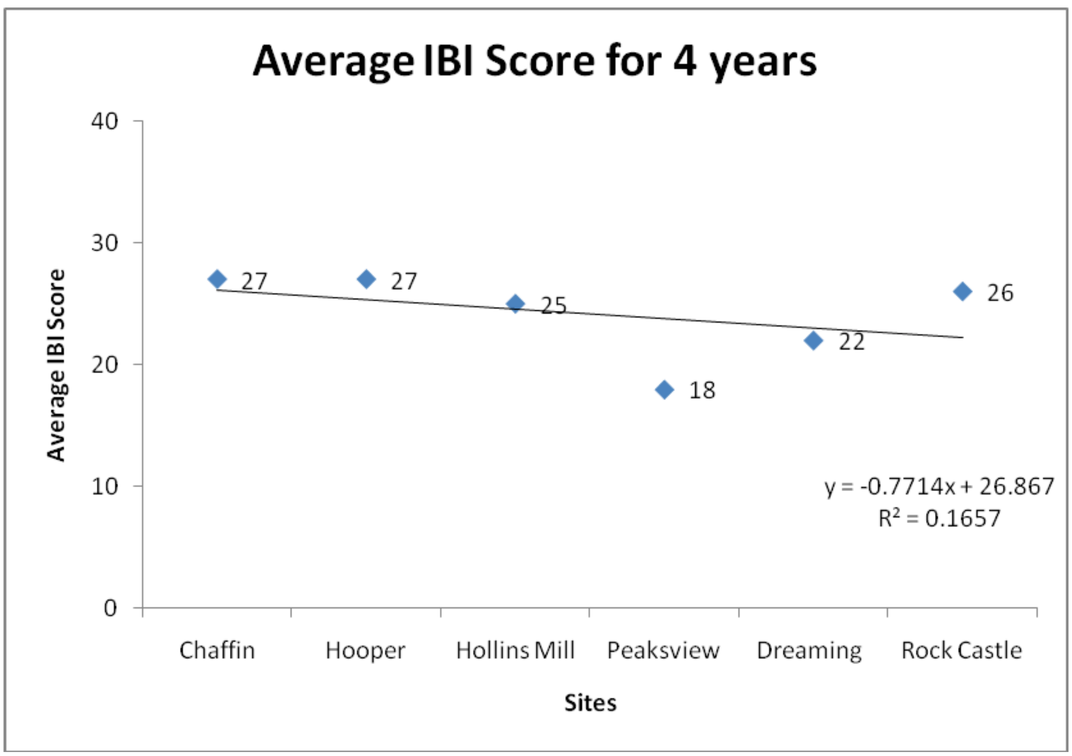

Figure 2. Shows average IBI scores over 4 years at six different sites

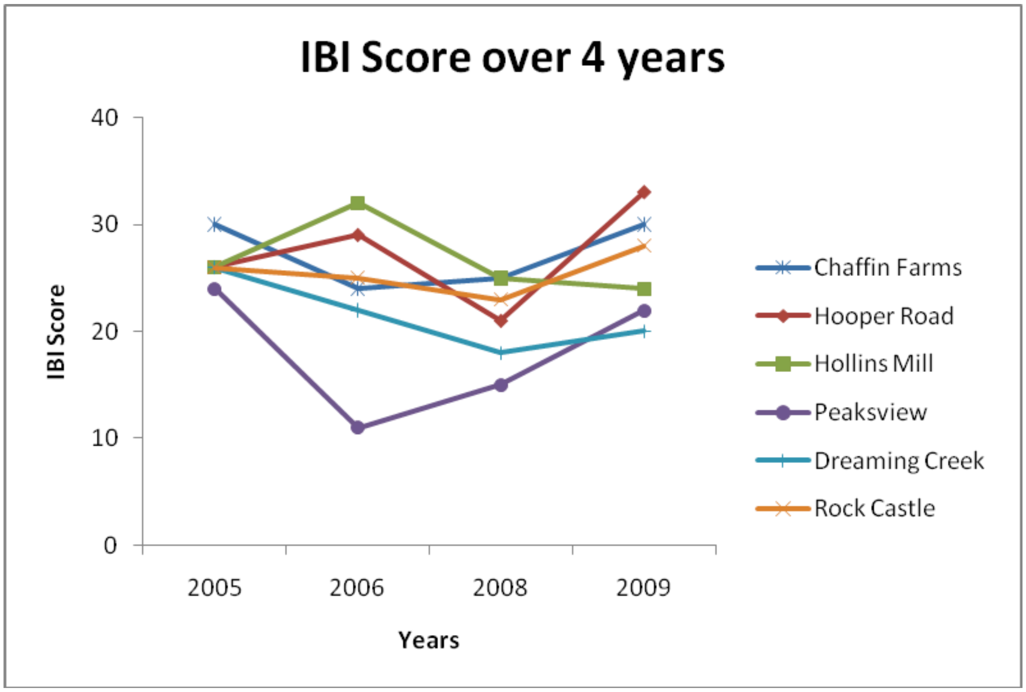

Figure 3. Shows IBI scores over 4 years for six different sites

Figure 1 demonstrates IBI scores compared to increasing urbanization spatially in 2009. There are three sites that have IBI scores higher than expected. Hooper Road has an IBI score of 33, and both Tomahawk and Rock Castle have IBI scores of 28.

Figure 2 shows the average IBI scores over 4 years for six sites. Tomahawk Creek is excluded. The sites are in order from left to right by increasing urbanization. The general trend indicates lower IBI scores for more urbanized areas. Two sites to point out include Rock Castle Creek and Ivy Creek at Peaksview, which are outliers. Ivy Creek at Peaksview shows an average IBI score of 18, significantly lower than most sites. Rock Castle, determined to be most urbanized, has an average IBI score of 26, which is close to the same average scores for Ivy Creek at Chaffin Farms and Ivy Creek at Hooper Road at 27.

