A VALIDATION STUDY OF THE NORTH CAROLINA RAPID FIELD-BASED RATING SYSTEM FOR DISCRIMINATING FLOW PERMANENCE CLASSES OF HEADWATER STREAMS IN AGRICULTURE BASINS IN SOUTHERN ILLINOIS

By

Miles Lampo

B.A., Augustana College, 2012

A Thesis
Submitted in Partial Fulfillment of the Requirements for the
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Department of Geography and Environmental Resources
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THESIS APPROVAL

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Approved by:

Dr. Jonathan Remo, Chair

Dr. Reuben Heine

Dr. Christopher Lant

Graduate School
Southern Illinois University Carbondale
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MILES LAMPO, for the Master of Science degree in Geography and Environmental Resources, presented on May 14, 2014, at Southern Illinois University Carbondale.

TITLE: A VALIDATION STUDY OF THE NORTH CAROLINA RAPID FIELD-BASED RATING SYSTEM FOR DISCRIMINATING FLOW PERMANENCE CLASSES OF HEADWATER STREAMS IN AGRICULTURE BASINS IN SOUTHERN ILLINOIS

MAJOR PROFESSOR: Dr. Jonathan Remo

Rapid field-based assessment methods for classifying stream permanence in headwater streams are needed to accurately inform regulatory decisions regarding which streams are protected under the Clean Water Act. In North Carolina, a rapid field-based assessment method for identification of intermittent and perennial streams has been developed. The North Carolina Method (NC method) uses 26 attributes divided into three categories geomorphology, hydrology, and biology to assess a particular study reach's flow permanence. In this method, the attribute scores for a given study reach are totaled and the sum of the score is used to rank the reach as ephemeral, intermittent, or perennial. The study objective were to (1) evaluate the NC method's ability to classify the flow permanence of agricultural, low order, study reaches in Southern Illinois and (2) create empirical models that predict flow permanence at a given stream location.

The results of the study show the NC method successfully differentiated ephemeral from intermittent and perennial study reaches 100% of the time. However, there was lower

fidelity in differentiating between intermittent and perennial study reaches and correctly determined flow permanence 82% of the time. In two of the cases where the NC method categorized the streams incorrectly, the score was on the threshold between intermittent and ephemeral. If these study reaches were categorized during a drier period they may have scored correctly. These results suggest the NC method would be a strong foundation for the development of a rapid field-based assessment protocol method for Illinois.

Regression models were developed to predict NC method scores using a variety of hydrologic, geomorphic, and land-cover metrics. Two statistically significant models (>95% confidence interval) for estimating NC method stream permanence scores were developed using these physical parameters. One of the significant regression models developed used watershed area alone as a predictor of the NC method stream permanence scores. The second significant regression model employed bankfull width, upslope surface-water area, and upslope area of grass lands. These models explained 61% and 69% of the variance in the NC method stream-permanence scores, respectively. While the regression models develop here are not capable of explicitly modeling stream-permanence class with a high degree of accuracy, they are useful for guiding stream-permanence study-site selection.

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CHAPTER 1

INTRODUCTION

Headwater streams are the first- and second- order streams throughout a watershed that serve as the critical hydrologic linkages between the surrounding terrestrial ecosystem and the downstream network (Stanford 1996). Headwater streams make up 60-90% of total stream length in U.S. watersheds (Leopold1964; Nadeau and Rains 2007) and these streams have been shown to exert a strong downstream influence on flooding (Stroud Water Research Center 2008), water quality (Anderson et al. 2007), and a stream's or river's ecological health (Freeman et al. 2007). Headwater streams are critical source areas for nutrients and serve as habitat for macroinvertebrates, fish, and amphibians within a watershed (Meyer and Wallace 2001). Headwater streams are prone to drying during at least a portion of the year because of their small catchment size. Due to the periodic drying, these streams are often misrepresented on maps and in geospatial databases (i.e., National Hydrography Dataset; Colson et al. 2008; Hansen 2001). Streams are classified by flow permanence as perennial, intermittent, or ephemeral. Perennial streams maintain flow throughout the year except during times of extreme drought. Intermittent streams maintain flow during wet seasons. Ephemeral streams contain flow only during and after precipitation events (Fritz et al. 2013).

