12-15-2000

An Evaluation of Stream Flow Characteristics and Fecal Coliform Loads in Sayler's Creek Watershed, South Central Virginia

David Straton Gilbert
Longwood University

An Evaluation of Stream Flow Characteristics and Fecal Coliform Loads in Sayler's Creek Watershed, South Central Virginia

By

David Straton Gilbert

A Thesis Submitted to the Faculty of Longwood College in partial Fulfillment of the Requirements for the Degree of

Master of Science

Environmental Studies

Longwood College
August 2000

Approved by:

Dr. Joseph E. Garcia (Director)

Dr. David W. Buckalew

Mrs. Frances Zaun

12.15.00
Date Approved

Abstract

The Sayler's Creek watershed is located within Prince Edward County, Nottoway, and Amelia Counties of the south central region of Virginia. The Sayler's Creek Watershed consists of two small creeks: Big Sayler's Creek and Little Sayler's Creek. The Environmental Protection Agency has Big Sayler's Creek listed as impaired and not Little Sayler's Creek. Based upon visual inspections of the Sayler's Creek watershed throughout the year, Little Sayler's Creek is impaired for fecal coliform instead of Big Sayler's Creek. Another hypothesis of this study is that fecal coliform levels are directly related to runoff from cattle ranches in the immediate floodplain of this river basin. The objectives of this study was to attempt to prove or support that there is a positive relationship between discharge and fecal coliform concentration and to analyze hydrologic conditions and fecal coliform concentrations in order to assist in an accurate determination of fecal coliform loads in Sayler's Creek.

Five sites were chosen for the study due to their accessibility. Cross sectional profiles, depths, and current velocities were measured at each site. Hydrologic and Microbiological data was regressed and graphically analyzed to determine the significance of relationships.

Within the watershed as a whole, the analyses show a statistically significant relationship between discharge and fecal coliform concentration (p-value = 0.004). Statistical analysis for each site was performed as well to examine the results obtained for the overall watershed. Fecal coliform loads are comparatively higher in Little Sayler's Creek than in Big Sayler's Creek.

Within the watershed as a whole, there is evidence to support that fecal coliform concentration is related to stream discharge. Comparatively speaking, Big Sayler's Creek has higher discharge values overall in the four flow stages. However, Little Sayler's Creek has a higher fecal coliform load.

The results from this study indicate that both Big Sayler's Creek and Little Sayler's Creek are impaired with respect to fecal coliform standards. More research is needed to accurately determine the level and potential causes of the fecal coliform impairment in the Sayler's Creek watershed. To determine the extent of impairment, hydrologic characteristics need to be determined. Loads of fecal coliform, instead of concentration, is a necessary determination to better assess the actual amounts of fecal coliform that is being delivered by the Sayler's Creek System. This data can be used to set a priority ranking for the Sayler's Creek Watershed. This method would incorporate hydrologic characteristics into the TMDL decision-making process.

Acknowledgements

First, I would like to thank my advisor, Dr. Garcia. It has taken some time to complete all the steps necessary in order to finish this paper and he was by my side the whole way. Next, I would like to thank Dr. Buckalew for his advice and assistance in the lab. I need to thank Dr. Carolyn Wells for her guidance while I attended Longwood College. I would like to thank everybody that assisted me in all aspects of my thesis and my educational career at Longwood College. Last, but most importantly, I would like to thank my parents for supporting me in everything I have done. Without them I would never have been able to accomplish what I have. Mom and Dad, I love you very much.

Tables

Introduction

In the past few years the impairment of our waterways has become an important public issue. In 1998, Virginia's Section 303d list consisted of 883 waters (lakes, rivers, streams, etc.) with a total of 1, 002 impairments. There were 43 different types of impairment within this group of impairments. Fecal coliform impairment accounts for 17% of the total number of impairments. The most extensive problem in rivers and streams, according to the 305b report for Virginia, is fecal coliform bacteria (State of Virginia, Department of Environmental Quality, 1998).

Waterways can not exceed an average of 400 colony forming units (cfu's)/ 100 mL of fecal coliform in order for fishing, swimming, and boating to be considered safe according to Virginia guidelines (State of Virginia, Department of Environmental Quality 1998). Some reports have indicated fecal coliform counts, in Virginia, as high as 424, 000 cfu's. This level of contamination would indicate nothing less than steady flow of fecal coliform bacteria in a waterway (The Washington Post, 1 June 1997).

The greatest amount of a pollutant that a waterway can receive without exceeding federal water quality standards is known as the Total Maximum Daily Load (TMDL). Traditionally, pollutants have been considered to be any substance that can prevent a lake, stream, or river from being fishable or swimmable. Some common pollutants listed on a TMDL list include sediment, toxic chemicals, heavy metals, heat, pH, and fecal coliform bacteria. States are required by Section 303(d) of the Clean Water Act (CWA) to list all waterways that violate these limits and to develop TMDL's for them (State of Virginia, Department of Environmental Quality 2000). According to the CWA, the EPA is required to designate any waterway as impaired if these criteria are not met. In order to assemble its TMDL list, the EPA requires a state to consider "all existing and readily available water quality-related data and information" (Conway, 1997). This includes accessible information from local, state, and federal agencies as well as academic institutions and members of the public (Conway, 1997).

A pollutant load is separated into wasteload allocations (point sources) and load allocations (designated as non-point and natural sources) once a TMDL is established (United States Environmental Protection Agency, Chapter 1, 2000). The origin of possible pollutants is also a main concern of the TMDL initiative. The TMDL list is a detailed plan explaining steps to be taken in order to find remedies for point and non-point source pollutants.

Most agriculturalists and industrialists are not supportive of the validity of the TMDL initiative due to the enormous regulatory restrictions that follow. They argue that there is insufficient data available to declare impairment (Casper Star-Tribune (WY), 1998). Lack of information about the source or nature of the source should not be a reason to delay TMDL deadlines. It is important that surface water users understand that clean water is more valuable than unclean water. Clean water increases surrounding property value as opposed to impaired water as in the case of the revitalization of Baltimore Harbor (Hun, 1998). The National Wildlife Federation, in a recent report, using EPA data, stated that 70%

of states have failed to protect their watersheds by using TMDL's criteria (Pelley, 1998).

From October 1999 to June 2000, the Piedmont Soil and Water District Office has been collecting data in the Sayler's Creek watershed for the TMDL initiative and will continue to collect water quality data for at least another year. The State of Virginia has continued funding for another year and has delayed the deadline for the TMDL lists. In the face of several lawsuits brought against numerous states (Ward 1997, DeHihns 1998), one can assume that determination of TMDL's for Virginia's waterways are inevitable.

Thirty states are or have been involved in TMDL litigation. Surprisingly, no government agency has filed suit. Private firms and citizens have instigated all suits relating to the TMDL program. (DeHihns 1998).

Objective of Study

Sayler's Creek, located near the town of Farmville within the Appomattox River watershed, has been labeled as impaired for fecal coliform bacteria (Commonwealth of Virginia, 1998 Clean Water Act Section 303d list, unpublished due to partial acceptance by EPA) (Appendix A). Sayler's Creek watershed consists of two major tributaries: Sayler's Creek and Little Sayler's Creek. Locally, Sayler's Creek is known as "Big Sayler's Creek" upstream of its confluence with Little Sayler's Creek. The stream is designated as Sayler's Creek downstream of the above-mentioned junction. Therefore, in this text, "Big Sayler's Creek" refers to the branch upstream of the above-mentioned confluence.

The Appomattox watershed of the South-central Piedmont region of Virginia has 11 rivers and streams, which total approximately 8, 200 miles. According to the Virginia's 303d list, 44% of all stream pollutants come from non-point sources (Commonwealth of Virginia, 1998 Clean Water Act Section 303d list, unpublished due to partial acceptance by EPA). Non-point sources of fecal coliform include wildlife, grazing cattle, land application of manure, and malfunctioning septic systems.

Research on Sayler's Creek is necessary to determine the degree of impairment caused by fecal coliform bacteria. Personal observations of cattle using the stream has led to the hypothesis that fecal coliform levels are directly related to runoff from cattle ranches in the immediate floodplain of this river basin. This study can be used to assist in the TMDL process associated with Sayler's Creek. Fortunately, most of the farmers in the Sayler's Creek watershed want to assist in the TMDL initiative (Garnett, 2000).

This evaluation is directly related to the TMDL program. It is an attempt to determine the level of impairment for fecal coliform loads for Sayler's Creek watershed. The Department of Environmental Quality (DEQ) has labeled Big Sayler's Creek as being impaired. The hypothesis of this study, based upon visual inspections of the Sayler's Creek watershed is that Little Sayler's Creek is impaired, according to EPA's established standards for fecal coliform bacteria as well as silt/ particulates, and that Big Sayler's Creek should not be designated as fecal coliform impaired. This study will attempt to provide evidence to support or refute this statement. This study will also attempt to prove or support that there is a positive relationship between discharge and fecal coliform concentrations

Study Area

Sayler's Creek watershed is located within Prince Edward, Nottoway, and Amelia counties of the south central Piedmont region of Virginia. The center of the watershed is located at Latitude 37° 17' 24'' N: Longitude 78° 14' 35'' W in Prince Edward County. The topography is characterized by gently rolling hills with elevations between 300 to 500 feet. The creek is bordered by an existing riparian zone, which may be considered, in the opinion of the author, insufficient as a buffer in some areas. General land use characteristics of the watershed are presented in Table 1.

Table 1. Land Use Map Category of Sayler's Creek Watershed

#	Land Use Category	Square Miles	Acres	Percent Cover
1	Cropland	1.459072	933.791	5.87
2	Hayland	1.581154	1011.922	6.36
3	Grown-up, Fallow	1.042045	666.898	4.19
4	Pasture	2.878493	1842.206	11.59
5	Woods/ Forest	16.25326	10,401.92	65.41
6	Residential	0.714754	457.435	2.88
7	Mixed Woods/ Residential	0.917876	587.431	3.69
	TOTAL	24.846653	15,901.60	100

Source: United States Department of Agriculture, Natural Resources Conservation Service, Water Quality Team, February 2000.

Literature Review

Past studies on bacterial pollution caused by grazing practices focused on the presence of bacteria, mainly fecal coliform and fecal streptococci, in rivers and streams of grazed watersheds (Darling and Coltharp, 1973; Doran and Linn, 1979; Milne, 1976; Fair and Morrison, 1966). These studies concluded that the presence of cattle in a watershed increases the concentration of fecal coliform bacteria in the water bodies of that watershed. Kunkle (1970) concluded that cattle grazing in close proximity to a stream significantly increased the fecal coliform concentrations while grazing some distance away had little impact (Gifford and Thelin, 1983).

A point source is a discrete discharge of pollutants from a pipe or similar conveyance (e.g. ditch), and a non-point source is essentially everything that is not considered a point source (State of New Mexico, New Mexico Water Quality Control Commission, 2000). The measurement and monitoring of point source and non-point source pollution differ in three ways: (1) monitoring a non-point source is very difficult due to the obscurity of the source, (2) the fundamental link between a farmer's practices and the resulting pollutants in a waterway are unclear, and (3) indiscriminate variables such as temperature, rain, and wind also affect the load of non-point source pollution making its way into waterways (Hyde and Lovejoy, 1997).

Cattle are considered non-point sources of pollution. Non-point source pollution is a major contributor to overall pollution in a watershed (State of New Mexico, New Mexico Water Quality Control Commission, 2000). A recent study had estimated that 92% of New Mexico's surface water quality problems come from non-point sources (State of New Mexico, New Mexico Water Quality Control Commission, 2000).

In a report to Congress, Claudia Copeland (1997), a Specialist in Environmental Policy, stated:

> "Section 303(d) of the Clean Water Act does not specifically state whether TMDL's should cover non-point sources. Traditionally, within the EPA,

polluted runoff has always been recognized as a point source. Farming and forestry groups want a more exact definition of a non-point source. Until this non-point source term is more clearly defined, these groups would prefer non-point sources to be excluded from the TMDL initiative due to the costs of implementing new abatement technology that are associated with new regulation. To limit TMDL implementation to only point sources would likely cause significantly new pollution control regulations on cities and industries as well" (Copeland, 1997).

A major problem for the TMDL initiative is that currently the EPA does not have the legal authority to require permits for emissions from non-point sources. Because of this issue, states have avoided establishing TMDL's (LeClair, 1997). EPA is currently involved in attempting to designate non-point sources, such as animal feeding lots and silvicultural activities, to point sources (United States Environmental Protection Agency, 2000). Other land usages that cannot be relabeled are being confronted in another way. Some non-point sources are being monitored and controlled by the implementation and use of Best Management Practices (BMP) (United States Environmental Protection Agency, 2000; Conway, 1997). In addition, the TMDL initiative will likely lead to the increase of BMP's.

Section 319 of the CWA addresses funds for Best Management Practices. These pollution control methods are implemented to meet the surface water quality standards set by a state. States need to implement these programs and ensure management practices by all contributors of non-point pollution in watersheds in order to address impaired water bodies that are affected by such pollution. It is still unclear as to whether BMP's will be able to alleviate the impairment in question. The lack of participation by all contributing parties within the watershed and inadequate selection of a BMP may even fail to cure the impairment (United States Environmental Protection Agency, 2000).

If the pollutant source is suspected to be a non-point type it is very difficult to determine the extent of impairment for fecal coliform. Different factors, such as sunlight, pH, temperature, precipitation, timing and rate of feces deposition, toxic substances, organic matter, soil conditions, and competitive organisms can affect the concentration of fecal coliform at any given time (Coyne et al., 1997).

If sampling is done at a time when any of the above factors are operating at their least or most efficient level, results will either be under or over estimated with respect to average fecal coliform levels within the stream. Therefore random monitoring may result in a waterway to be designated as impaired when in reality it is not or vice-versa.

The purpose of this study is to analyze hydrologic conditions and fecal coliform concentrations in order to assist in an accurate determination of fecal coliform loads in Sayler's Creek. It is anticipated that the results from this study will be used to develop the proper TMDL response for this particular watershed and to establish a priority ranking for Sayler's Creek with respect to other fecal coliform impaired streams within the state of Virginia.

Methods and Materials

The five sampling locations, chosen due to accessibility, included Double Bridge at Route 619 (Site 1), Big Sayler's Creek upstream from Route 619 (Site

2), Route 620 (Site 3), Route 617 (Site 4), and Highway 307 (Site 5) (See Appendix A).

Site 1 is located after the confluence of Big and Little Sayler's Creek approximately 15 meters downstream from the bridge. Site 2 is located approximately 100 meters upstream from the confluence at Route 619 on the Big Sayler's Creek branch. Site 3 is located approximately ten meters downstream from the bridge on Little Sayler's Creek. Site 4 is located approximately five meters downstream from the bridge on Big Sayler's Creek. Site 5 is located on Highway 307 heading north towards Richmond, Virginia approximately 0.5 miles after exiting Highway 460. The sampling site is approximately 20 meters downhill off the left side of the highway.

Hydrologic characteristics were measured on May 31, June 7, June 21, and June 29, 2000. Characteristics include cross-sectional areas (ft^2), current velocity (ft/s), and discharge (cf/s). Discharge, Q, which stands for quantity expressed as cubic feet per second, is the product of cross sectional area times current velocity (Dunne and Leopold, 1978). There are five steps in constructing cross sectional graphs. The following steps are:

1. **Set up the transect.** Set two stakes, one on each side of the creek. These stakes should extend past the water's edge so the transect includes a larger section of channel than just the portion holding water. The transect should be perpendicular to the direction of flow. Stretch a string across the creek and tie it to both stakes keeping it taut to prevent sagging.

2. **Level the string.** Leveling the string can be done by measuring the distance from the string to the water on river right stake and river left stake. If the measurements are equal across the creek, the string is level. If not, repositioning the stakes may help. Record distance from string to water.
3. **Mark measurment locations on the string.** This step was completed before fieldwork had begun. A section of string (60 feet) was staked off in a field. A point, every two feet along the string, was painted fluorescent orange for the entire length of the string. These marks designate measurement locations.
4. **Record three important pieces of information.** First, record distance from river right stake to edge of water; second, record the distance from river left stake to edge of water; and third, record total distance across river from stake to stake.
5. **Take a depth measurement at each mark on your string (every two feet).** These measurements will be used to draw a diagram showing channel geometry. Measurements always began from river left stake looking upstream. These measurements are taken from string to the creek bed. Subtract distance from string to water from distance from string to creek bed to get actual water depth.

Current velocity was measured with a digital current meter. Velocity measurements were taken at each measurement location across entire transect. Velocity measurements were taken 0.25 of the total depth from the creek bed at each measurement location. Stream level was also measured during this period using a levelogger. A levelogger is an instrument that takes measurements of stream level every fifteen minutes.

Water samples, collected for fecal coliform analysis, were collected at the above-mentioned sites. Each water sample was obtained by using a polyvinyl Whirlpak bag. The samples were taken at ½ of the depth measured from the creek bed. Water samples were collected and prepared for incubation as soon as possible after collection. Reason being, colonies of fecal coliform bacteria grow rapidly and therefore need to be prepared within six hours of collection (Best, L.C. *et al.,* 1965; Geldreich *et al.,* 1975; Sartory, 1980; Coubrough P., 1981; Rychert and Stephenson, 1981).

Membrane filtrations were performed on each sample to assess fecal coliform colonies. The broth used to culture each sample was m-FC (endo-medium for Fecal Coliform). The samples were incubated at 45°C +/- 0.5°C to preclude growth of free-living coliforms and competing heterotrophic bacteria. After incubation (24 hours @ 44.5 °C) colonies were counted microscopically (20x) to assure for thorough counts.