Figure 3 represents a temporal demonstration of IBI scores over 4 years. Six sites are presented in this figure excluding Tomahawk Creek because 2009 was the first year for sampling at that site. Two sites that have increased from 2006 to 2009 in terms of IBI scores are Ivy Creek at Chaffin Farms and Ivy Creek at Peaksview. Dreaming Creek and Rock Castle Creek have the same general trend from 2005 to 2009. IBI scores slightly decreased from 2005 to 2008, and both sites have slight increases in IBI scores from 2008 to 2009. Hooper Road has showed a wide range of IBI scores over 4 years, but had a dramatic increase in 2009. IBI scores for Blackwater Creek at Hollins Mill have been declining since 2006, and the 2009 IBI score continues to show this downward trend.

Discussion

Before discussing our data, a couple points need to be made clear. Urbanization can be described as the decrease in percentage of rural land (Paul and Meyer 2001). Urbanization by mere definition is the process of becoming urbanized, basically meaning the process of becoming a city. Rural land is the amount of land devoted to agricultural practices or preserved forest.

Our 2009 data supports our hypothesis suggesting water quality decreases with decreasing rural land percentage (figure 1). Noting that, figure one shows a negative correlation between decreasing percentage in rural area versus water quality. The regression line of figure one has a slope of -1.2 indicating negative correlation. Although Hooper Road, Tomahawk Creek, and Rock Castle Creek scored higher IBI scores relative to other sites, our data suggests the new construction being performed around Hooper Road has not impacted fish, which can take years to be affected by urbanization. Tomahawk Creek had some restoration efforts performed 5-10 years ago (City of Lynchburg, personal communication) consisting of buffer zones along the flood plans to decrease water runoff turbidity, as well as decrease sedimentation runoff. Rock Castle Creek, on the other hand, has been impacted by urbanization for many years (25+) and there is no ongoing construction right now. The fish have somewhat adapted to the poor stream quality (black nose dace and creek chub dominance). Fitzgerald et. al (1999) supports this conclusion finding creek chubs colonizing streams where fish populations were depauperated. For the remaining four sites, they fall right into place, supporting our hypothesis as well as showing a decrease in water quality as percentage of rural land decreases.

Figure two represents the average IBI score over the four years of data that have been collected. It supports our hypothesis as well, noting that the regression line has a slope of -0.77 indicating a water quality decrease with a decrease in percentage of rural land. However, Rock Castle Creek's average IBI score is relatively good compared to the other sites and has the lowest percentage of rural land among the seven sites we sampled. Again we have concluded this to be because the site has been urbanized for so long and over the previous four years of data, there has been very little new construction. IBI may not be the best predictor of these spatial-temporal trends (Jacobson 2000). Also, the water runoff from the parking lots of Wards Crossing shopping center, Wal-Mart, and Sams Club have holding ponds which allows some water to infiltrate the ground as well as slow down water runoff. Peaksview Park has a very low average IBI score compared to the other sites for the four previous years of data, and we have concluded this to be because of the site being a recreational facility. Recreational facilities tend to have a lot of human impacts from just routine sporting events to fertilizing the grass to channel alterations, all of which impact fish species. Perhaps incorporating physical parameters into the IBI matrix would capture some of differences in fish habitat and population abundance.

Figure three represents each IBI score over the previous four years of data plotted to indicate whether the site has a trend of decreasing water quality, increasing water quality, or relatively steady water quality. Chaffin Farms has been increasing in IBI scores since 2006 and could be mainly contributed to buffer zones established and the increased efforts to keep livestock out of the stream beds. Hooper Road does not have a significant trend visible. The IBI scores were increasing from 2005-2006, decreasing from 2006-2008, and increasing from 2008-2009. We cannot make conclusions on the trend of water quality for this site until ladder years of data have been collected and analyzed. Hollins Mill has been decreasing in water quality since 2006; our findings suggest this to be because urbanization has been increasing, and there have been no restoration projects implemented to counter act the effects of urbanization. Peaksview Park has been increasing in water quality since 2006; our data suggests this trend because new construction has been minimal. Dreaming Creek was decreasing in water quality from 2005-2008, and increasing from 2008-2009. However, no conclusions regarding the trend of water quality can be made about this site until additional years of data have been collected. Rock Castle Creek has remained relatively steady with a slight increase in water quality from 2008-2009. This trend could be contributed to increased public awareness of how their actions affect stream quality as well as holding ponds implemented by the city of Lynchburg (City of Lynchburg, personal communication).

Based on fish data, urbanization has adverse effects on IBI scores in the Blackwater Creek watershed, which is supported by 2009 data as well as the previous four years of data that have been collected. Paul and Meyer (2001) support our conclusion stating urbanization has an adverse effects and consistent declines in the richness of fish communities. Although urbanization has shown unfavorable results to water quality as well as fish communities, increased public awareness of their actions and increased measures to control sedimentation issues could have a beneficial outcome on water quality.

Physical Analysis

Methods and Materials

The physical monitoring of a stream and its condition plays a large part in the assessment of a streams water quality. The physical characteristics of the stream describe the potential impact of the surrounding landscape has upon the stream. Over time, the landscape has an influence upon the streams flow and the form due to the ever changing characteristics. With the completion of gathering data for this assessment, relationships can be formed between the physical assessment and biological measuring.