In the U.S., the most common source of mapped perennial- and intermittent- stream-channel networks is from the medium- and large-scale U.S. Geologic Survey (USGS) hydrography on the 1:100,000 and 1:24,000 topographic series maps and the National Hydrography Dataset (NHD). On the printed topographic maps, perennial steams are drawn as solid blue lines and intermittent streams are drawn with dashed blue lines. While every USGS topographical map distinguishes between perennial and intermittent streams, several authors suggest these categorizations may not reflect reality. For example, Drummond (1974) lists the technical working instructions and criteria for several governmental mapping agencies and noted that none were based on field observations or stream gauging records. Gardner and Archfield (2002), when discussing the potential for using the existing 1:24,000 blue-line network for implementing a buffer program stated that blue lines on USGS topographic maps “may not accurately represent whether a stream reach is perennial or intermittent.”

In addition to water-resource managers, regulators require accurate information on the permanence of these streams for effective permitting and mitigation decision making. For example, the administration of key provisions of the Clean Water Act (CWA; discharge permits and 404 fill permits) require regulators to make determinations of whether a stream segment is part of the “Waters of the United States” – a determination that is made based on: (1) whether the stream is a tributary of a “navigatable waterway” and (2) “whether the steams contains flow for at least 3 months of the year” (U.S. Environmental Protection Agency [U.S.EPA], 2008). Since most streams in the Midwest are tributaries to a navigatable waterway, regulations apply to all streams that flow for at least 25% of the year (U.S. EPA 2008). These determinations are currently made on a site-by-site basis because existing maps and datasets do not accurately depict the flow characteristics of headwater streams (U.S. EPA 2012).

“Significant Nexus”, “Waters of the United States”, and “navigable waterways” are defined under the clean water act in order for practitioners to make correct determinations about which streams are protected and which ones are not, but scientific evidence does not support the existence of solid line separating protected streams vs. non-protected streams (Nadeau and Rains 2007). In the policy it seems clear, but headwater streams vary so much from one stream to another even in the same physiographic province. It is recommended by the Illinois Department of Natural Resources (IDNR, 2014) that any land owner applies for a permit if the following modifications are made to a stream: Any disturbance to the bed or banks of a stream; any disturbance to a wetland; the damming of a stream channel to create a pond or lake; placement of any material within a stream, wetland or open water, including material that is necessary for construction; culvert installation; causeways; road fills; dams; dikes or artificial island; property protection; reclamation devices and fill for pipes or utility lines; temporary impacts including dewatering of dredged material prior to final disposal and temporary fill for access roads; cofferdams; storage and work areas. Who is actually applying for these permits? Who is making sure that when modification is done to a stream they have acquired the appropriate permit? For example, in industrial agriculture specifically in Illinois extensive amount of subsurface drainage tile are being installed, culverts are installed and modifications are being done without any type of permit.

Regulatory needs regarding the CWA jurisdiction are the primary driver for protocols for the field identification and mapping of headwater streams (Fritz et al. 2006; NC Division Water Quality 2009). At the national level, the U.S. EPA is in the early stages of developing a national standard for the rapid assessment of flow permanence in headwater streams. As of April 21, 2014 the U.S Army Corps of Engineers and the Environmental Protection Agency has proposed rules defining the scope of waters protected under the CWA (Federal Registrar 2014). The intent of these rules is to provide clarity about which streams are protected for agencies that make decisions regarding 404 and 401 permits. There is a need for more efficient methods to distinguish which streams are protected under the CWA especially those in basins that are composed primarily of agricultural land use; this has not been widely studied before (Fritz et al. 2013). This is a significant rule change that could potentially affect a majority of streams in states like Illinois where 75% of the land area is in agriculture (U.S. Census Bureau 2007). Accurate assessment methods are needed to protect the environment and the farmer.