Hydrologic data and bacterial concentrations were statistically correlated to determine the relationship between discharge and fecal coliform levels at each of the sampling locations. The discharge was computed after obtaining cross sectional areas of Sayler's Creek at five points. The Analysis section of this paper will illustrate methods used to achieve the results.

Analysis

Field Design

The purpose of this study was to determine the relationship between discharge (stream flow) and fecal coliform concentrations in Sayler's Creek Watershed. In order to determine discharge at each of the five sampling sites cross sectional profiles, depths, and current velocities were measured at each site. An example of the stream profile for May 31, 2000 is illustrated on the following page. Data collected in the field, such as cross sectional areas and current velocities was used to determine discharge. Water samples were collected, after hydrologic data was obtained at each site, and transported to Longwood College's microbiology laboratory for fecal coliform analysis. The remaining stream profiles for the above-mentioned sampling dates can be found in Appendix B.

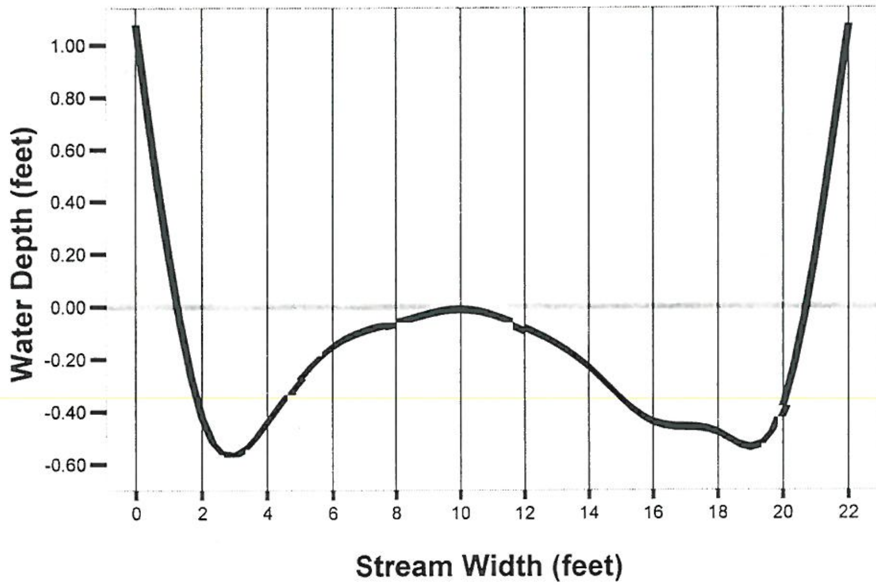
Computer and Microbiological Analysis

Secondary analysis includes all techniques used in the microbiology and computer laboratory of Longwood College to statistically analyze data obtained from the field. The Double Bridge area at Route 619 is an established sample site, with an installed datalogger that continuously records stream levels and is maintained by the Piedmont Soil and Water Office and Longwood College. However, there is no other information collected or recorded elsewhere in Sayler's Creek watershed. Hydrologic data for each site was regressed and graphically analyzed to determine significance of relationship/s. The purpose of these regressions was to find relationships between stream levels at other sites along Sayler's Creek and relate them to Route 619. The statistical relationships

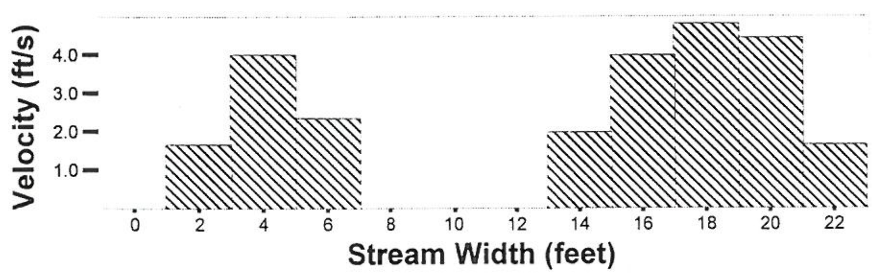
Stream Profile at Route 617

Looking Upstream

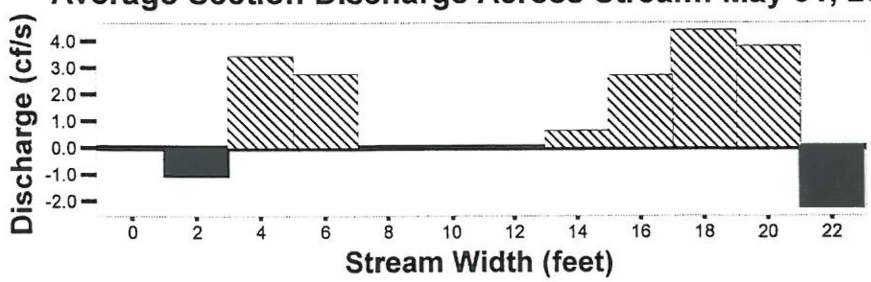
Cross Section: May 31, 2000



Average Section Velocity Across Stream: May 31, 2000



Average Section Discharge Across Stream: May 31, 2000



* Hydrological characteristics of Big Sayler's Creek located at Site 4 on Route 617.

can be used to predict stream levels, and therefore, discharge upstream from the Double Bridge at Route 619 without additional fieldwork. The statistical output and graphs of these analyses are presented in Appendix C.

Results

Comparison of Discharge Within Sayler's Creek Watershed

A comparison of discharge values determined for sites 1-5 indicates that discharge increases as distance downstream increases (Table 2). In order to determine the relationship between discharge calculated for upstream sites and discharge calculated for site 1 (furthest site downstream), discharge data for upstream sites were regressed upon the site 1discharge values (Appendix C). This comparison of discharge was done in order to construct the above-mentioned relationship so that stream levels and discharge values could be predicted for flood events without fieldwork.

Significance factors are based on a 95% confidence level ($p \leq 0.05$ significance factor). Adjusted R^2 values were used in order to account for degrees of freedom. Comparison of discharge between sites 1 and 2 resulted in a p – value = 0.191 with an adjusted R^2 value = 0.826. Comparison of sites 1 and 3 resulted in a p – value = 0.014 with an adjusted R^2 value = 0.958. Comparison between sites 1 and 4 resulted in a p – value = 0.055 with an adjusted R^2 value = 0.839. Comparison between sites 1 and 5 resulted in a p – value = 0.004 with an adjusted R^2 value = 0.988. The statistical analysis along with the graphical relationships can be seen in Appendix C. The sites that resulted in statistically insignificant relationships could be caused by the small population sizes used to

Table 2. Hydrologic Characteristics of Sample Sites

Site 1. Route 619 (furthest downstream for both Big and Little sayler's Creek)

	Low	Middle low	Middle high	High
	6/12/00	5/31/00	6/7/00	6/29/00
Total Cross Sectional Area (sq ft)	4.69	6.94	11.3	22.68
Channel Width (ft)	24.04	24.86	27.1	24.67
Average Transect Depth (ft)	0.24	0.32	0.47	0.98
Average Flow Velocity Estimates (ft/sec)	2.43	4.06	4.96	5.15
Discharge Estimates (cfs)	25.89	43.19	72.22	142.82
Fecal Coliform Concentration (cfu)	5500	800	2600	32,100
Fecal Coliform Load (cfu/s)	4.10E+07	9.90E+06	5.40E+07	1.30E+09

Site 2. Route 619, Upstream from Double Bridges (middle site Big Sayler's Creek)

	6/12/00	5/31/00	6/7/00	6/29/00
Total Cross Sectional Area (sq ft)	6.05	N/A	10.61	12.28
Channel Width (ft)	16.71	N/A	18.08	18.21
Average Transect Depth (ft)	0.4	N/A	0.63	0.74
Average Flow Velocity Estimates (ft/sec)	1.15	N/A	2.58	3.54
Discharge Estimates (cfs)	12.06	N/A	39.94	54.45
Fecal Coliform Concentration (cfu)	6300	N/A	800	6,000
Fecal Coliform Load (cfu/s)	2.20E+07	N/A	9.10E+06	93,000,000

Site 4. Route 617 (furthest upstream site on Big Sayler's Creek)

	6/12/00	5/31/00	6/7/00	6/29/00
Total Cross Sectional Area (sq ft)	2.37	5.22	5.21	5.35
Channel Width (ft)	19.29	19.5	19.96	20.17
Average Transect Depth (ft)	0.24	0.27	0.27	0.32
Average Flow Velocity Estimates (ft/sec)	1.38	2.06	1.75	3.46
Discharge Estimates (cfs)	5.01	14.34	14.97	25.56
Fecal Coliform Concentration (cfu)	200	0	0	1800
Fecal Coliform Load (cfu/s)	2.90E+05	0	0	1.30E+07

Continued on next page.

Table 2. Continued

Site 1. Route 619 (furthest downstream for both Big and Little sayler's Creek)

	Low 6/12/00	Middle low 5/31/00	Middle high 6/7/00	High 6/29/00
Total Cross Sectional Area (sq ft)	4.69	6.94	11.3	22.68
Channel Width (ft)	24.04	24.86	27.1	24.67
Average Transect Depth (ft)	0.24	0.32	0.47	0.98
Average Flow Velocity Estimates (ft/sec)	2.43	4.06	4.96	5.15
Discharge Estimates (cfs)	25.89	43.19	72.22	142.82
Fecal Coliform Concentration (cfu)	5500	800	2600	32,100
Fecal Coliform Load (cfu/s)	4.10E+07	9.90E+06	5.40E+07	1.30E+09

Site 3. Route 620 (middle site for Little Sayler's Creek)

	6/12/00	5/31/00	6/7/00	6/29/00
Total Cross Sectional Area (sq ft)	4.26	7.12	7.06	13.51
Channel Width (ft)	22.92	20.21	23.08	23.17
Average Transect Depth (ft)	0.21	0.37	0.35	0.59
Average Flow Velocity Estimates (ft/sec)	3.36	3.06	3.6	3.99
Discharge Estimates (cfs)	16.19	23.13	28.39	66.33
Fecal Coliform Concentration (cfu)	400	600	1800	32,400
Fecal Coliform Load (cfu/s)	1.90E+06	3.90E+06	1.50E+07	610,000,000

Site 5. Highway 307 (furthest upstream site on Little Sayler's Creek)

	6/12/00	5/31/00	6/7/00	6/29/00
Total Cross Sectional Area (sq ft)	1.27	1.49	2.46	2.98
Channel Width (ft)	12.67	13.08	12.75	13.13
Average Transect Depth (ft)	0.1	0.153	0.21	0.25
Average Flow Velocity Estimates (ft/sec)	1.07	2.49	2.2	3.3
Discharge Estimates (cfs)	0.631	2.81	6.71	13.32
Fecal Coliform Concentration (cfu)	1500	2100	1300	25,100
Fecal Coliform Load (cfu/s)	2.70E+05	1.70E+06	2.50E+06	9.60E+07

during the analysis. Relationships between the logarithmic transformations of the discharge data were also examined but did not statistically improve the regression results.

Discharge vs. Fecal Coliform Concentration at the Five Sampling Sites

In order to examine the relationship between fecal coliform and discharge, fecal coliform data was compared with discharge data for Sites 1 –5. The results are presented in Appendix D. Within the watershed as a whole, the analyses suggest a statistically significant relationship between discharge and fecal coliform concentration (0.004). Regression analysis suggests that approximately 40% of the variation in fecal coliform bacteria can be accounted for by discharge. Regressions of logarithmically transformed discharge data were performed but resulted in no statistical improvement. Statistical analysis for each site was performed as well to examine the results obtained for the overall watershed. Linear regressions between fecal coliform and discharge data at each site are presented in Appendix E.

Regression analysis for fecal coliform and discharge data at Site 1 resulted in a p - value = 0.103 with an adjusted R^2 value = 0.70. At Site 2, regression analysis resulted in a p – value = 0.854 with an adjusted R^2 value = -0.897. Results for site 3 indicate a p – value = 0.018 with an adjusted R^2 value ≅ 0.95. Sites 4 and 5 regression analysis resulted in p – values = 0.223 and 0.113, respectively with adjusted R^2 values = 0.405 and 0.679, respectively.

Table 3. Results: Summary Table

Location	p - value	Adj. R Square
(A) *A Comparison of Discharge Within Sayler's Creek*		
Site 1 vs. 2	0.191	0.826
Site 1 vs. 3	0.014	0.958
Site 1 vs. 4	0.055	0.839
Site 1 vs. 5	0.004	0.988
(B) *Discharge vs. Fecal Coliform at the Five Sampling Sites*		
Location	p - value	Adj. R Square
Overall	0.004	0.4
Site 1	0.103	0.7
Site 2	0.854	-0.897
Site 3	0.018	0.95
Site 4	0.223	0.405
Site 5	0.113	0.679

Table 3. Summary of (A) regression analysis of discharge between sites 1-5; (B) regression analysis of discharge and fecal coliform for sites 1-5.

Fecal Coliform Load

As illustrated in Table 2, fecal coliform loads are comparatively higher in Little Sayler's Creek than in Big Sayler's Creek. This is a very significant finding and will be discussed in greater depth later in the paper.

Discussion

A Comparison of Discharge Within Sayler's Creek Watershed

There is a strong correlation between discharge values determined for Site 1 and Site 2 (adj. R^2 value = 0.826) but the relationship is not statistically significant ($p = 0.191$). The results (Appendix C) obtained for Site 1 and Site 2 can be best explained by their location (See Appendix A). Site 1 is located downstream of the confluence of Big Sayler's Creek and Little Sayler's Creek. Site 2 is located on Big Sayler's Creek just upstream (approximately 200 ft.) of the confluence. Site 1 measures the discharge of both tributaries. Due to the close proximity of the sites there should be a correlation. However, due to the small sample size (5 data points), these results end up not being statistically significant.

There is a statistically significant relationship between discharge for sites 1 and 3 ($p = 0.014$) along with a substantial correlation (adj. R^2 value = 0.958). Site 3 is positioned approximately 0.25 – 0.50 miles upstream from Site 1. These two sites could be receiving comparable amounts of runoff from the surrounding areas. The relationship and the effect that one discharge has on the other might possibly be related to the amount of runoff entering these sites.

Site 2 and Site 3 are both located directly upstream from Site 1. Site 2 did not show a statistically significant relationship ($p = 0.191$) while Site 3 did. Why do the results show a significant effect for one site and not the other? It could be possible that one half of the watershed received more rainfall than the other. A rain gauge is located on the Big Sayler's Creek branch, but not on Little Sayler's Creek. Rain gauges are needed on both branches to determine this.

Regression analysis illustrates a relatively strong relationship ($p = 0.055$) for discharge between sites 1 and 4 with a strong correlation between the two (adj. R^2 value = 0.839). Site 4 is located on the Big Sayler's Creek portion of the watershed and happens to be situated in the middle of Sayler's Creek Battlefield. According to Table 2, discharge values are greater for Little Sayler's Creek than Big Sayler's Creek. Since Site 4 is centrally located on Big Sayler's Creek it has had time to accumulate discharge and is a major contributor to the discharge at Site 2. The discharge at Site 4 affects all discharge values at downstream sites. It would be expected that the discharge at Site 4 would have an effect on the discharge found at Site 1.

There was a significant relationship between site 1 and 5 for discharge ($p = 0.004$) with a very strong correlation (adj. R^2 value = 0.988). Site 5 is the headwaters for Little Sayler's Creek. This is a similar situation as Site 4. Data for all hydrologic values downstream, especially at Site 1, will have a relationship with the results obtained at Site 5.

<u>Discharge vs. Fecal Coliform Concentration at the Five Sampling Sites</u>

Within the watershed, as a whole, there is evidence to support that fecal coliform concentration is related to stream discharge. However, the relationship between the two is not statistically strong. Regression results for Site 1, the most downstream site, did not show a statistically significant relationship between discharge and fecal coliform concentration (adj. R^2 value = 0.7, $p = 0.103$). This could be due to background interference such as wildlife and cattle. Sayler's Creek is surrounded by pastureland on both sides at this sampling site. Through personal observation, it is evident that cattle have unrestricted accessibility to the creek at this site. This random direct contact could weaken the correlation between discharge and fecal coliform bacteria. Results do indicate that 70% of the variation in fecal coliform can be explained by discharge, although this correlation is not statistically significant.

Site 2 did not show a significant correlation between discharge and fecal coliform content (adj. R^2 value = -0.897, $p = 0.854$). This site is located in a wooded area with no access available to cattle. However, wildlife can easily access this site. Any fecal coliform bacteria found at this site would have to be contributed by an upstream source found between Site 2 and Site 4. It is conceivable that any additional discharge, caused by runoff, found at this site would not be related to the fecal coliform content within it.

Results from the analysis of data collected from Site 3 suggest a very strong relationship between discharge and fecal coliform concentration (adj. R^2 value $\cong 0.95$, $p = 0.018$). Site 3, being situated in the middle of Little Sayler's Creek, is influenced by upstream discharge and any fecal coliform bacteria introduced upstream of Site 3. The results indicate that additional runoff will cause an increase in fecal coliform values.