We record measurements through visual interpretation of five main characteristics by performing the Unified Stream Methodology (USM) due to how it is becoming popular throughout stream's physical assessment due to its universality. The five main characteristics are channel condition, riparian buffers, in stream habitat/available cover, channel alteration, and impact factor. Upon arriving at a site the first data that was collected was the reach, which to perform we first found a ripple and then measured the width, from bank to bank, in feet, and then multiplied it by thirty. This gave us our total reach for the stream, and dividing this total by two, gave us how far we need to walk from the mid-point of the stream to reach the top and bottom of the reach. At each location, middle, top, and bottom, we also recorded the GPS coordinates and took pictures of the left bank, right bank, upstream, downstream, and any other impact that we feel necessary to report upon.

We then began our stream walk in accessing the previously mentioned five characteristics. The first, channel condition, we assessed the cross-section of the stream and prevailing condition based upon erosion and aggradations. The purpose of this evaluation is to determine if the current condition of the channel to the evolutionary process of the stream. The way this is done is by observing the incision, banks, vegetative surface protection, access to the original floodplain, and sediment cover. Next parameter is grading the riparian buffers, which is an evaluation of the cover types that make up the riparian buffer of a 100 foot area along the banks. This is done by determining what kinds of vegetation cover is present on both sides of the bank and then figuring out what percent this makes up of the total riparian buffer. The characteristics to look for in doing this assessment is the tree stratum, the circumference of a tree at chest height, percent canopy cover, and the presence of wetlands.

In-stream habitat is the assessment of the available locations within the stream for wildlife to effectively create a niche and survive in. Typical characteristics to look for are varied substrate sizes, water velocity and depth, presence of debris, embeddedness, bank undercut, and presence of riffles. Using these characteristics as a guideline, a percent of habitat elements is then obtained. Next, Channel alteration takes into considering the direct impacts of humans upon the stream. Some characteristics to look for are channelization, dredging, or alteration of the stream. Any type of human impact upon the stream is taken note of and goes into this section of calculation. The last assessment, impact factor, takes into considering the permitted influences effect upon the stream. Such permitted influences are bridges, elimination or filling of stream channel, and hardening of the stream bed to name a few. After giving scores, based upon grading parameters given by USM classification of the stream, we then add up all five parameters and divide by five to get a Reach Condition Index (RCI). The RCI is a numerical value placed on the stream assessment reach using the previously mentioned criteria in order to come up with a number that will give a final score for the streams physical impact quality.

Scores can range from 0.5 to 1.5, with the higher numbers being a more successful and physically healthy stream.

Results

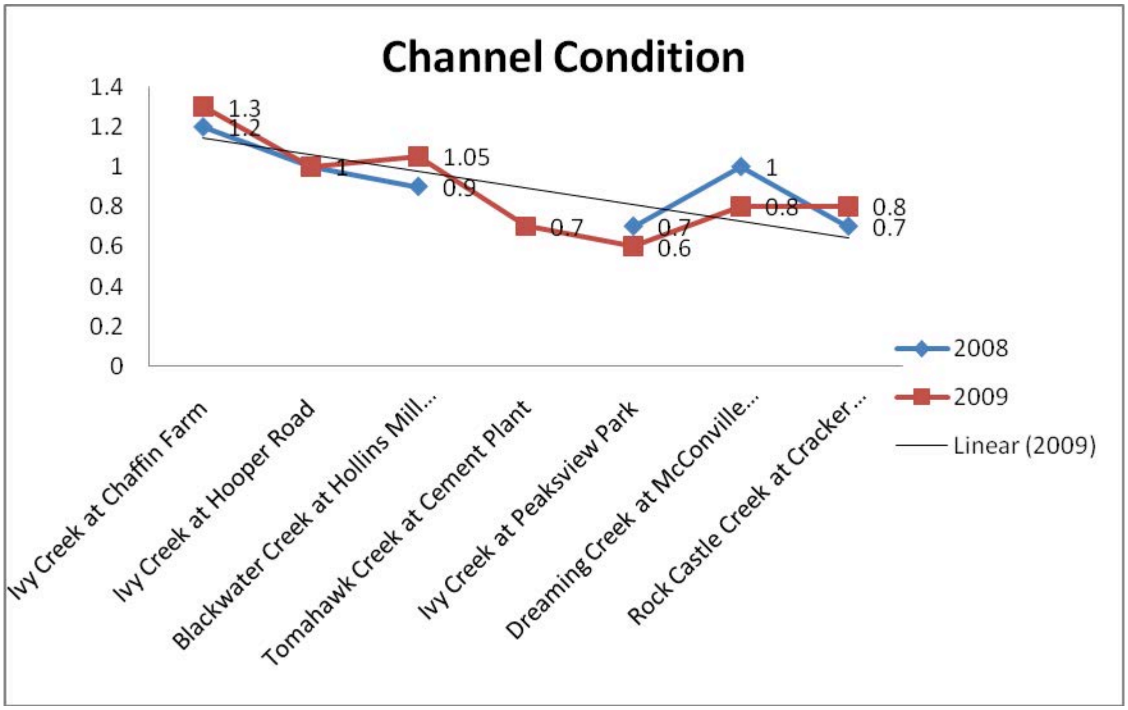

Figure 1. Channel Condition

Channel Condition is an assessment of the cross-section of the stream, along the stream reach. Under most circumstances, channels responds to disturbances or changes in flow regime in a sequential, predictable manner. The way a stream responds to changes to changes by degrading to a lower elevation and eventually re-stabilizing at the lower elevation. The purpose of evaluating channel condition is to determine the current condition of the channel cross-section, as it relates to this evolutionary process, and to make a correlation to the current state of stream stability. Because of this we can only make a vague assumption as to the evolutionary process of these streams.