States have developed methods to assess headwater streams including the Streamflow Duration Assessment Method for Oregon and the Methodology for Identification of Intermittent and Perennial Streams and Their Origins Version 4.11, hereafter referred to as the NC method. The NC method was developed using the Streamflow Duration Assessment Method for Oregon as the foundation. The NC method has gone through five drafts that were tested and revised in order to be more robust and clear. The NC method was tested in South Carolina and was found to successfully distinguish ephemeral streams from intermittent and perennial streams, and is being recommended as a foundation for a South Carolina rapid assessment form (Wenerick et al. 2012)

To date, methods have been tested to assess flow permanence for forested watersheds in Indiana, Kentucky, North Carolina and Ohio. The methodology for the Identification of Intermittent and Perennial Streams and Their Origins (NC method) developed in North Carolina was created to identify intermittent and perennial streams using 26 attributes in geomorphology, hydrology, and biology categories (Table 1; Fritz et al. 2013). The attributes are weighted depending on if the attribute is strong (3), moderate (2), weak (1) or absent (0) in the 100-foot study reach. The highest score a stream can achieve is 63. Streams reaches receiving a score of at least 30 are classified as perennial streams. The study reaches scoring at least 19 are classified as intermittent. Ephemeral study reaches have a score <19 (Fritz et al. 2013). The NC method was developed for headwater streams in the Coastal Plain, Piedmont, and Mountain physiographic provinces in North Carolina (NCDWQ 2010). The NC method is also currently being used or being considered for use by Fairfax County (Virginia) Stormwater Planning Division (FCSPD 2003), the Athens-Clarke County, Georgia, Department of Transportation and Public Works, State of Oregon US Army Corps of Engineers (USACE), South Carolina Department of Health and Environmental Control, and the Tennessee Department of Environment Conservation (TNDEC 2011). While efforts to validate the NC method rapid assessment protocol (RAP) have been undertaken in varying forested watersheds across the U.S. (i.e., Fritz et al. 2013), there is a need to evaluate its utility in other watersheds with varying land uses (i.e., agriculture or urban) where flow permanence determinations are also needed to inform regulatory decisions (Fritz et al. 2013).

The objective of this study was to evaluate the NC method for characterizing flow permanence in headwater study reaches in watersheds dominated by agricultural land use in Southern Illinois. Specifically, this study attempts to (1) determine how the applicability of the NC method to characterize flow permanence in agricultural watersheds in Southern Illinois and (2) develop a model to predict flow permanence in Southern Illinois.

Table 1 North Carolina Method attributes, Indicator type, and the associated weighted scores (e.g. 0=absent, 3=strong)

Attribute	Indicator Type	Weighted Scores (absent to strong)
Continuity of Channel bed and bank	Geomorphology	0,1,2,3
Sinuosity of channel along thalweg	Geomorphology	0,1,2,3
in-channel structure	Geomorphology	0,1,2,3
Particle size of stream substrate	Geomorphology	0,1,2,3
active/relict floodplain	Geomorphology	0,1,2,3
Depositional bars or benches	Geomorphology	0,1,2,3
Recent alluvial deposits	Geomorphology	0,1,2,3
Headcuts	Geomorphology	0,1,2,13
Grade control	Geomorphology	0,.5,1,1.5
Natural valley	Geomorphology	0,.5,1,1.5
Second or greater order channel	Geomorphology	0,3
Presence of baseflow	Hydrology	0,1,2,3
Iron oxidizing bacteria	Hydrology	0,1,2,3
Leaf litter	Hydrology	1.5,1,.5,0
Sediment on plants or debris	Hydrology	0,.5,1,1.5
Organic debris lines or piles	Hydrology	0,.5,1,1.5
Soil-based evidence of high water table	Hydrology	0,3
Fibrous roots in streambed	Biology	3,2,1
Rooted upland plants in streambed	Biology	3,2,1,0
Macrobenthos	Biology	0,1,2,3
Aquatic mollusks	Biology	0,1,2,3
Fish	Biology	0,.5,1,1.5
Crayfish	Biology	0,0.5,1,1.5
Amphibians	Biology	0,0.5,1,1.5
Algae	Biology	0,0.5,1,1.5
Wetland plants in streambed	Biology	0,0.75,1.5