Results from analyses of data collected at Sites 4 and 5 demonstrate a relationship (adj. R^2 value = 0.405 and 0.697), respectively, but this relationship is not statistically significant between discharge and fecal coliform concentration ($p = 0.223$ and 0.113 respectively). Site 4 is located in the Sayler's Creek Battlefield, a state managed historic park that contains no pastures for cattle. Therefore, one would expect to find little or no traces of fecal material, if cattle were considered to be the main sources of fecal coliform in this watershed. Fecal coliform results presented in Table 2 indicate relatively low concentrations measured at Site 4. An upstream source would be responsible for any fecal coliform bacteria found here. This explains the weak impact of any additional discharge, caused by runoff, on fecal coliform concentration. Site 5 is the headwaters for Little Sayler's Creek and is located approximately 0.5 miles away from a dairy farm. If cattle were the primary contributor of fecal coliform bacteria, one would expect to see a relationship between discharge and fecal coliform bacteria. Consequently, a relatively stronger relationship between discharge and fecal coliform is found at this site, although it is still statistically insignificant ($p = 0.113$). In the author's opinion, further analysis may reveal this farm to be a major non-point source contributor for fecal coliform contamination for this watershed.

Fecal Coliform Load

Table 2 illustrates that fecal coliform load increases as distance downstream increases. This is due to the positive correlation between load and discharge. Comparatively speaking, Big Sayler's Creek has higher discharge values overall in the four flow stages. However, Little Sayler's Creek has a higher fecal coliform load. This is an important finding because, in the author's opinion, the DEQ has not classified Little Sayler's Creek as being impaired.

Conclusion and Recommendations

The purpose of this study was to examine the possible relationship between discharge and fecal coliform concentration. The evaluation shows that there is a relationship between these variables in all of the selected sites within the watershed except for Site 2. Results presented in Table 2 indicate that Little Sayler's Creek has a relatively higher fecal coliform load than Big Sayler's Creek. Results at different flow stages suggest that there may be other factors involved in the amount of fecal coliform measured within the stream channel at any given time. The results from this study indicate that both Big Sayler's Creek and Little

Sayler's Creek are impaired with respect to fecal coliform standards. Results from this study suggest that both tributaries be classified as impaired.

The magnitude of impairment has not yet been determined. This study suggests that more research will be needed to accurately determine the level and potential causes of fecal coliform impairment. However, if water samples are taken at low and/or high flow stages, and the results indicate consistent high levels of fecal coliform, it would be necessary to label it as impaired at that time. The next step, after impairment, would be to determine if hydrologic characteristics were involved in producing high fecal coliform concentration. Investigation into possible sources will also be needed. A reasonable source would be drainage ways from fields and pastures created by rainfall.

In order to accurately determine the extent of impairment, hydrologic characteristics, such as stream flow or discharge, need to be determined. Loads of fecal coliform, instead of concentration, is a necessary determination to better assess the actual amounts of fecal coliform that is being delivered by the Sayler's Creek system. Along with more research, this data can be used to set a priority ranking for the Sayler's Creek watershed. This method would incorporate hydrologic characteristics into the TMDL decision-making process.

Works Cited

Best, L. C., Clark H. F., Geldreich, E.E., and C.B. Huff. 1965. Fecal-coliform-organism medium for the membrane filter technique. *J. Amer. Water Works Assoc.* 57:208

Coltharp, G.B., and L.A. Darling. 1973. Effects of livestock grazing on the water quality mountain streams. p. 1-8. *In* H.F. Mayland (ed.) Water-Animal Relations Symposium. Snake River Conservation Res. Center, Twin Falls, Idaho. June 1973.

Conway, Dianne K. 1997. TMDL litigation: So now what? *Virginia Environmental Law Journal* 17: 83-121.

Copeland, Claudia. 1997. Congressional Research Service: Report for Congress, Clean Water Act and TMDLs: Committee for the National Institute for the Environment, 11 September.

Coubrough, P., Grabow, W.O.K., and C.A. Hilner. 1981. Evaluation of standard and modified M-FC, MacConkey, and Teepol media for membrane filter counting of fecal coliform in water. *Appl. Environ. Microbiol.* 42:192.

Coyne, M.S., T.C. Daniel, D.R. Edwards, P.A. Moore, Jr., J.F. Murdoch, and P.F. Vendrell. 1997. Fecal coliform and Streptococcus concentrations in runoff from grazed pastures in northwest Arkansas. *Journal of the American Water Resources Association* 33 (April): 413-422.

DeHihns III, Lee A. "Suits Over Water Quality Spark Action; Challenges to EPA's Failure to Establish 'Total Maximum Daily Loads' for States Have Prompted New Policy and Renewed Activity." *The National Law Journal*, 16 March 1998, pB7 col 1.

Doran, J.W., and D.M. Linn. 1979. Bacteriological quality of runoff water from Pastureland. *Applied Environmental Microbiology*. 37: 985-99.

Dunne, Thomas, and Luna B. Leopold. 1978. *Water in Environmental Planning.* New York: W.H. Freeman and Company.

Fair, J.F., and S.M. Morrison. 1996. Hydrology Paper no. 13, Colorado State Univ., Fort Collins.

Franson, Mary Ann H., ed. 1995. *Standard Methods for the Examination of Water and Wastewater.* Washington D.C.: American Public Health Association. 9-53.

Garnett, James (farmer in Sayler's Creek watershed). 2000. Interview by author, 10 May, Rice, VA. Personal. Longwood College, Farmville, Virginia.

Gifford, Gerald F., and Richard Thelin. 1983. Fecal coliform release patterns from fecal material of cattle. *Journal of Environmental Quality* 12 (Jan.-Mar.): 57-63.

Higgins, D.A., Quigley, T.M., and Tiedemann, A. R. 1987. Responses of fecal coliform in streamwater to four grazing strategies. *Journal of Range Management* 40 (July): 322-9.

Hun, Tara. 1998. Costs, non-point sources are top TMDL concerns. *Water Environment and Technology* 10: 36-39.

Hyde, Jeffrey, and Stephen B. Lovejoy. 1997. Non-point source pollution defies U.S. water policy. *Forum for Applied Research and Public Policy* 12 (winter): 98-101.

Kunkle, S.H. 1970. Sources and transport of bacterial indicators in rural streams. p. 105-132. *In* Proc. Symp. on Interdisciplinary aspects of watershed management. ASCE, New York.

LeClair, Vincent. 1997. Courts push states, EPA to create TMDL water programs. *Environmental Science and Technology* 31 (April): 178A(2).

Milne, C.M. 1976. Effect of a livestock wintering operation on a western mountain stream. Trans. ASAE 19: 749-752.

Pelley, Janet. 1998. Advisory panel completes work on TMDL watershed guidelines. *Environmental Science and Technology* 32 (May): 212A(1).

Geldreich, E.E., Litsky W., and R.E. Rose. 1975. Improved membrane filter method for fecal coliform analysis. *Appl. Microbiol.* 29:532.

Rychert, R.C. and G.R. Stephenson. 1981. Atypical *Escherichia coli* in streams. *Appl. Environ. Microbiol.* 41:1276.

Sartory, D. P. 1980. Membrane filtration fecal coliform determinations with unmodified and modified M-FC medium. *Water SA* 6:113.

State of New Mexico, New Mexico Water Quality Control Commission. 2000. "Water Quality and Water Pollution Control in New Mexico: A Report Prepared for Submission to the Congress of the United States by the State of New Mexico Pursuant to Section 305(b) of the Federal Clean Water Act," p.54; available from ftp://www.nmenv.state.nm.us/docs/swqb/305b/2000; Internet; accessed 18 May 2000.

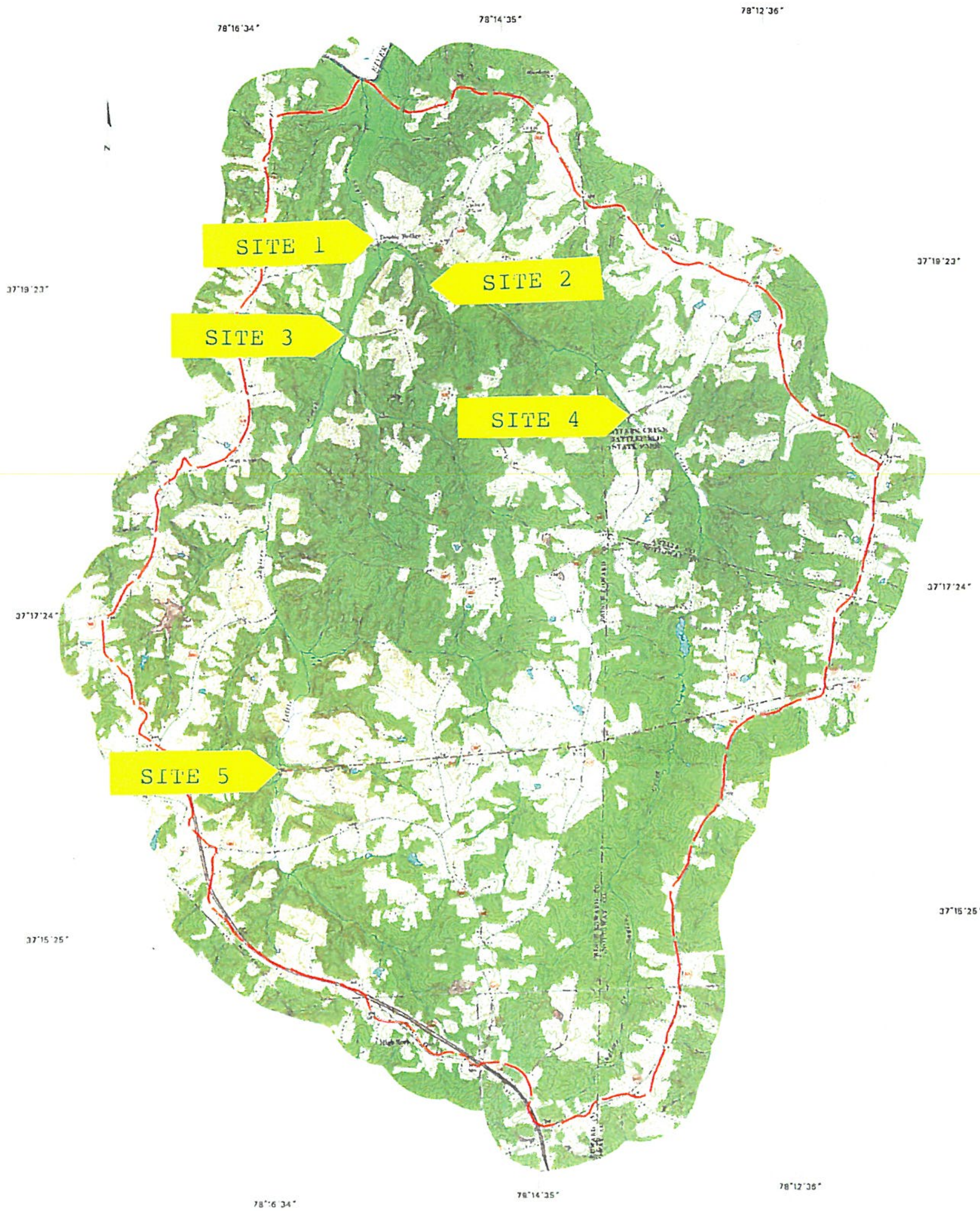
State of Virginia, Department of Environmental Quality. 1998. "305(b) Water Quality Assessment Report," p.1.1-1 – 4.1-7; available from http://www.deq.state.va.us/pdf/305b/rpt305.pdf; Internet; accessed 6 February 2000.

State of Virginia, Department of Environmental Quality. 2000. "Water Quality Assessment Guidance Manual for Y2000: 305(b) Water Quality Report and 303(d) TMDL Priority List," p. 6; Revised Draft 22 May 2000. United States Environmental Protection Agency. 2000. "Guidance for Water Quality – Based Decisions: The TMDL Process," p.1-83; available from http://www.epa.gov/OWOW/tmdl/decisions/dec3c.html; Internet; accessed 25 April 2000.

Ward Jr., Ken. "Stream Cleanup Lawsuit to Bring Statewide Changes." *The Charleston Gazette* (WV), 17 November 1997.

Appendix A.

Map of Sayler's Creek Watershed



SAYLERS CREEK WATERSHED

LOCATION MAP

SAYLERS CREEK WATERSHED

AMELIA, NOTTOWAY, AND PRINCE EDWARD COUNTIES

VIRGINIA

1 0 1 MILES

1 0 1 KILOMETERS

Source:
USGS 1:24,000 Topographic Quadrangles and
Information from NRCS Field Personnel.
UTM Projection, Zone 17, NAD27.

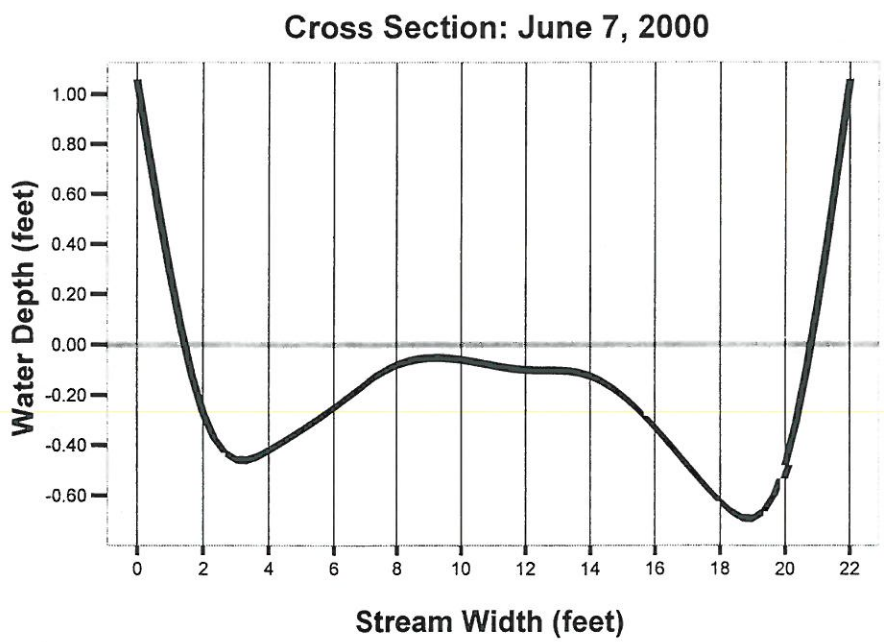
October 1999 1008510

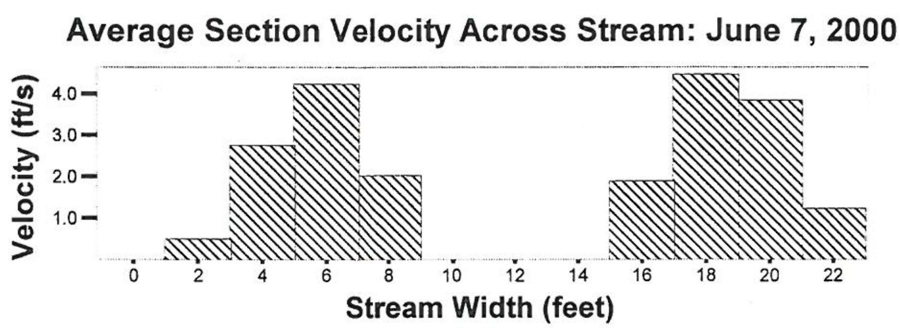
Appendix B.

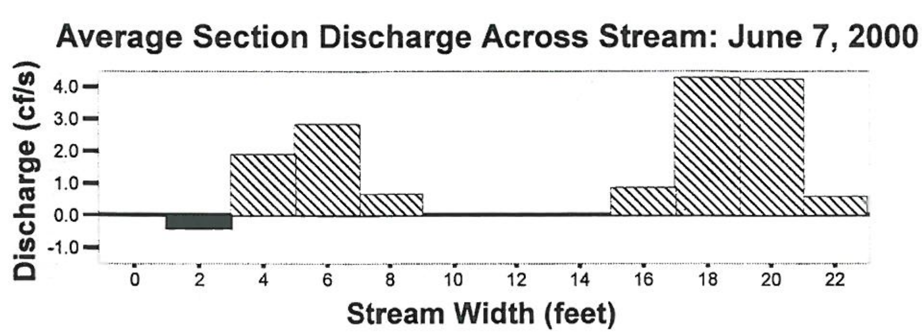
Stream Profiles for Sampling Sites on May 31, June 7, June12, and June 29

Stream Profile at Route 617

Looking Upstream



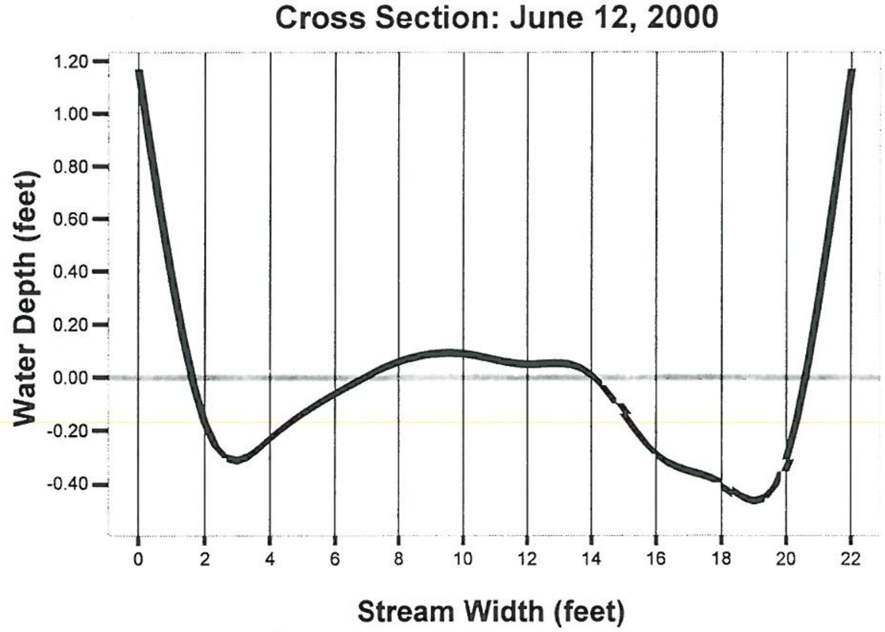


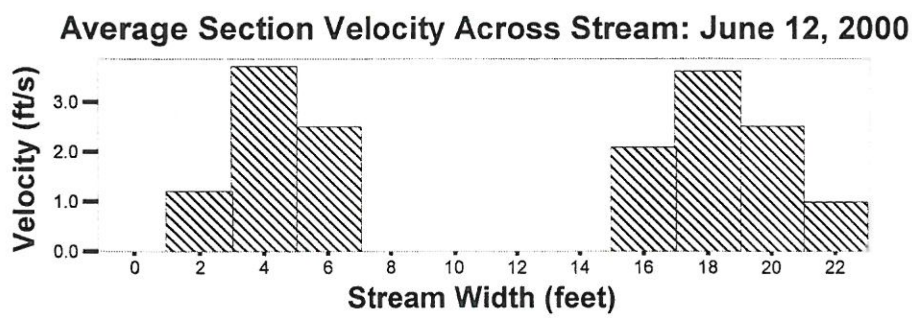


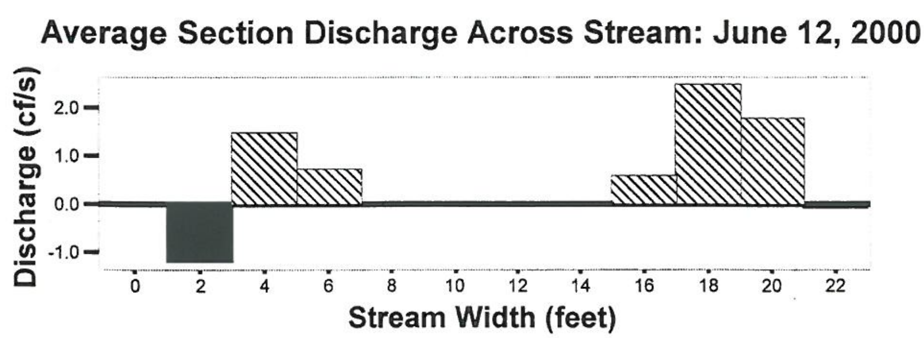
* Hydrological characteristics of Big Sayler's Creek located at Site 4 on Route 617.