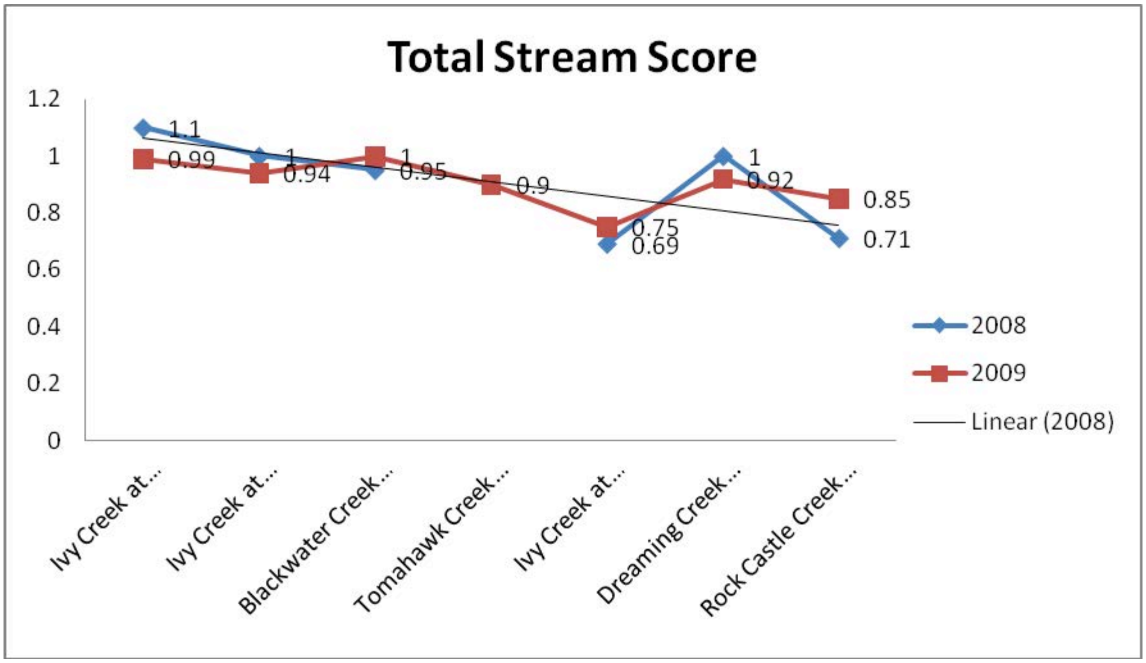

Figure 2. Total Stream Score
This takes into account all of the parameters in giving the stream an overall score. We are capable of seeing a decrease in the stream physical qualities from rural streams to more urban streams.

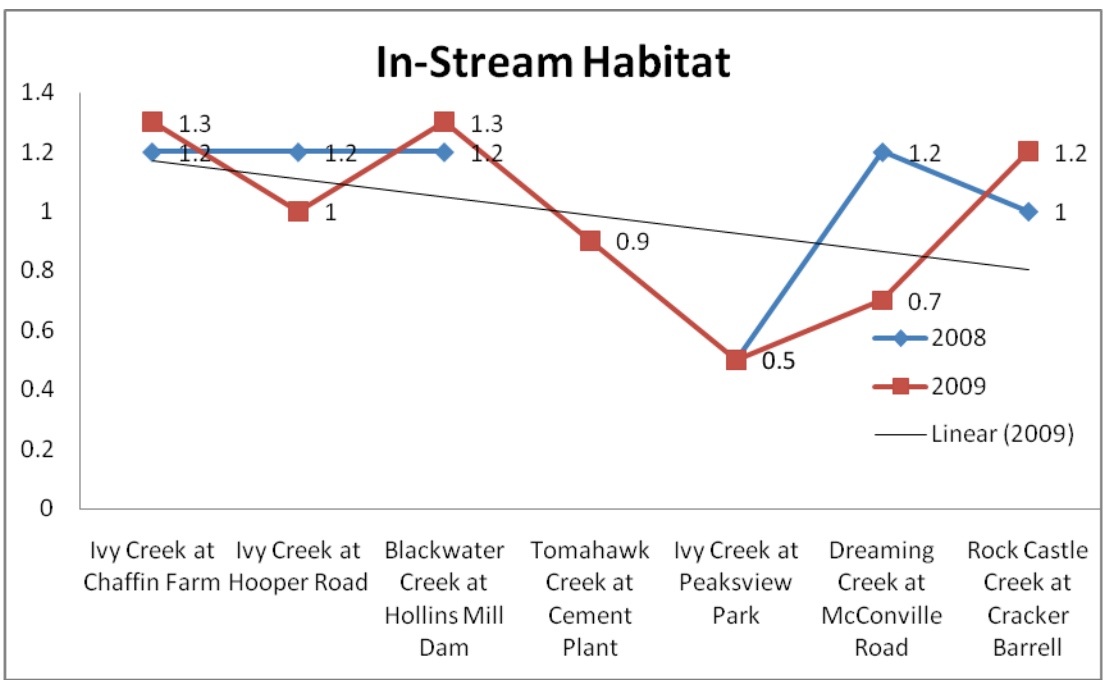

Figure 3. In-Stream Habitat
The in-stream habitat assessment considers the habitat suitability for effective colonization or use by fish, amphibians, and/or macro invertebrates. This parameter does not consider the

abundance of types of organisms present, nor does it consider the water chemistry and/0or quality of the stream. In-stream habitat is capable of taking into account if the stream is either a high or low gradient stream. High gradient streams possess optimal conditions that will help support and increase streams diversity while a low gradient stream does not possess these characteristics. Regardless of the streams possible capabilities, we did not take into account and grade different depending on if the stream was either classified as a high or low gradient stream. Even though this parameter does not and cannot take into account the wildlife present or water quality, you are able to assume that with the more available habitat it will allow a wider variety and/or abundance of in stream habitat features to provide to macro invertebrates and fish with large number of niches, thus increasing species diversity.