Stream Profile at Route 617

Looking Upstream





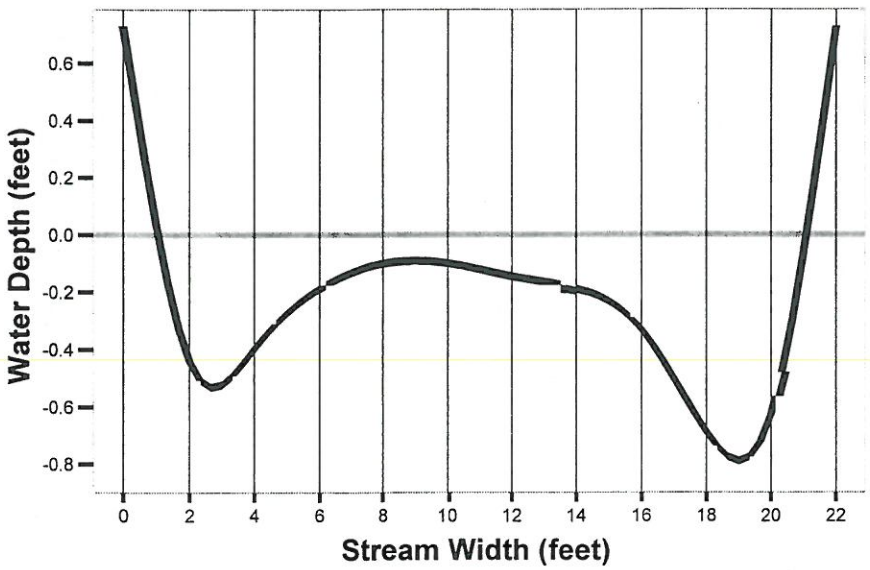


* Hydrological characteristics of Big Sayler's Creek located at Site 4 on Route 617.

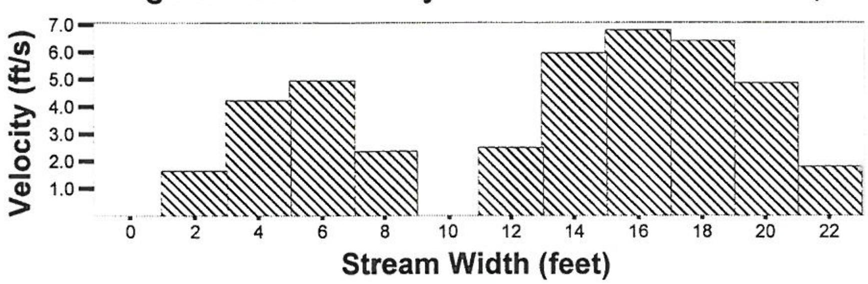
Stream Profile at Route 617

Looking Upstream

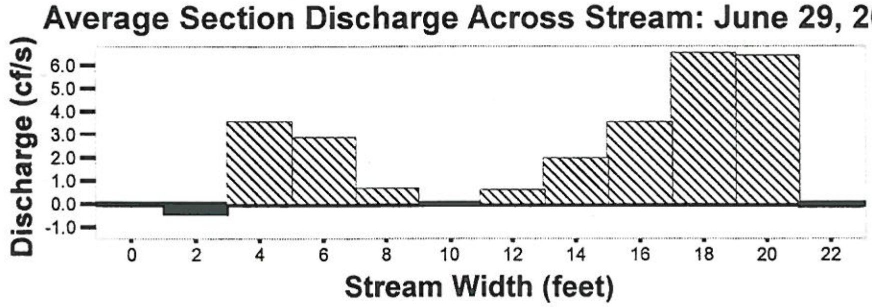
Cross Section: June 29, 2000



Average Section Velocity Across Stream: June 29, 2000



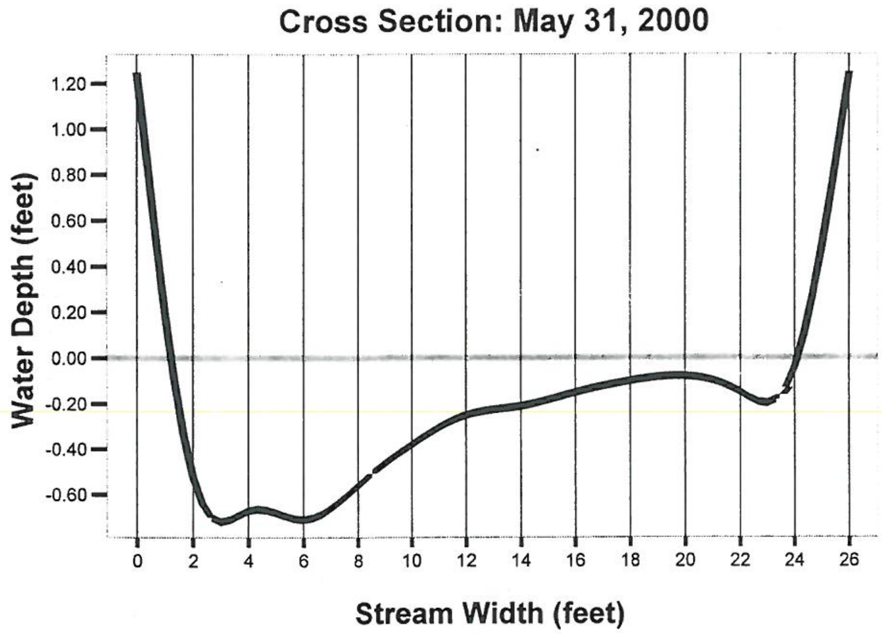
Average Section Discharge Across Stream: June 29, 2000

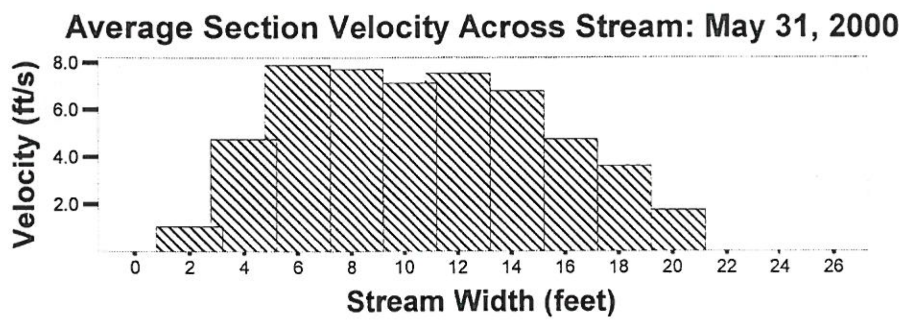


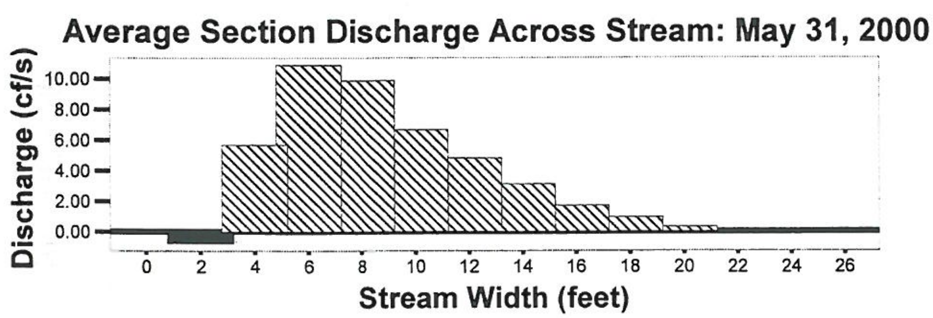
* Hydrological characteristics of Big Sayler's Creek located at Site 4 on Route 617.

Stream Profile at Route 619

Looking Upstream





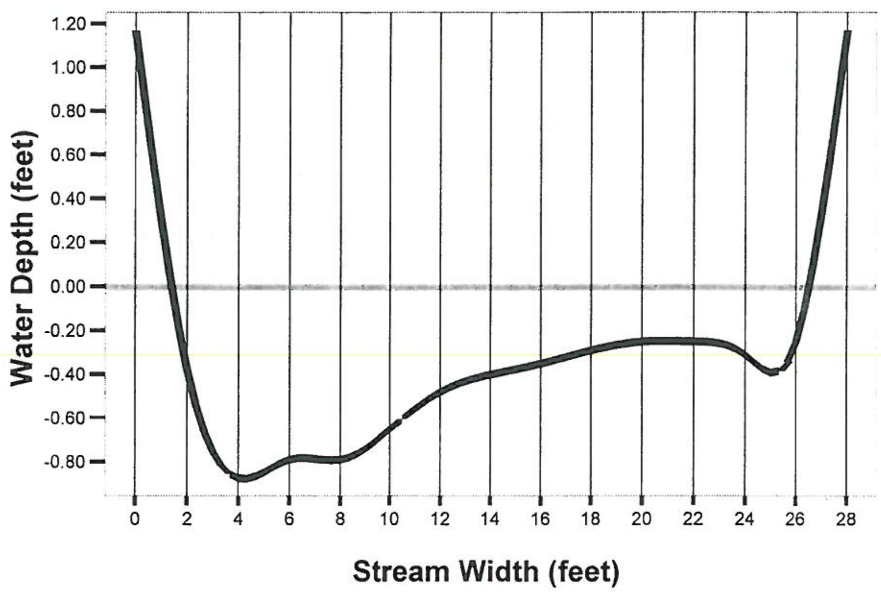


* Hydrological characteristics of Sayler's Creek located at Site 1 after the confluence of Big and Little Sayler's Creek.

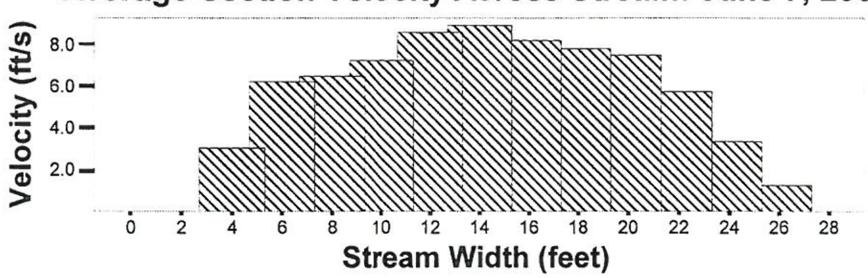
Stream Profile at Route 619

Looking Upstream

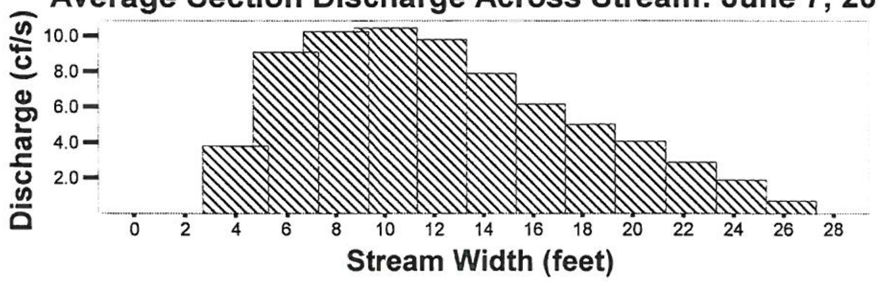
Cross Section: June 7, 2000



Average Section Velocity Across Stream: June 7, 2000



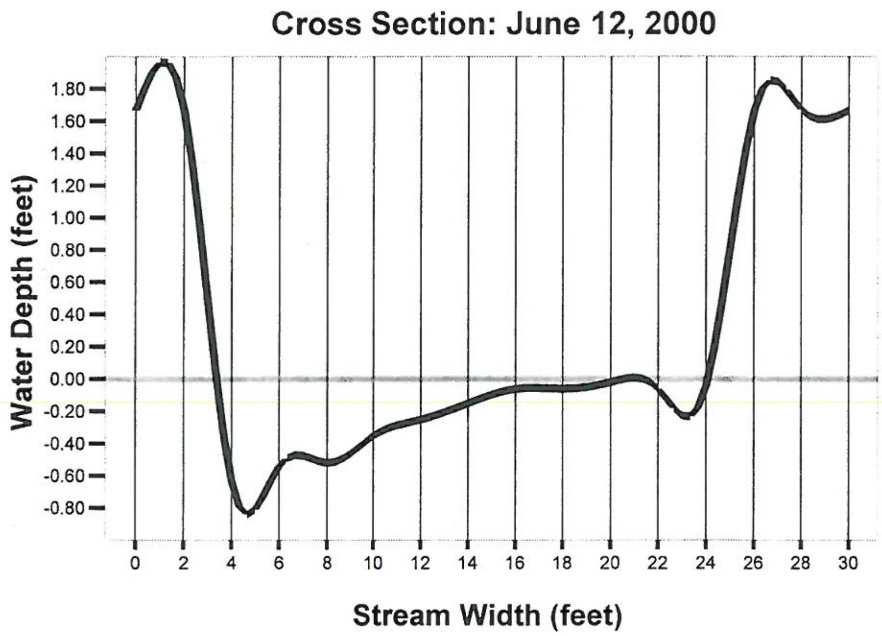
Average Section Discharge Across Stream: June 7, 2000

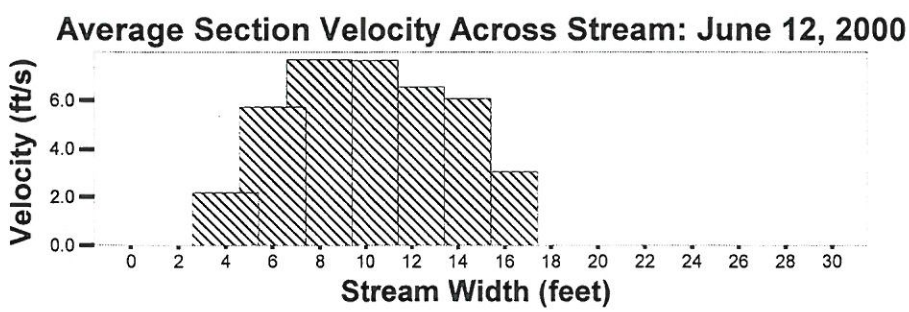


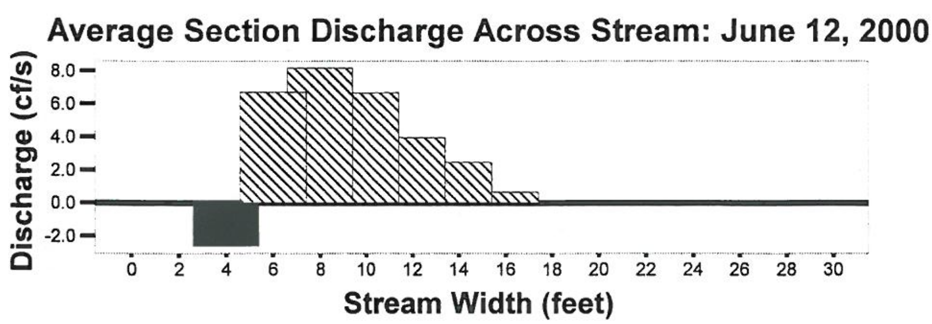
* Hydrological characteristics of Sayler's Creek located at Site 1 after the confluence of Big and Little Sayler's Creek.