- Chaffin's Farm

This was the most rural site in our sampling. Chaffin Farm had the highest stream scores of all seven sites. When we took our sample the weather was cloudy and there had not been any rain for almost a week. The characteristics of the stream channel were mostly runs with a few riffles. The stream bottom was mostly embedded with silt. The riparian buffers were weak but there were restoration buffers that were recently added to keep the cattle out of the stream. Overall the banks were moderate, and the stream looked to be restoring itself from the agricultural use.

- Hooper Road

This location had bad stream bank and channel conditions. The banks on both right and left side were collapsing, and had very steep walls. There were mainly pools throughout the stream. This stream had the worst embeddedness, barely any rocks present. The water was very muddy and dark. The area was still considered rural and it had very strong riparian buffers.

- Hollins Mill Dam

Overall this stream had poor conditions, but it was an area that was being restored. This stream appeared to be slightly embedded and the channel consisted of mostly runs and only a few riffles. The stream had major alterations including, a dam and the pathway that boarded it. The day we sampled there was a bad sewer odor and we spotted a sewer leak in the pipe over passing the stream. It was a large stream and the riparian buffers were suboptimal on both banks.

- Tomahawk

This location was recently added to the data system for Blackwater Creek. This location had very poor stream characteristics. Both channel condition and in-stream habitat was very low. The banks were severely eroded and the stream had have debris throughout the sample. The water was very muddy and the bed was extremely embedded. This stream had optimal riparian buffers on both sides. A concrete plant was located downstream and there was a lot of debris dumped into the stream from the concrete plant.

- Peaks View Park

We sampled this location after a heavy rain. The stream consisted of runs, pools, and a few riffles. The whole stream had very high banks on both sides, and they were covered with riprap. The area was surrounded with sport fields and houses, consisted of weak riparian buffers. Overall the stream has been altered in many occasions, with riprap and channelization.

- Dreaming Creek

The stream is located on in a recently developing area with multiple new construction sites. When sampling we found the stream to be very shallow and consisted of mostly riffles and a few runs. The area we sampled had weak riparian buffers but there was a restored buffer upstream of the area. Overall there were houses and other construction being built supplying the stream with a lot of sediment. The bed was mostly embedded allowing the water to be dark and muddy. There was one major channel alteration located in the middle of the sample. A bridge for the road way nearby had almost blocked the whole stream, slowing down the stream flow.

- Rock Castle Creek

This location was the most urbanized area. The channel conditions in this sample were strong, but the stream was impacted severely by the two bridges at both upper and lower reaches of the sample. The riparian buffers contained nearly no trees. The right side of the stream was Wards and the left side grass and parking lots for the surrounding businesses. This stream had been impacted for a very long time. There was little embeddedness, but the buffers and stream were covered in trash and other debris.

Discussion

In conclusion, looking at the total stream score, in-stream habitat and the channel condition as our main qualities that have an effect upon water quality indirectly or show a grade for the physical condition of the stream, each graph shows a decrease from rural streams to urban streams. Understanding the in-stream habitat graph you can see the general decline in in-stream habitat availability from the most rural stream to the most urban stream. As mentioned before, the greater the in-stream habitat conditions are allows for greater bio-diversity. With more niches in the stream and with that you can assume that the macro-invertebrates population will rise and with the presence of macro-invertebrates that shows that the water quality is good due to the fact that they cannot survive in poor water qualities. The same can be said for the channel condition as that it shows an evolutionary trend in the stream, and even though we do not have a lot of years to compare data with we can see the general decline in trends of streams, which also in turn affects the water quality.

All the factors come together in the total stream score which grades the whole stream as a snapshot in time and judging from the general decline it is safe to assume that the streams' physical qualities throughout have also decline and therefore impact the water quality. In comparing the two years of stream assessment date between 2008 and 2009, there is a direct correlation between the two years with each site going from least urbanized, Ivy Creek at Chaffin farm to most urbanized, Rock Castle Creek. Our data shows a decrease in all parameters of USM. This in turn further helps and supports our conclusion that urbanization decreases water quality.

Discussion

Indices of Water Quality

The multitude of different indices of water quality provide the researcher a wide array of tests that can support or dispute various hypotheses. Each test has its own value in the grand scheme of water quality assessments. When looking into the water quality of a stream in general, one must take into consideration all aspects of a stream, from the chemical analysis to the physical buffers. However, and especially when comparing streams on a temporal scale, one must remember that certain indices detail the larger picture. Chemical data is a brief “snapshot” of water quality at any given time. Thus, it is more susceptible to subtle, daily changes. Fish, on the other hand, adapt and respond slower and over longer periods of time. So a pollution event that has only recently begun will not be represented in an IBI analysis. An urbanization event that has been in production for three years, however, will be demonstrated in species of fish, and how many fish, are present in a stream while pH level may be stable for the region.

Water quality is studied in these different layers: recent changes as displayed by chemical data, on-going changes as displayed by fish and macroinvertebrates, and ancient human impacts as displayed by physical alterations. Not only must one examine the sites individually, but an assessment of the watershed as a whole entity is necessary to determine if the hypothesis is correct. If the quality of two streams of the same order are vastly different, there is certainly some event or interference in the streams natural state. If two streams in equally urbanized areas show similar results, then definitive conclusions can be reached.

Overall Water Quality for 2009: Supportive Evidence

Based on the culmination of the individual indices for 2009, we can conclude that the Blackwater Creek Watershed supports our initial hypothesis that urbanization degrades water quality (Table 1). By “averaging” the general scores from each index, we were able to rank each site vaguely to see the general pattern. By examining each individual index, we can see the general trend moving from Ivy Creek at Chaffin’s Farm to Rock Castle Creek at Cracker Barrel for water quality to decrease.

Table 1. General water quality assessment as decided by “average” indices evaluation

Testing Sites	% Rural	Water Quality
Chaffin’s Farm	85.01	Good
Hooper Road	71.9	Good
Hollins Mill	41.49	Fair
Tomahawk	39.03	Fair
Peaks View Park	36.67	Fair
Dreaming Creek	31.97	Fair
Rock Castle Creek	31.41	Poor

Examining conductivity, there is a dramatic increase in conductivity moving to more urbanized locations. Higher conductivity indicates the presence of sediment and other materials in the water. A healthy conductivity level for a stream is between 50 and 100 µs/L. Rock Castle Creek at Cracker Barrel has a conductivity reading of 232 µs/, way beyond an acceptable healthy level. The other indices have little or no trend, so conductivity provides the best chemical assessment of water quality.

Looking at long-term impacts, "biological indicators are the best and most accurate measure of the health of a river, stream, or lake" (2009). In examining macroinvertebrates, and primarily EPT scores, there is a definite difference between our reference stream, Ivy Creek at Chaffin's Farm, and the most urbanized stream, Rock Castel Creek. Chaffin's Farm scored a PMA of over 64 and an EPT score of between 6.0 and 9.0 indicating very good water quality. Rock Castle Creek, at the other extreme, scored a PMA of less than 35 and an EPT of 0 to 1 – very poor water quality. The 2009 fish IBI also showed a slight downward trend with an R^2 value of 0.3233. The slight correlation is skewed only by Rock Castle Creek, while the other testing sites follow a significant trend.

Overall Water Quality for 2009: Deviations

Although much of the data does in fact support the hypothesis, there are some slight deviations, such as the IBI at Rock Castle Creek mentioned before. IBI at Rock Castle scored a 28, only two less than Ivy Creek Chaffin's Farm. This sudden spike in fish quality may be the result of stabilized urbanization or rapid fish adaptation. Procedurally, the Rock Castle Creek region had a team of seven individuals gathering and identifying fish while other sites only had four hands on deck. Increased fish numbers are most likely the result of this extra help.

Weather must also be taken into consideration. In comparison with previous testing years, this spring has been significantly wetter, with more recent precipitation. The increased volume of water and flow of water may have accounted for the excellent macroinvertebrate score at Dreaming Creek. The lack of multiple trials for each index must also be considered. One great day of species collection may not account for actual quality.

The physical analysis also showed significant deviations from the general trend, such as Dreaming Creek's impressive total stream score. Physical data, however, is one aspect of stream quality with can be quickly destroyed but also easily covered up. Quick restoration projects give streams the appearance of being healthy, and indeed they may be so, but the organisms living in the stream require time to actually recover.

Tomahawk

Tomahawk, a new random testing site added this year, was the same stream order as Hooper Road and Dreaming Creek. Tomahawk, in terms of percent rural, fit in the middle of the general trend with 39.03 percent rural (Table 1). In terms of most individual indices, Tomahawk did indeed fit with lower water quality than Hooper Road but better water quality than Dreaming Creek. This same order stream further supports the hypothesis that urbanization degrades water quality. Addition sites that are comparable stream order to Chaffin's Farm would also be a welcoming addition.

Water Quality Over Time

Discussing changes in the watershed as a whole over time, we must look back at the watershed prior to human interference. When all the area was naturally wooded and rivers were allowed to flow naturally and undisturbed, was there a different trend? Higher order streams, such as Dreaming and Tomahawk, have slower moving bodies of water and deeper channels in general. In such streams, there is higher diversity of fish and macroinvertebrate species as well as more benthic and organic matter left to be picked up by microorganisms rather than being flushed away downstream by rapid runs (Matthews 1998). These large bodies of water can be said to then be slightly better water quality than the faster moving, lower order streams (such as Chaffin's Farm). In exploring the recent data, where the larger order streams are in more urbanized areas, we can clearly see that this trend has reversed itself – lower order streams are now healthiest because they are settled in more rural regions. Human impact has indeed affected the streams over time.

Exploring individual sites overtime, many highly urbanized sights (such as Rock Castle Creek) show improvement in some areas, for example the IBI score. This sudden improvement from previous years demonstrates stabilization or the adaptivity of the species. Other sites, such as Peaks View Park, continue on the downward trend from the previous year, showing drastic decreases in water quality.

Urbanization in Lynchburg City and the surrounding counties is expected to increase in the coming years, with Bedford County experiencing an 18 percent population increase. It can be assumed that without corrective and preventative measures, the streams in these growing areas will degrade with the coming cluster of urban development.

Subjectivity and Potential Errors

In sampling, there is always the potential for something to go awry. Either some equipment will break or some bias will emerge when examining the data. First, species classification for the macroinvertebrate and fish analysis could be skewed. By using a standard set of identification books, we are able to minimize misclassifying a species. But since photos and descriptions of aquatic organisms are usually colorful (warm water colors) and the creatures caught are more muted in shade (cold water colors) there is always the risk for the wrong label. Using one's eyes as a tool for analysis is difficult, and a better method would be to use blood tests, but that procedure is expensive and time consuming.

Equipment used, especially in chemical analysis, must be properly calibrated before use and there is the chance that calibration was performed improperly. Sensitive meters, such as the pH meter, also have the tendency to short out or reset themselves. Multiple tests using different meters is one way to correct the problem and ensure an accurate average assessment.

Before examining a site, there is always the potential for personal bias. When arriving at a stream next to a busy highway, researchers automatically make the assumption that the stream will be polluted and immediately begin looking for damaging evidence of pollution. Even titles, such as "restoration site" can influence results. A stream labeled "restoration" must automatically be seeing improvements, although the data may show a decreasing trend. While bias is nearly impossible to discount initially, when examining the actual numbers and data, one must push aside any previous thoughts or notions and report objectively on the results.