Stream Profile at Route 619

Looking Upstream





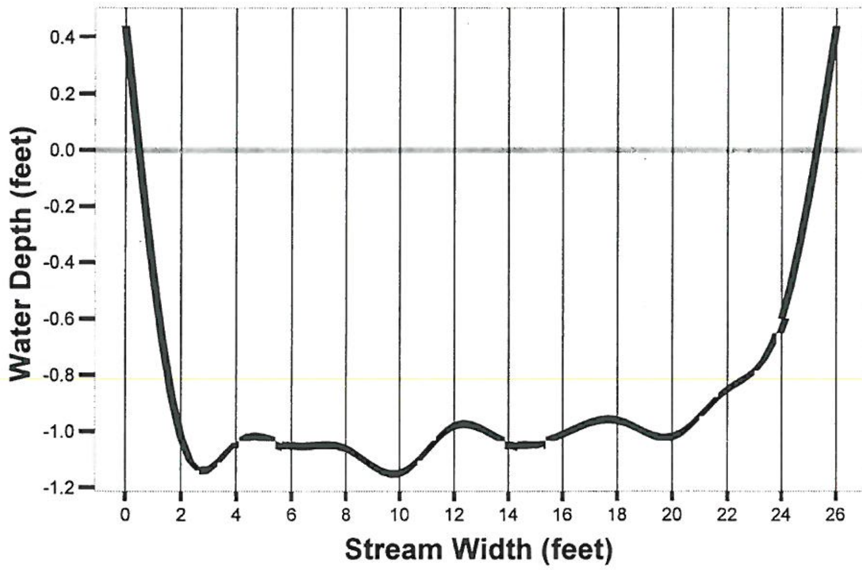


* Hydrological characteristics of Sayler's Creek located at Site 1 after the confluence of Big and Little Sayler's Creek.

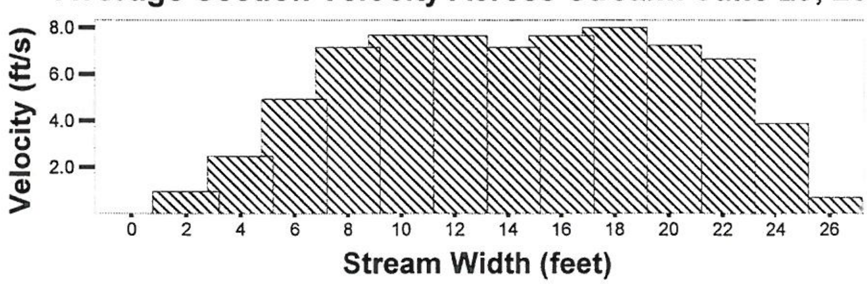
Stream Profile at Route 619

Looking Upstream

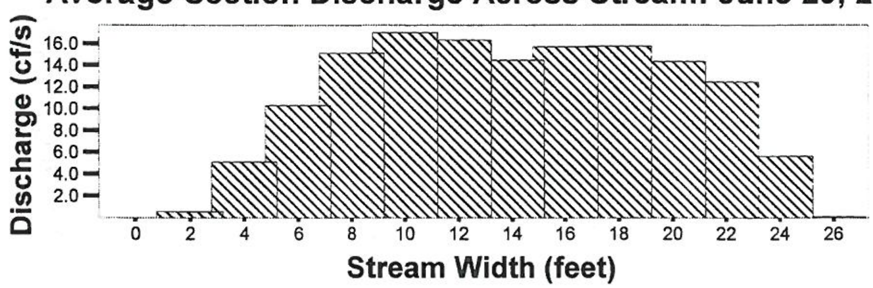
Cross Section: June 29, 2000



Average Section Velocity Across Stream: June 29, 2000



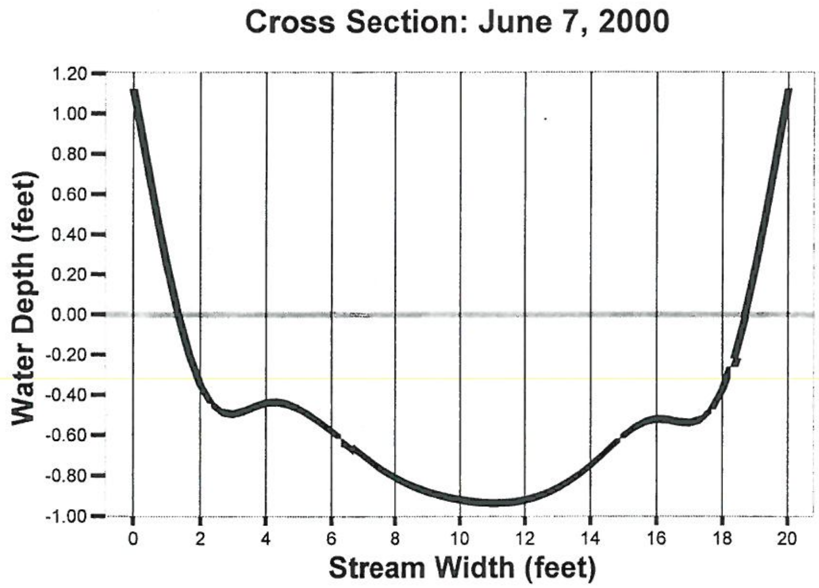
Average Section Discharge Across Stream: June 29, 2000

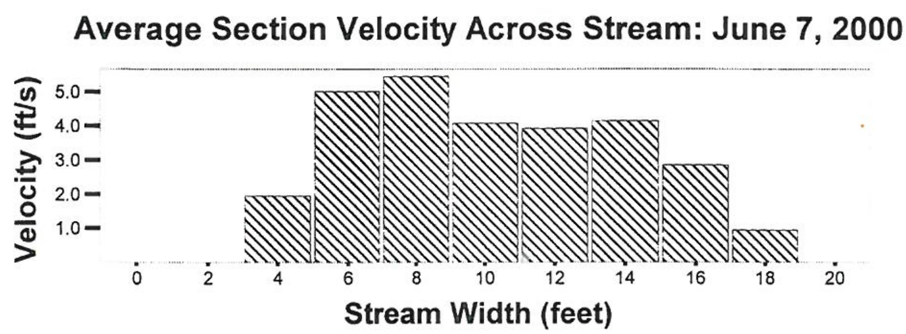


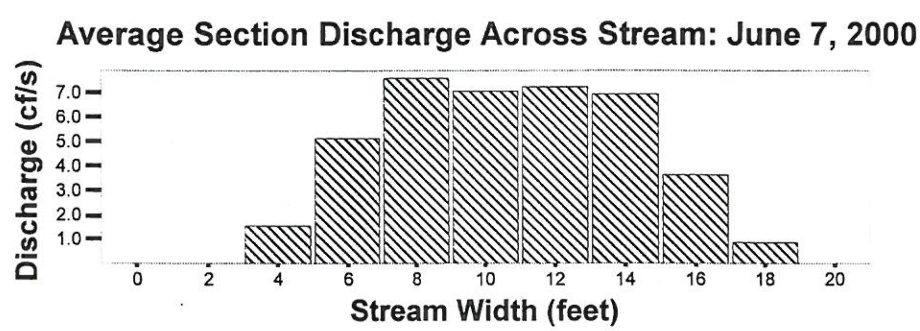
* Hydrological characteristics of Sayler's Creek located at Site 1 after the confluence of Big and Little Sayler's Creek.

Stream Profile of Big Sayler's Creek Upstream From Route 619

Looking Upstream



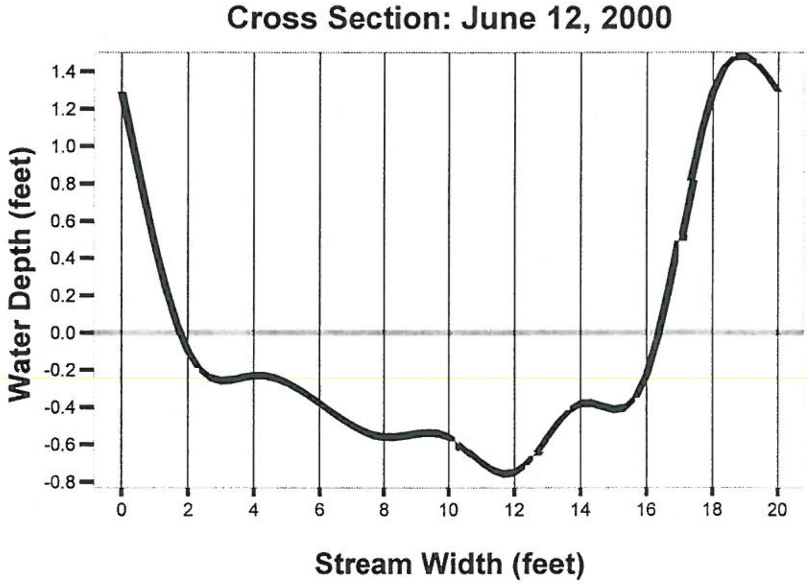


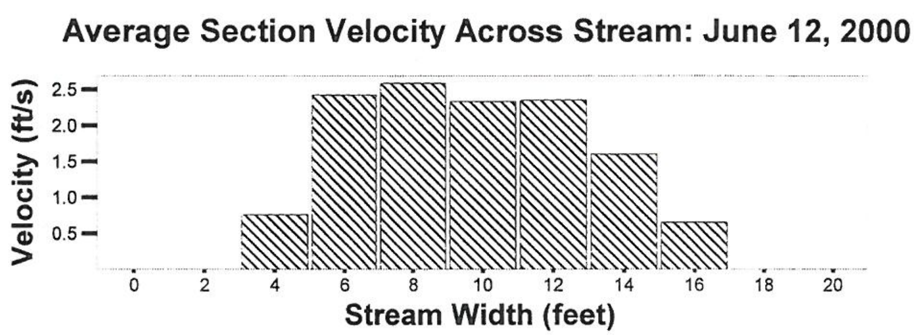


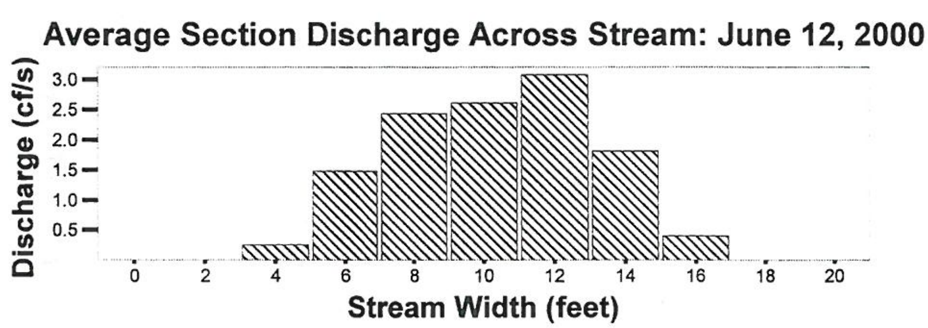
* Hydrological characteristics of Big Sayler's Creek located at Site 2 preceding the confluence near Route 619.

Stream Profile of Big Sayler's Creek Upstream From Route 619

Looking Upstream



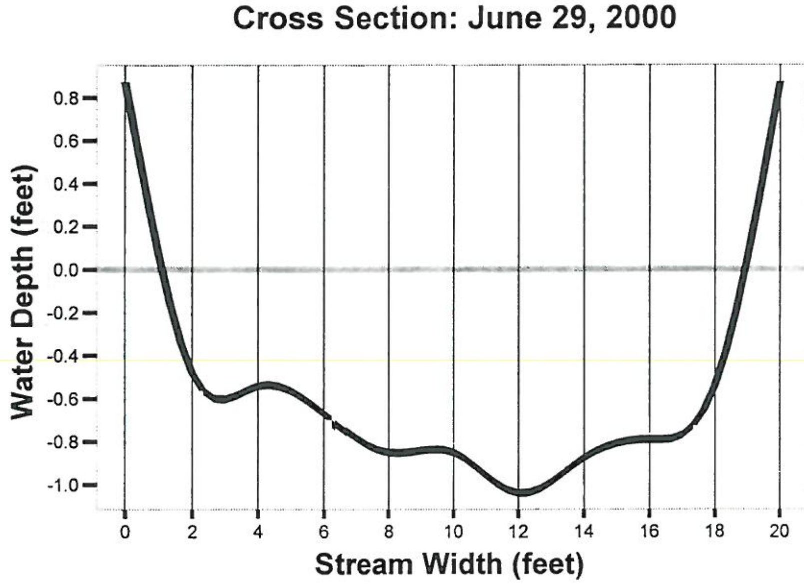


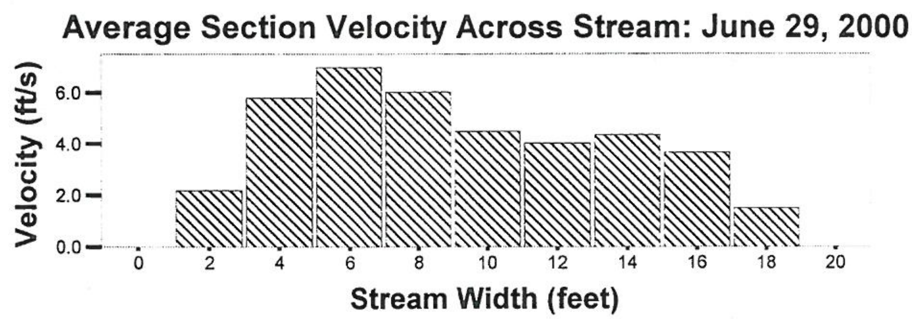


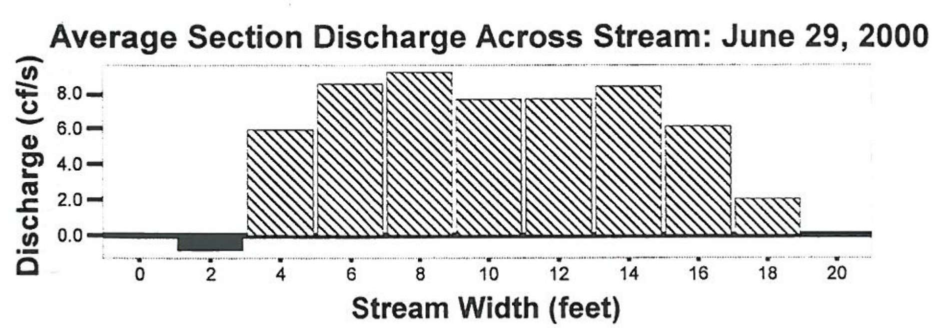
* Hydrological characteristics of Big Sayler's Creek located at Site 2 preceding the confluence near Route 619.

Stream Profile of Big Sayler's Creek Upstream From Route 619

Looking Upstream





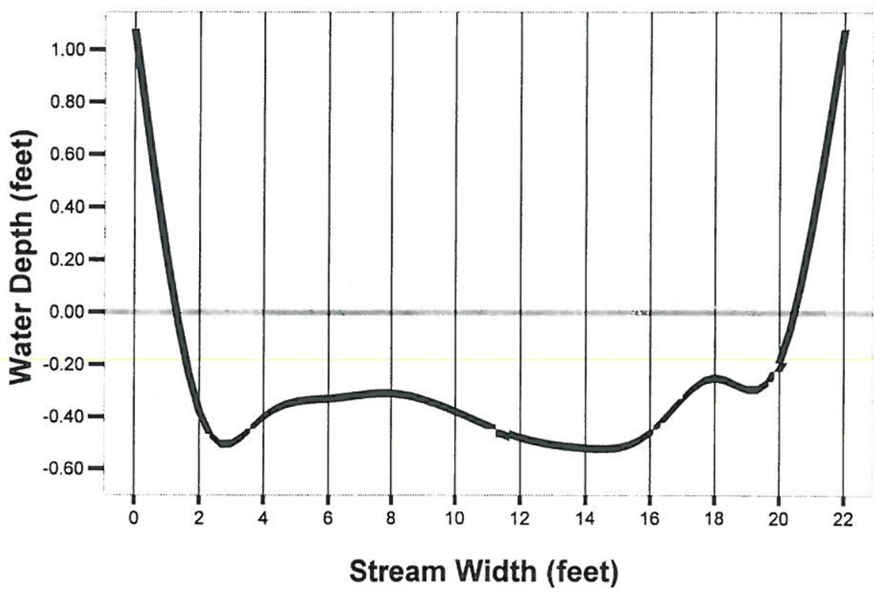


* Hydrological characteristics of Big Sayler's Creek located at Site 2 preceding the confluence near Route 619.