Suggestions for Best Water Management Plan

The consequences of the current urbanization and land uses in the Blackwater and Ivy Creek Watersheds need to be addressed to reach future water quality improvements. The Blackwater Creek Watershed continues to be impacted through urbanization and increasing impervious surface, resulting in sedimentation, channelization, nutrient runoff, loss and alteration of riparian habitat, and combined sewer/storm water overflow (Shahady, 2008). In order to achieve and maintain the water quality levels necessary to support the aquatic resources of the watershed, and to protect human health concerns, restoration measures must be implemented on a short term time frame. Recommendations for improvement approaches include general site proposals concerning land use and best management practices (BMPs), increased government involvement, and community watershed outreach opportunities.

With increased government involvement, the issues of regulation and enforcement can be dealt with. Additional tax breaks and subsidies encouraging restoration, preservation, and sustainable development have the potential to significantly increase water quality within the watershed. By providing incentives for activities such as stream bank restoration, citizens will be more likely to do their individual part in helping to improve water quality. BMPs for private land owners, developers, and current businesses also encourage the protection of streams within the watershed. BMPs can be defined as effective, practical, structural or nonstructural methods which prevent or reduce the movement of sediment, nutrients, pesticides and other pollutants from the land to surface or ground water, or which otherwise protect water quality from potential adverse effects of land use (2008). These practices are developed to achieve a balance between water quality protection and the continuing development in the watershed, considering both natural and economic limitations. BMP performance includes structural BMPs such as improved infiltration devices, retention ponds, and constructed wetlands; and the effectiveness of non-structural BMPs, comprising of low impact development practices and management measures such as land maintenance practices, street sweeping, public education and outreach programs (2008). The practices coincide with the idea of implementing sustainable development practices in the watershed.

Sustainable development can be defined in brief as the ability to make development sustainable in a way that ensures it meets the needs of the present without compromising the ability of future generations to meet their own needs (Kates 2005). For example in the City of Lynchburg, a continued revitalization of the historic downtown area would reduce urban sprawl to the outlying areas on the city as well as in Bedford and Campbell Counties. Other examples of sustainable development practices include the incorporation of green roofs which help infiltration rates in impervious areas and the use of gravel instead of pavement when the opportunity arises. The use of bio-filtration in parking lots has proved to reduce pollution inflow to adjacent streams. Finally the continued use of porous pavement in development projects has the potential to positively affect water quality by allowing greater infiltration and reduce runoff quantity and velocity.

Because the watershed is contained within three different governmental jurisdictions including the City of Lynchburg, Bedford County, and Campbell County, a comprehensive conservation and regulation framework would enhance future land use and create a relationship between development and environmental protection. The framework must be adopted equally among the three jurisdictions in order to bring a more holistic management approach into the Blackwater and Ivy Creek Watershed. If a comprehensive holistic framework cannot be accomplished within a short term time frame, the review of local codes and ordinances in each individual locality would be beneficial (Shahady 2008). The strengthening of current regulations addressing stream protection and water quality, along with the development of additional regulations will help improve the overall water quality, assuming that there would be proper enforcement of the laws.

Obtaining an overall compliance of the regulations must be accomplished in order for any regulation to be deemed affective. Penalties for noncompliance must also be created in each jurisdiction. Stricter fines and penalties could be applied and enforced when the laws are not followed. One regulation that would significantly help increase water quality would be the development of a stream buffer ordinance, with minimum of 75 feet on either side (Shahady 2008). Specificities could include maintaining the buffer with a certain percentage of native vegetation. Increased buffer would protect the water from nonpoint source pollution coming from runoff as well as strengthen the stream bank health and reduce erosion. The velocity of the water coming off the land would be decreased with the enlarged area of vegetation.

Stewardship and community engagement is another way of addressing the issue of improving water quality. By promoting individual stewardship and assisting individuals who share an interest in the environment, groups including community-based organizations, businesses, and schools can successfully put into action initiatives that will help improve water quality especially over a long period of time. Another aspect of community outreach that would help to improve water quality involves the promotion of landowner stewardship which emphasizes the need to adjust human activities to preserve, promote, and improve natural resources (Shahady 2008). Volunteer opportunities including trash removal and tree plantings along streams banks help to promote the value of our natural systems to the surrounding community. By communicating the potential effects of human activities on water quality such as septic systems, fertilizer rates, and recycling strategies, the community gains a better understanding of their effects on the environment (Shahady 2008). Through education, the probability will increase that citizens will practice better land use practices.

One restoration measure that should be implemented as soon as possible is the minimizing of impacts of future development on the ecosystem to prevent further degradation of water quality within the Blackwater Creek Watershed. Watershed protection often requires local government to secure additional staff and resources to monitor, enforce, and, manage watershed protection features. Therefore in order to improve overall water quality, an increase in financial responsibility on the local governments will be necessary.

Recommendations for Future Studies

The analysis of the effects of urbanization on the Blackwater and Ivy Creek Watersheds thoroughly addresses many of the components that contribute to water quality. However, urbanization also influences fecal bacteria and other microbes that indicate stream health. Bacterial densities are a major issue after storms, especially for Combined Sewer Overflow (CSO) drainage systems, which collect rainwater overflow, domestic sewage, and industrial wastewater in a single pipe. Currently, Lynchburg is switching from such a system and creating two separate systems for the two water sources. Although the sewer waste is usually discharged at a sewage treatment plant, the volume of wastewater may exceed the capacity of the sewer system or treatment plant, especially during periods of heavy precipitation.