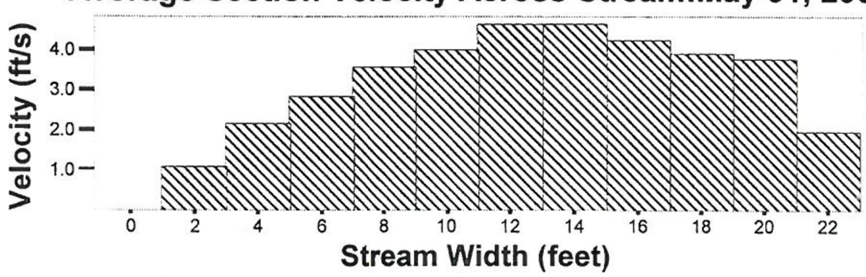
Stream Profile at Route 620

Looking Upstream

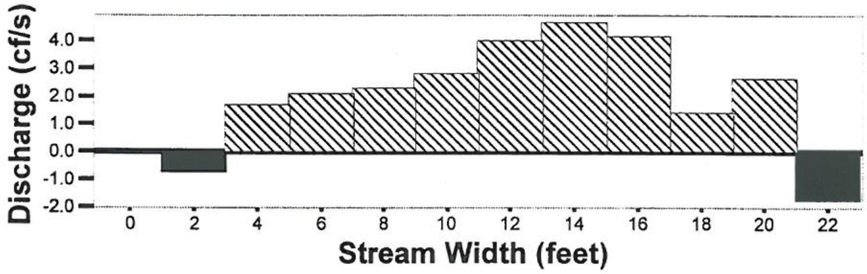
Cross Section: May 31, 2000



Average Section Velocity Across Stream:May 31, 2000



Average Section Discharge Across Stream: May 31, 2000

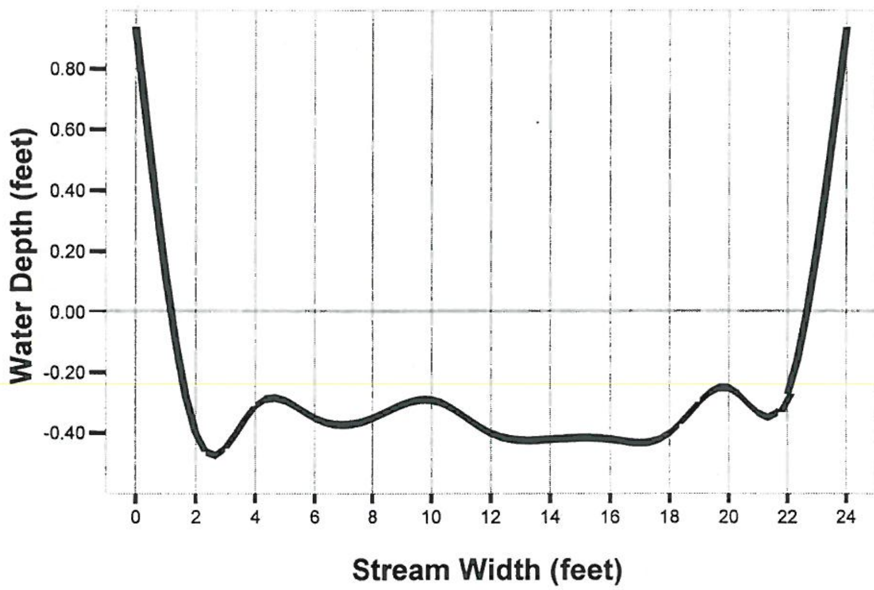


* Hydrological characteristics of Little Sayler's Creek located at Site 3 near Route 620.

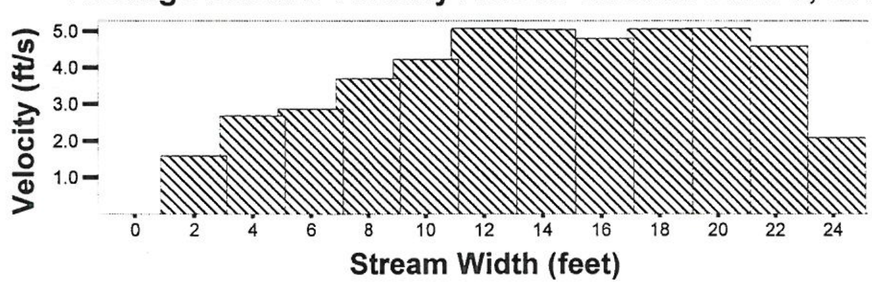
Stream Profile at Route 620

Looking Upstream

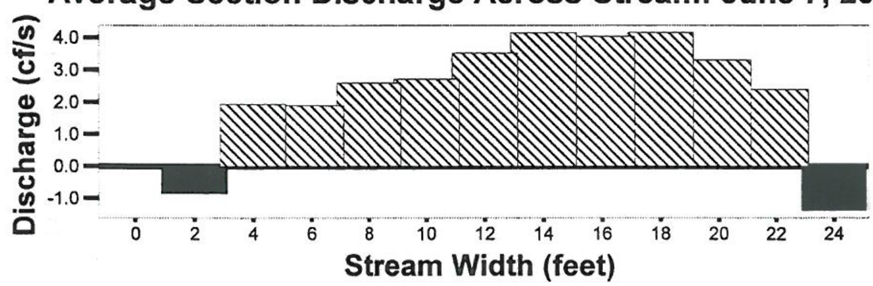
Cross Section: June 7, 2000



Average Section Velocity Across Stream: June 7, 2000



Average Section Discharge Across Stream: June 7, 2000

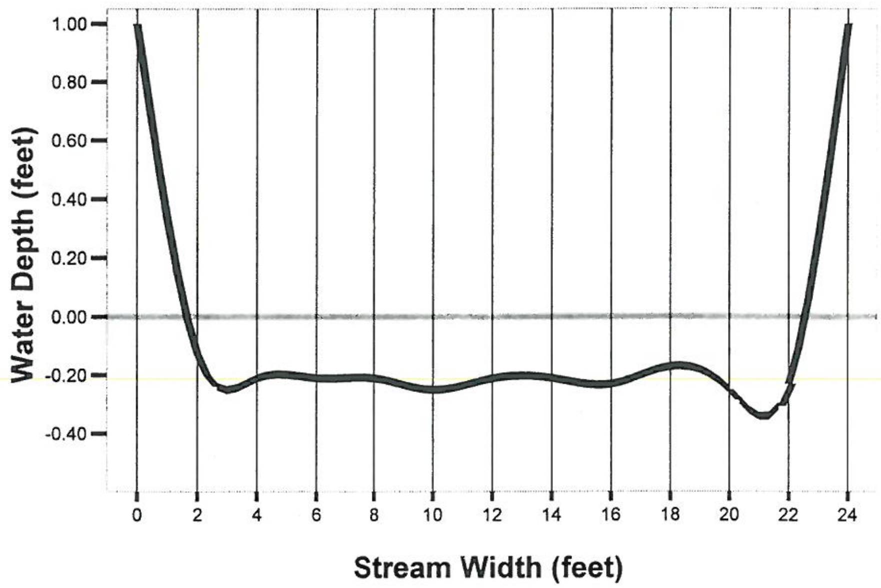


* Hydrological characteristics of Little Sayler's Creek located at Site 3 near Route 620.

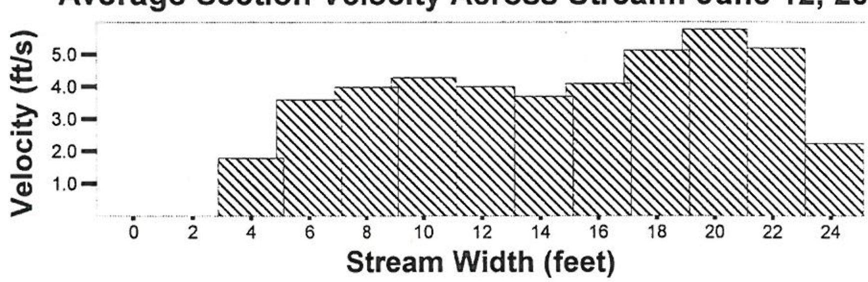
Stream Profile at Route 620

Looking Upstream

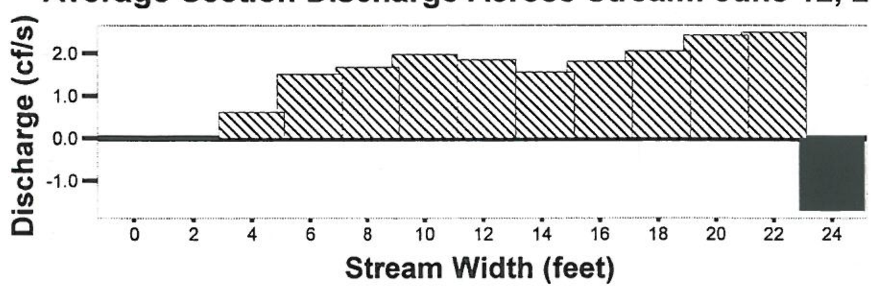
Cross Section: June 12, 2000



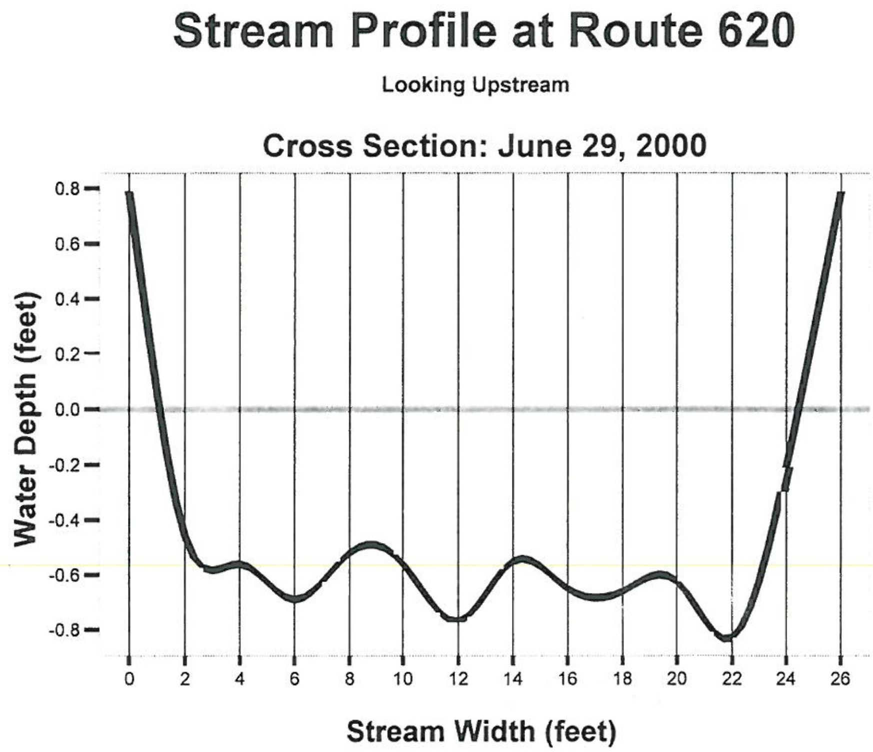
Average Section Velocity Across Stream: June 12, 2000

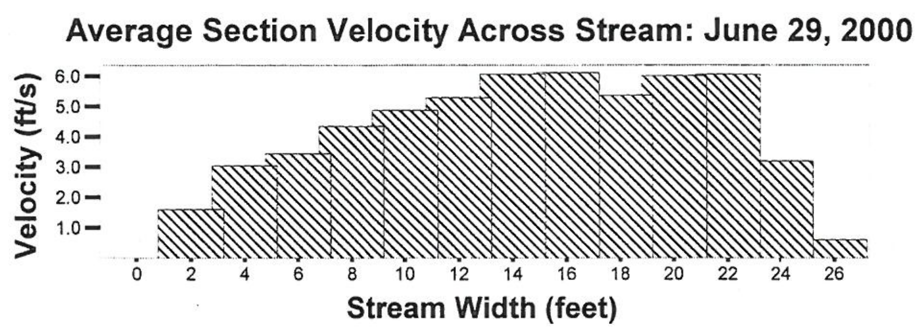


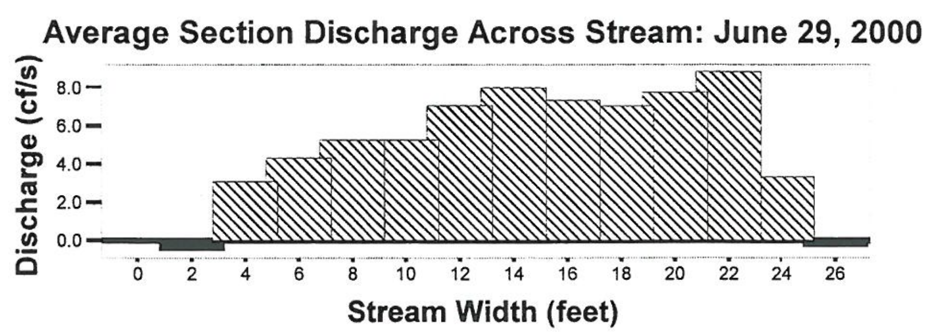
Average Section Discharge Across Stream: June 12, 2000



* Hydrological characteristics of Little Sayler's Creek located at Site 3 near Route 620.





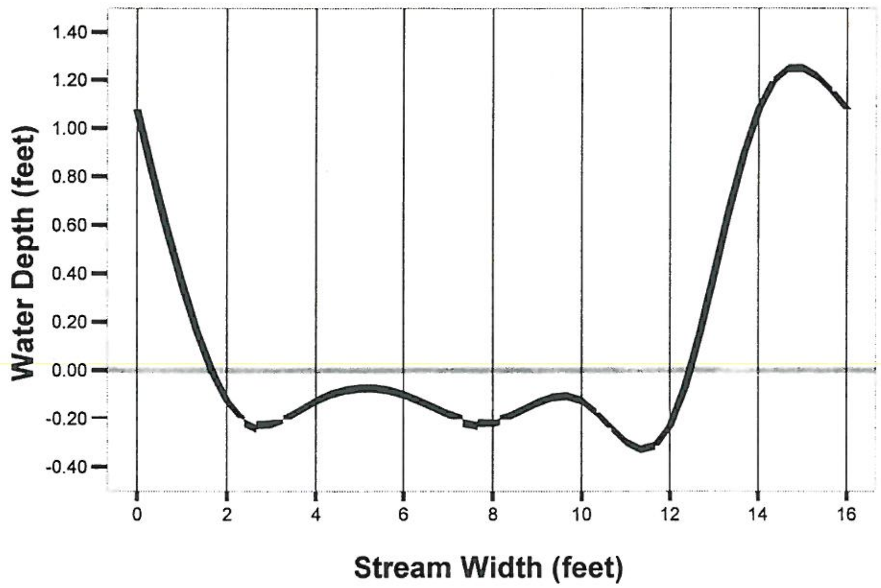


* Hydrological characteristics of Little Sayler's Creek located at Site 3 near Route 620.

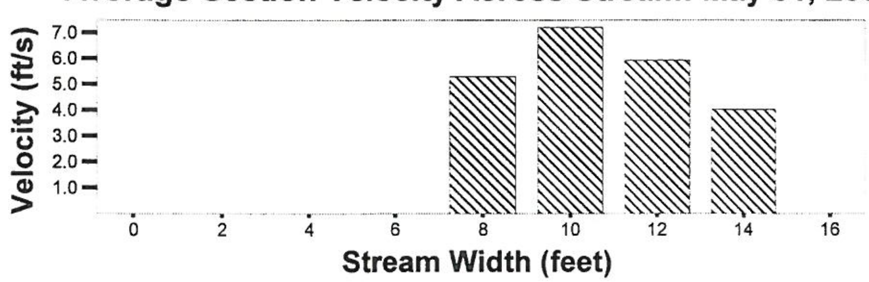
Stream Profile at Highway 307

Looking Upstream

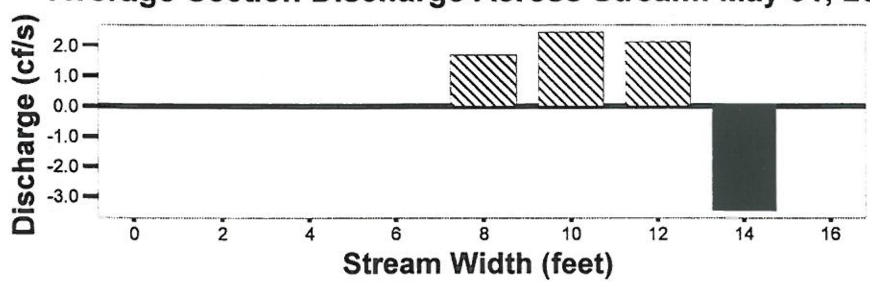
Cross Section: May 31, 2000



Average Section Velocity Across Stream: May 31, 2000



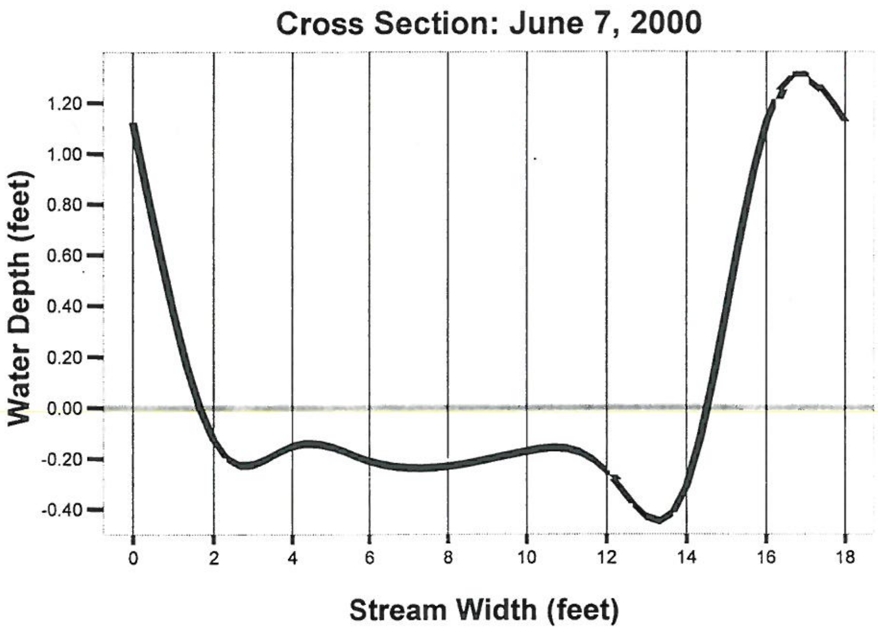
Average Section Discharge Across Stream: May 31, 2000

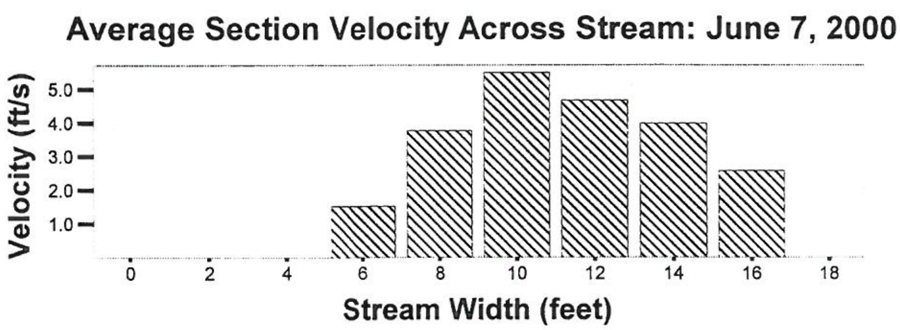


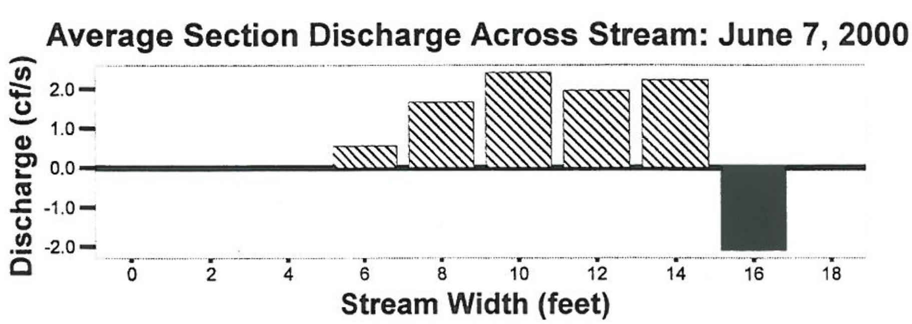
* Hydrological characteristics of Little Sayler's Creek located at Site 5 near Highway 307.

Stream Profile at Highway 307

Looking Upstream





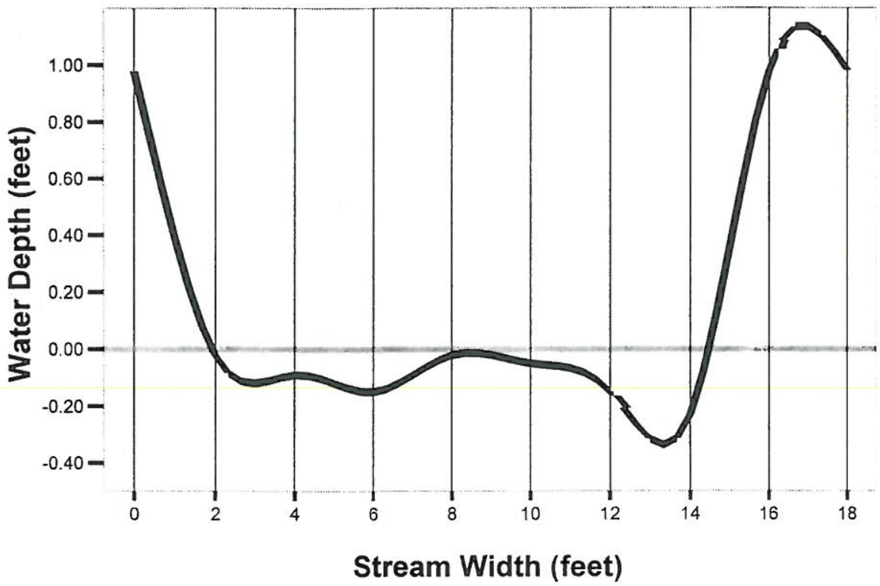


* Hydrological characteristics of Little Sayler's Creek located at Site 5 near Highway 307.

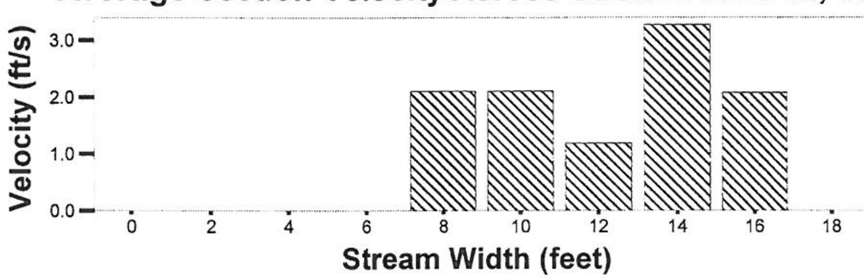
Stream Profile at Highway 307

Looking Upstream

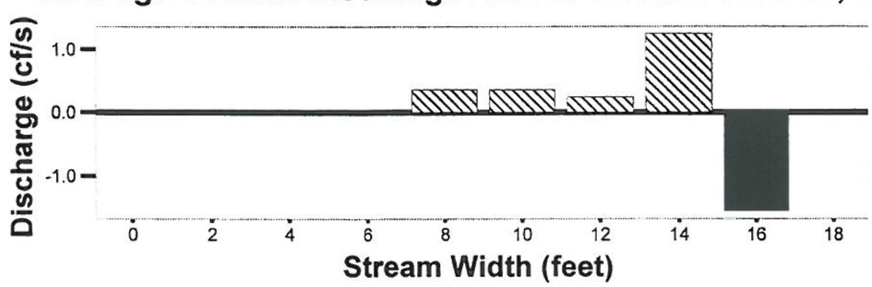
Cross Section: June 12, 2000



Average Section Velocity Across Stream: June 12, 2000



Average Section Discharge Across Stream: June 12, 2000

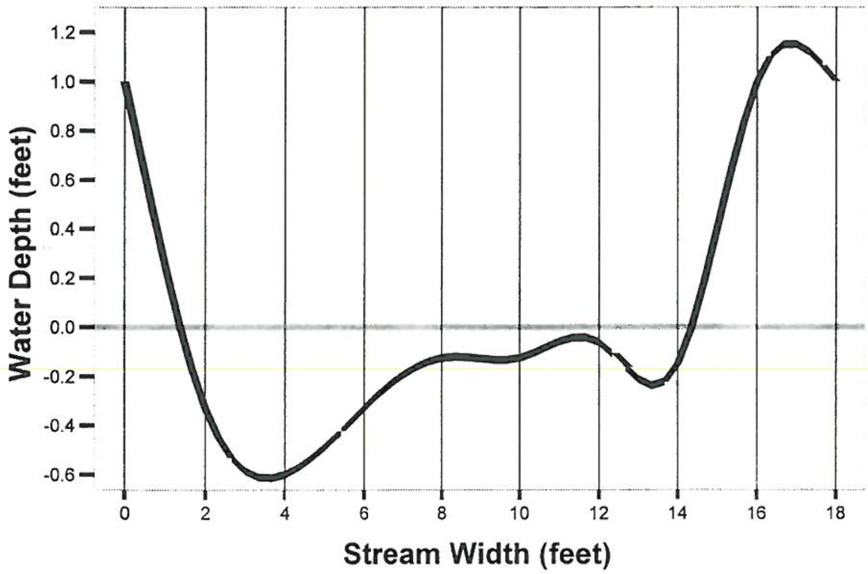


* Hydrological characteristics of Little Sayler's Creek located at Site 5 near Highway 307.

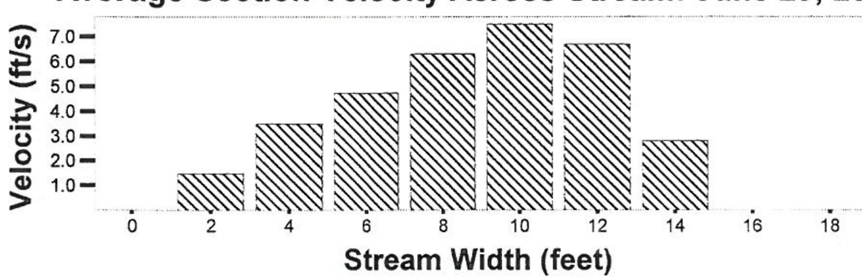
Stream Profile at Highway 307

Looking Upstream

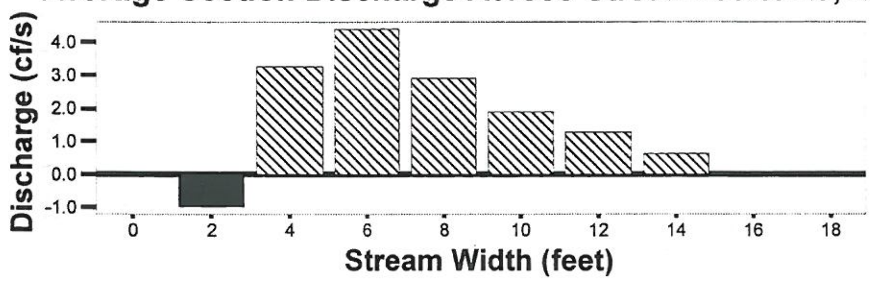
Cross Section: June 29, 2000



Average Section Velocity Across Stream: June 29, 2000



Average Section Discharge Across Stream: June 29, 2000

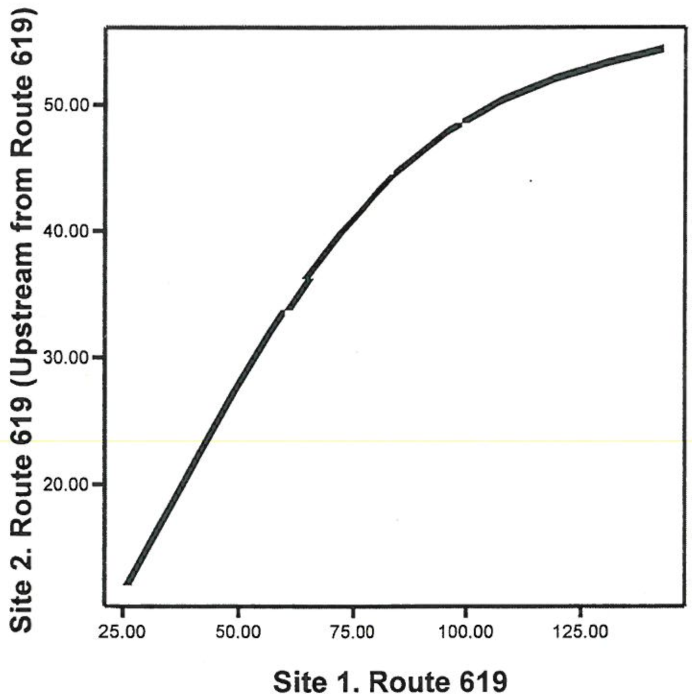


* Hydrological characteristics of Little Sayler's Creek located at Site 5 near Highway 307.

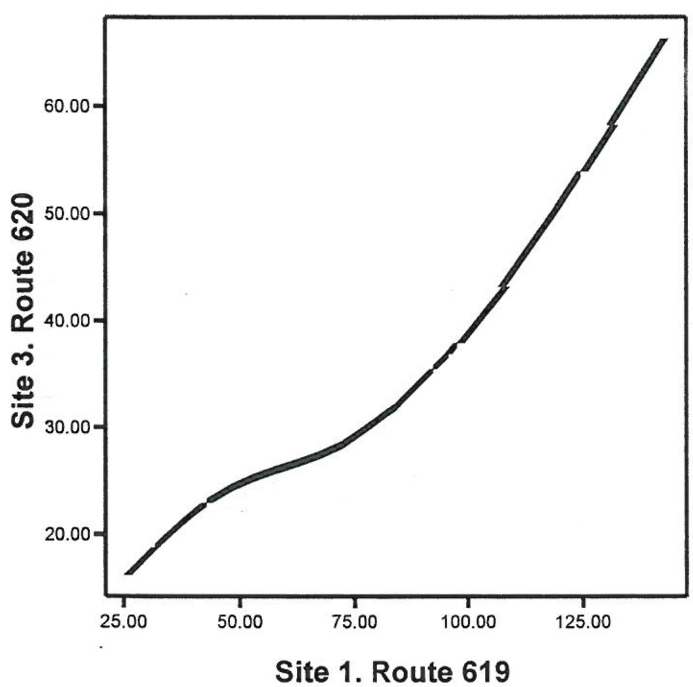
Appendix C.

Correlations Between Discharge at Site 1. Route 619 and Upstream Locations

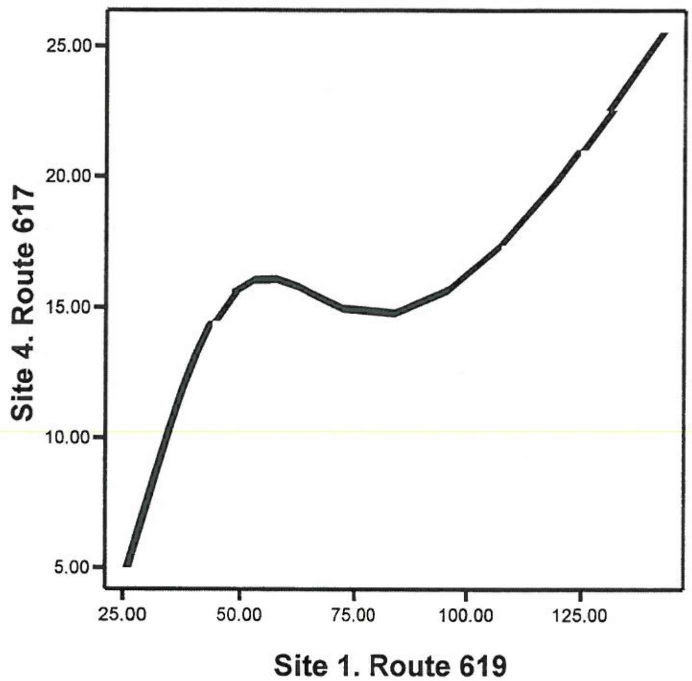
Relationship Between Discharge at Site 1 (Route 619) and Site 2 (Upstream from Route 619)



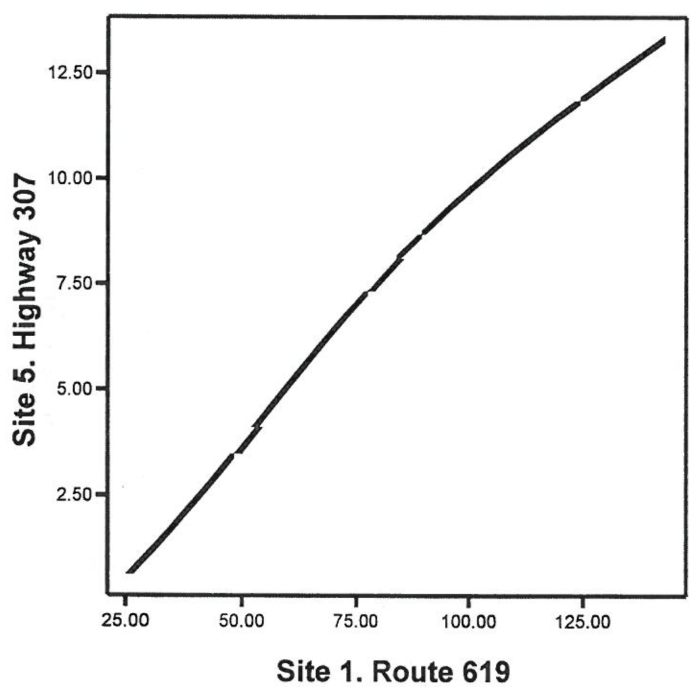
Relationship Between Discharge at Site 1 (Route 619) and Site 3 (Route 620



Relationship Between Discharge at Site 1 (Route 619) and Site 4 (Route 617)



Relationship Between Discharge at Site 1 (Route 619) and Site 5 (Highway 307)



Regression Model for Discharge Between Sample Sites: Site 1 (Route 619) and Site 2 (Upstream from Route 619)

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.956[a]	.913	.826	8.98595

a. Predictors: (Constant), SS1

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	847.502	1	847.502	10.496	.191[a]
	Residual	80.747	1	80.747		
	Total	928.249	2			

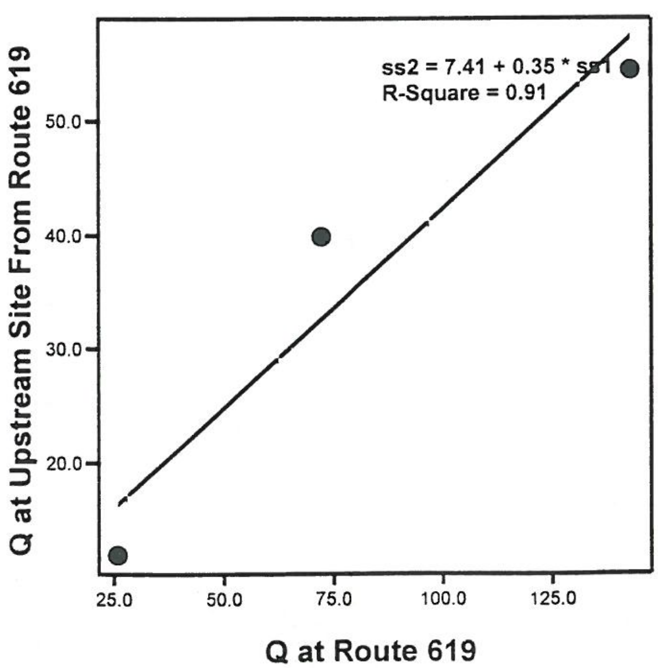
a. Predictors: (Constant), SS1

b. Dependent Variable: SS2

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	7.407	10.100		.733	.597
	SS1	.350	.108	.956	3.240	.191