CSO drainage systems are designed to overflow into nearby streams, rivers, or other bodies of water when the capacity of the drainage system is exceeded (EPA 2008). Bacterial contamination is prevalent in streams during this time, which poses human health hazards such as exposure to fecal coliform bacteria, with the most common member being *Escherichia coli*, commonly abbreviated E. coli, a type of bacteria that causes abdominal cramps and bloody diarrhea when ingested. Other bacteria contribute to eutrophication, breaking down dissolved oxygen (Porcella & Sorenson 1980).

The presence of the fecal coliform bacteria in aquatic ecosystems indicated that the water has been contaminated with fecal material. The water could be at risk of containing pathogens or disease producing bacteria and viruses that prove to detrimental to both humans and other aquatic life forms (Porcella & Sorenson 1980). By including fecal testing in water quality reports, the community would react with a greater concern if the tests came back positive with elevated readings. Fecal testing has a role in overall water quality of watersheds and the inclusion of testing in future studies would only benefit the continuous pursuit of improved water quality in the Blackwater and Ivy Creek Watersheds.

Future studies regarding the analysis of freshwater ecology and water quality in the Blackwater and Ivy Creek Watershed should expand on the current focus of research relating solely to how urbanization affects water quality. The research and study of urban stream restoration is currently dominated by engineers and physical scientists who focus on storm water management and bank stabilization. Although the physical composition of a stream is critical to its health, there needs to be more of a focus directed on the restoration of native stream biota and the ecological services that streams provide. Rehabilitation should follow the natural progression of the physical, chemical, and biological processes of a stream to restore an impaired ecosystem to its original condition prior to human impact. A holistic approach should be implemented as a way to focus on the aesthetics and human attitudes towards the landscape (Paul and Meyer 2001). As population continues to grow and expand with urban and suburban sprawl, humans must position themselves to be incorporated as components of their ecosystems, rather than just manipulators.

The underlying environmental problem of population growth that directly effects urbanization is that as population continuously increases, urbanization follows the same trend. An increase in population contributes to more waste and the depletion of natural resources. Other problems include a strain on the environment due to an increased demand for food and other natural resources, as well as the need for more land required to sustain the growing population. Urban and suburban sprawl are also contributing problems because high population densities degrade the general condition of the environment. The predicted population increases in all three jurisdictions within the watershed emphasize the growing concern that without proper regulations, urban sprawl will increase human environmental degradation exponentially until there is no area left for expansion.

One way to analyze the effects of urbanization on the Blackwater Watershed is to compare the watershed quality over an extended period of time. By comparing the current water quality results with research indicating the water quality of the region prior to human development (hundreds of years ago), the severity of the situation can be assessed. By evaluating the natural environmental influences on water quality, for example stream order and physical layout, the impact from human interference can be more thoroughly scrutinized. For example if unique environmental conditions play a large role in water quality, than the influence of humans on the environment can be smaller than what is currently assumed in a specific watershed.

Acknowledgements

Much thanks to Dr. Thomas Shahady for teaching us the necessary lessons to complete this project, as well as data interpretation and collection. Thank you to Adam Bonaventura for assisting us in data collection and analysis, and a hearty thanks to Steve Burris for his assistance and vigilance.

References

(1996) U.S. Geological Survey. Water: Resources Investigations Report. *Everyone lives downstream.* Retrieved April 26, 2009 from: http://ga.water.usgs.gov/edu/urbanquality.html.

(2008, June 11). Preliminary Data Summary of Urban Stormwater Best Management Practices. Retrieved May 5, 2009, from United States Environmental Protection Agency Web site: http://www.epa.gov/waterscience/guide/stormwater.

Arnold, C., and Gibbons, C. 1996. Impervious surface coverage: the emergence of a key environmental indicator. American Planners Association. J. 62:243-58.

Dunne, T. and Leopold, L. 1978. Water in Environmental Planning. New York: Freeman, 818.

Farnworth, E., Nichols, M. and C. Vann. 1979. *Impact of sediments on nutrients and biota in surface waters of the United States.* EPA-600/3-79-105. USEPA. Washington, DC. 3, 311-315.

Fitzgerald et al. *A Comparison of a Sentinel Species Evaluation Using Creek Chub (Semotilus Atromaculatus Mitchill) to a Fish Community Evaluation for the Initial Identification of Environmental Stressors in Small Streams*. Ecotoxicology 8, 33-48. 1999.

Jacobson, P. Evaluation of multi-metric bioassessment as an approach for assessing impacts of entrainment and impingement under Section 316(b) of the Clean Water Act. Environmental Science and Policy 3, 107-115. 2000.

Kates, R., Parris, T., and Leiserowitz, A. 2005. What is Sustainable Development? Goals, Indicators, Values, and Practice. *Environment: Science and Policy for Sustainable Development*. 47. 3, 821.

Kemp, S., and Spotila, J. 1997. Effects of Urbanization on Brown Trout *Salmo trutta*, Other fishes, and Macroinvertebrates in Valley Creek, Valley Forge, Pennsylvania. [Online Version] American Midland Naturalist 138, 55-68.

Matthews, W. (1998). *Patterns in freshwater fish ecology*. Springer.

Meyer, J., and Paul, M. (2001). Streams in the urban landscapes. [Online Version] *Annual Review of Ecology and Systematics*. 32, 333-365.

Shahady, T. 2009. Freshwater ecology laboratory manual. Lynchburg College. Lynchburg, Virginia.

Shahady, T. 2006. State of the watershed report. Lynchburg College. Lynchburg, Virginia.

Shahady, T., and Fitzsimmons, P. 2008. Blackwater creek watershed management plan. Lynchburg College. Lynchburg, Virginia.

Waters, T. 1995. Sediment in streams: sources, biological effects and control. American Fisheries Society, Maryland.