Discharge Relationship Between Site 1 (Route 619) and Site 2 (Upstream From Route 619)



Regression Model for Discharge Between Sample Sites: Site 1 (Route 619) and Site 3 (Route 620)

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.986[a]	.972	.958	4.60527

a. Predictors: (Constant), SS1

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1468.677	1	1468.677	69.249	.014[a]
	Residual	42.417	2	21.208		
	Total	1511.094	3			

a. Predictors: (Constant), SS1

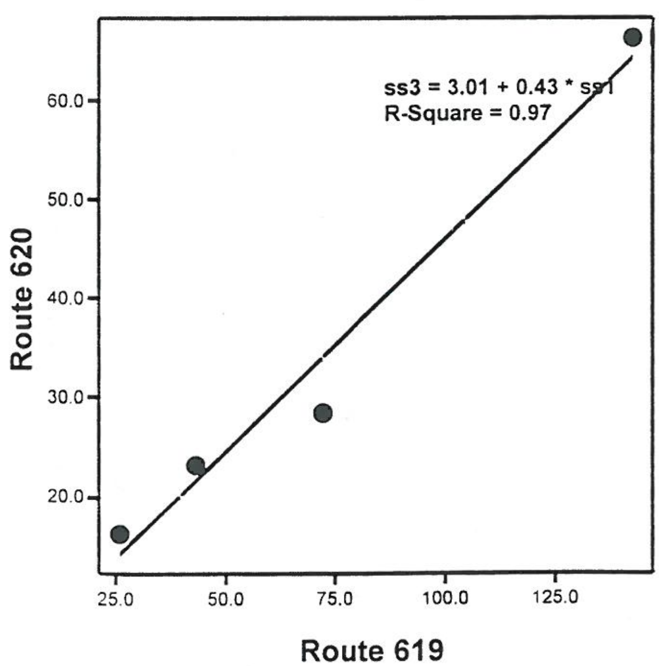
b. Dependent Variable: SS3

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	3.015	4.328		.697	.558
	SS1	.429	.052	.986	8.322	.014

a. Dependent Variable: SS3

Discharge Relationship Between Site 1 (Route 619) and Site 3 (Route 620)



Regression Model for Discharge Between Sample Sites: Site 1 (Route 619) and Site 4 (Route 617)

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.945[a]	.893	.839	3.3673

a. Predictors: (Constant), SS1

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	189.069	1	189.069	16.675	.055[a]
	Residual	22.677	2	11.339		
	Total	211.747	3			

a. Predictors: (Constant), SS1

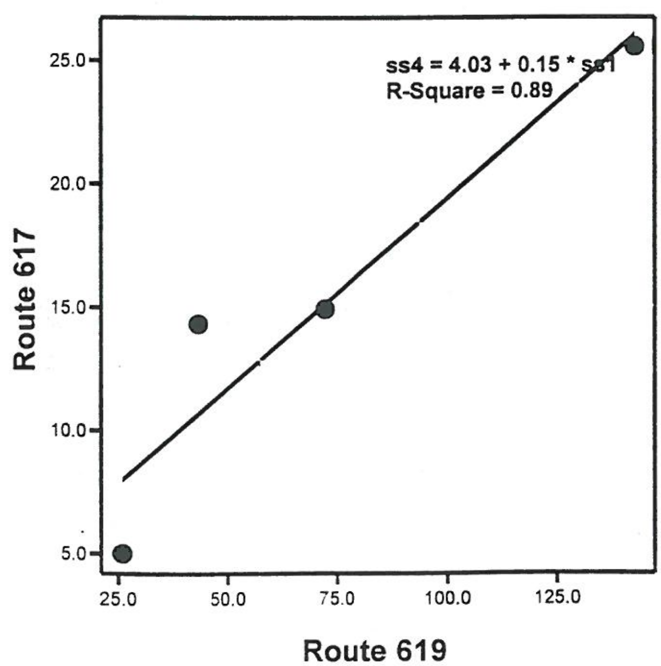
b. Dependent Variable: SS4

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	4.028	3.165		1.273	.331
	SS1	.154	.038	.945	4.083	.055

a. Dependent Variable: SS4

Discharge Relationship Between Site 1 (Route 619) and Site 4 (Route 617)



Regression Model for Discharge Between Sample Sites: Site 1(Route 619) and Site 5 (Highway 307)

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.996[a]	.992	.988	.60510

a. Predictors: (Constant), SS1

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	92.287	1	92.287	252.049	.004[a]
	Residual	.732	2	.366		
	Total	93.019	3			

a. Predictors: (Constant), SS1

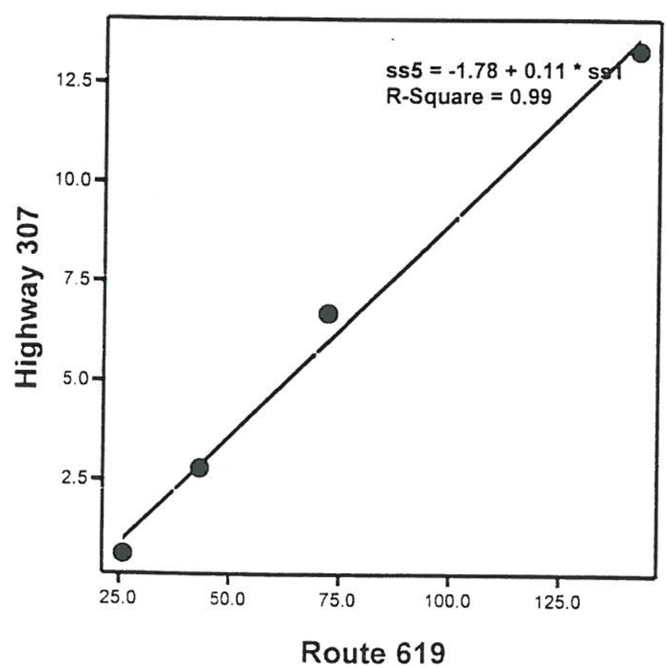
b. Dependent Variable: SS5

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-1.777	.569		-3.124	.089
	SS1	.108	.007	.996	15.876	.004

a. Dependent Variable: SS5

Discharge Relationship Between Site 1 (Route 619) and Site 5 (Highway 307)



Appendix D.

Regression Analysis on Discharge and Fecal Coliform Analysis at All Sites

Regression Analysis Illustrating Relationship Between Discharge and Fecal Coliform Concentration at All Sites

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.629[a]	.396	.361	8564.0020

a. Predictors: (Constant), Q

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	8.18E+08	1	8.18E+08	11.158	.004[a]
	Residual	1.25E+09	17	73342130		
	Total	2.07E+09	18			

a. Predictors: (Constant), Q

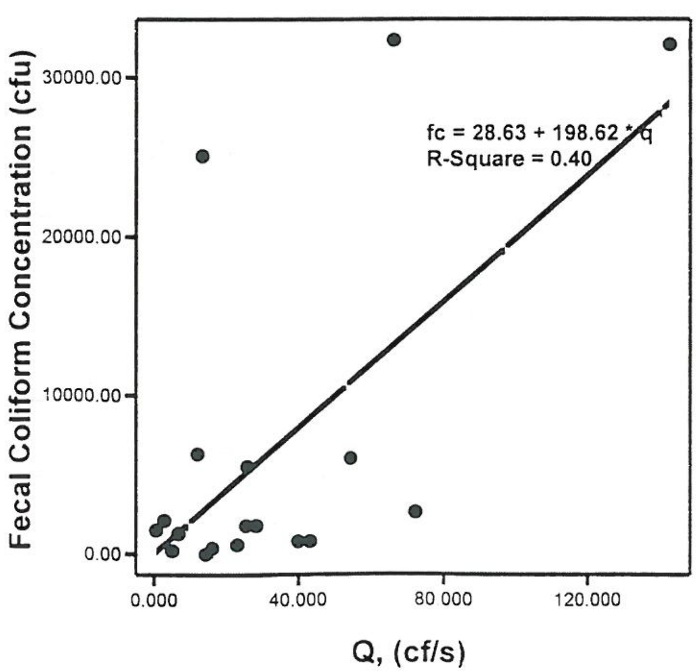
b. Dependent Variable: FC

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	28.634	2735.020		.010	.992
	Q	198.624	59.463	.629	3.340	.004

a. Dependent Variable: FC

Relationship Between Discharge and Fecal Coliform Concentration at All Sites



Appendix E.

Regression Analysis Between Discharge and Fecal Coliform Concentration at Individual Sites

Regression Analysis Illustrating Relationship Between Discharge (Q) and Fecal Coliform Concentration at Site 1 (Route 619)

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.897[a]	.804	.706	7970.0706

a. Predictors: (Constant), Q

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	5.21E+08	1	5.21E+08	8.198	.103[a]
	Residual	1.27E+08	2	63522026		
	Total	6.48E+08	3			

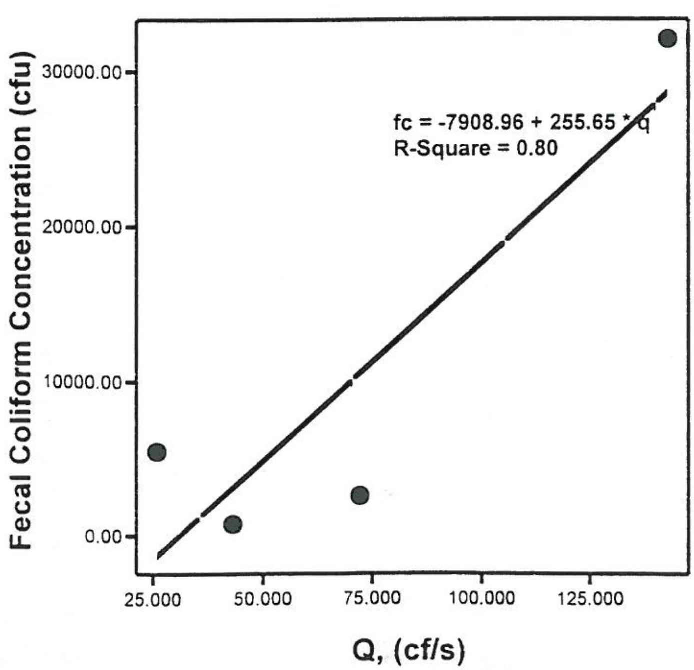
a. Predictors: (Constant), Q

b. Dependent Variable: FC

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-7908.962	7490.161		-1.056	.402
	Q	255.652	89.287	.897	2.863	.103

Relationship Between Discharge and Fecal Coliform at Site 1 (Route 619)



Regression Analysis Illustrating Relationship Between Q and Fecal Coliform Concentration at Site 2 (Upstream from Route 619)

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.227[a]	.051	-.897	4259.5798

a. Predictors: (Constant), Q1

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	982646.68	1	982646.68	.054	.854[a]
	Residual	18144020	1	18144020		
	Total	19126667	2			

a. Predictors: (Constant), Q1

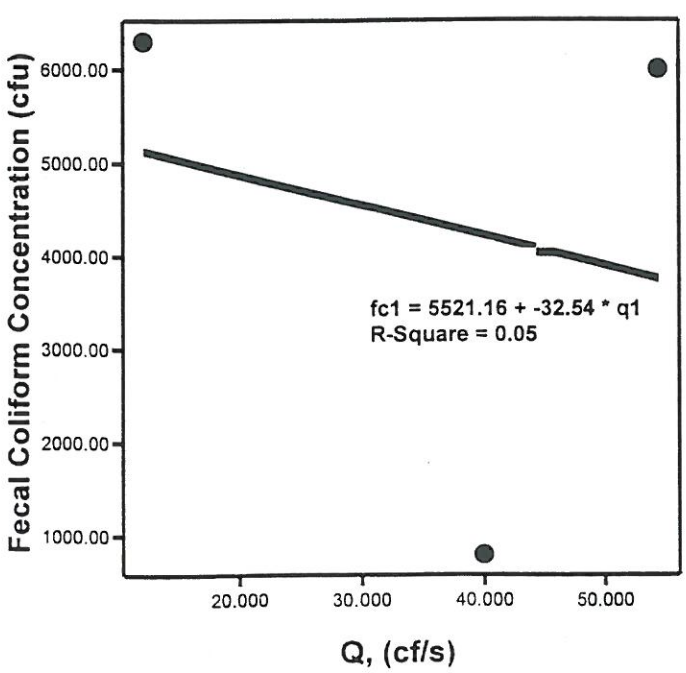
b. Dependent Variable: FC1

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	5521.159	5536.999		.997	.501
	Q1	-32.536	139.809	-.227	-.233	.854

a. Dependent Variable: FC1

Relationship Between Discharge and Fecal Coliform at Site 2 (Upstream from Route 619)



Regression Analysis Illustrating Relationship Between Q and Fecal Coliform Concentration at Site 3 (Route 620)

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.982[a]	.964	.946	3647.9695

a. Predictors: (Constant), Q2

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	7.17E+08	1	7.17E+08	53.890	.018[a]
	Residual	26615362	2	13307681		
	Total	7.44E+08	3			

a. Predictors: (Constant), Q2

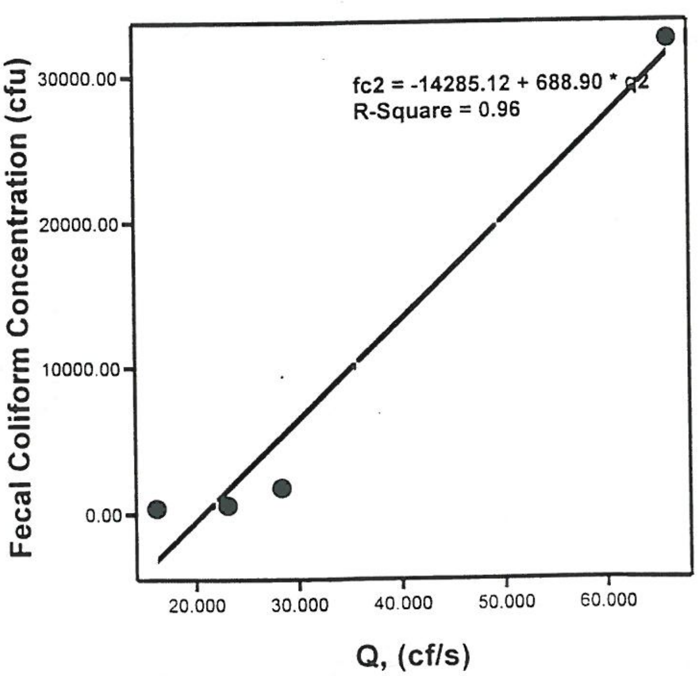
b. Dependent Variable: FC2

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-14285.119	3635.394		-3.929	.059
	Q2	688.902	93.844	.982	7.341	.018

a. Dependent Variable: FC2

Relationship Between Discharge and Fecal Coliform at Site 3 (Route 620)



Regression Analysis Illustrating Relationship Between Q and Fecal Coliform Concentration at Site 4 (Route 617)

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.777[a]	.604	.405	672.2716

a. Predictors: (Constant), Q3

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1376101.9	1	1376101.9	3.045	.223[a]
	Residual	903898.09	2	451949.05		
	Total	2280000.0	3			

a. Predictors: (Constant), Q3

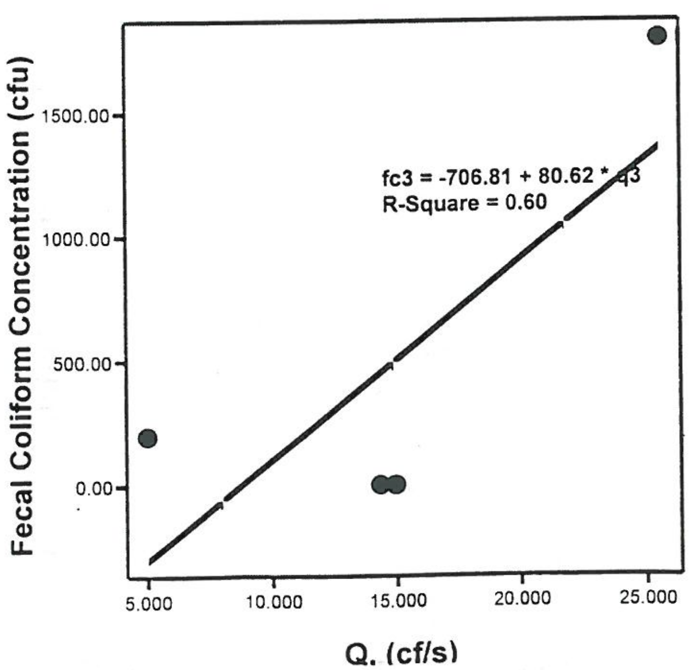
b. Dependent Variable: FC3

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-706.810	768.964		-.919	.455
	Q3	80.615	46.199	.777	1.745	.223

a. Dependent Variable: FC3

Relationship Between Discharge and Fecal Coliform at Site 4 (Route 617)



Regression Analysis Illustrating Relationship Between Q and Fecal Coliform Concentration at Site 5 (Highway 307)

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.887[a]	.786	.679	6646.9385

a. Predictors: (Constant), Q4

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	3.25E+08	1	3.25E+08	7.356	.113[a]
	Residual	88363584	2	44181792		
	Total	4.13E+08	3			

a. Predictors: (Constant), Q4

b. Dependent Variable: FC4

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-3467.951	5234.419		-.663	.576
	Q4	1869.192	689.186	.887	2.712	.113

a. Dependent Variable: FC4

Relationship Between Discharge and Fecal Coliform at Site 5 (Highway 307)