CHAPTER 2

METHODS

2.1 Stream Reaches

For this study, 17 stream reaches were selected along low-order streams in basins dominated by agricultural land use on Southern Illinois University farm property located in Jackson County, Illinois (Figure 1). Each of the stream reaches and its corresponding watersheds are located in the Shawnee Hills Section of the Interior Low Plateaus Physiographic Province. This physiographic province is characterized by a complex dissected upland, underlain by Mississippian and Pennsylvanian bedrock comprised of various sedimentary lithologies. The bedrock is generally overlain by either a thin layer of glacial drift or residual soils in the uplands and alluvium and/or Pleistocene lake clays in stream valleys (Leighton et al. 1948). Figures 2-7 are high resolution aerial photographs of each study reach and basin.

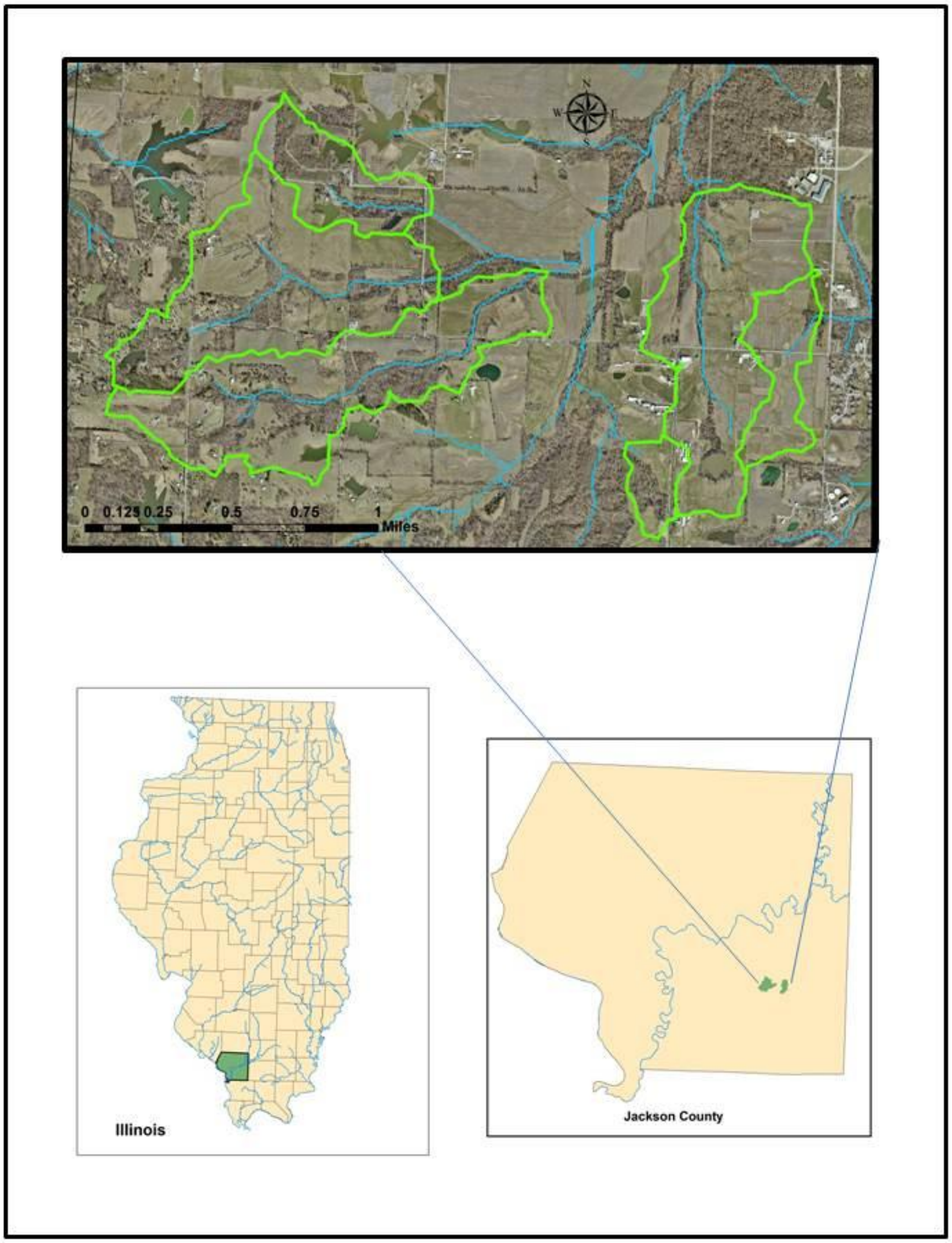

Figure 1 Study reaches and their associated watersheds within Jackson County, IL

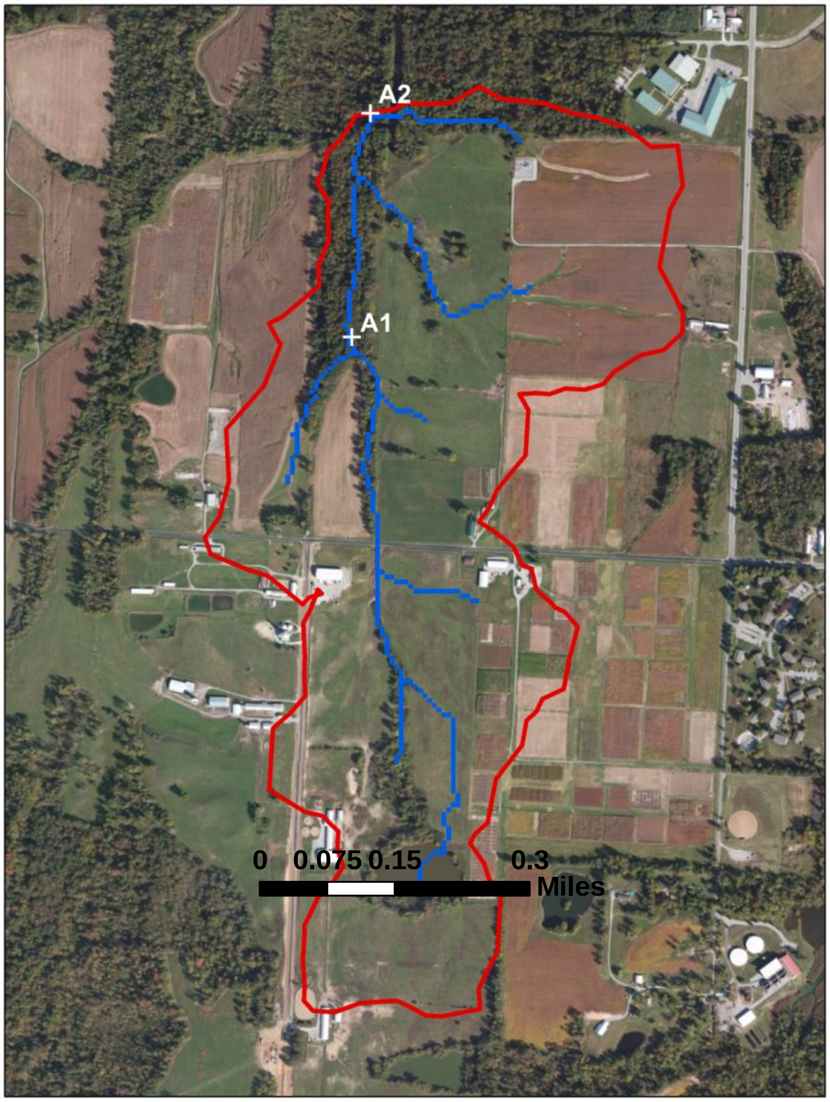

Figure 2 Stream reach locations A1 and A2

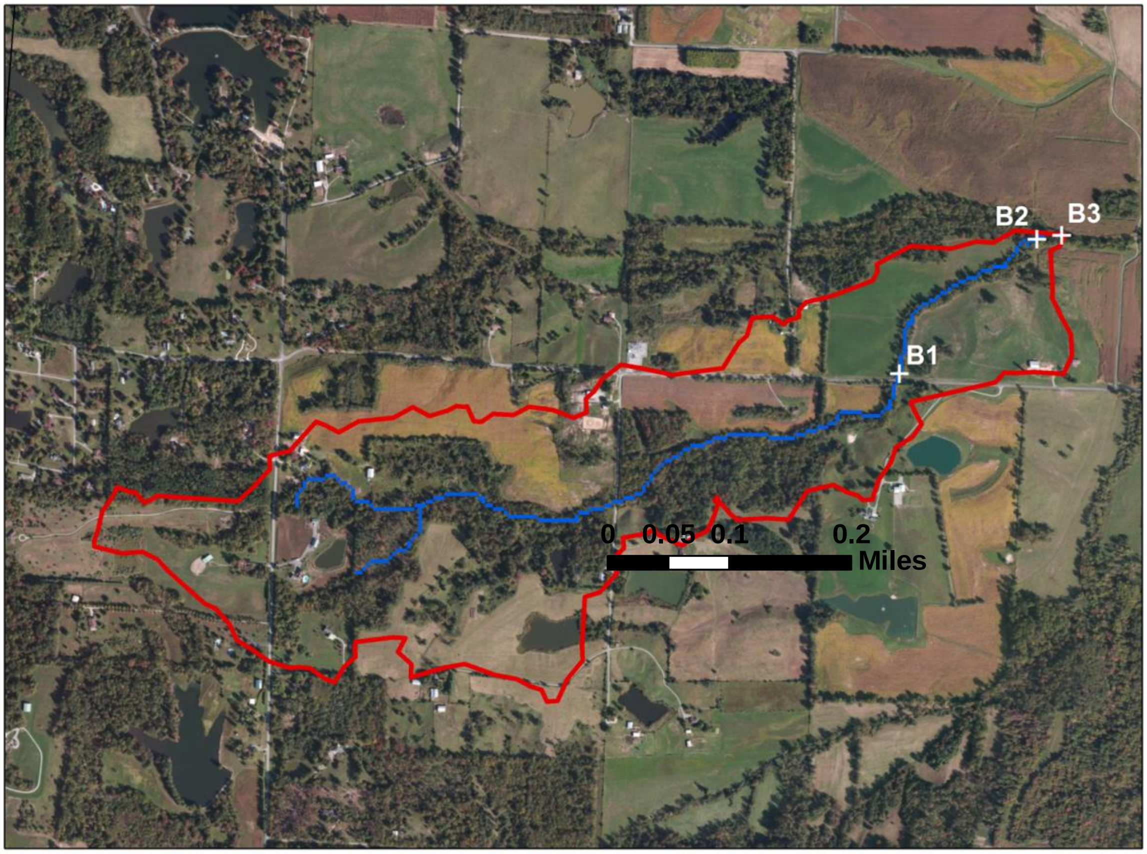

Figure 3 Stream reach locations B1, B2 and B3

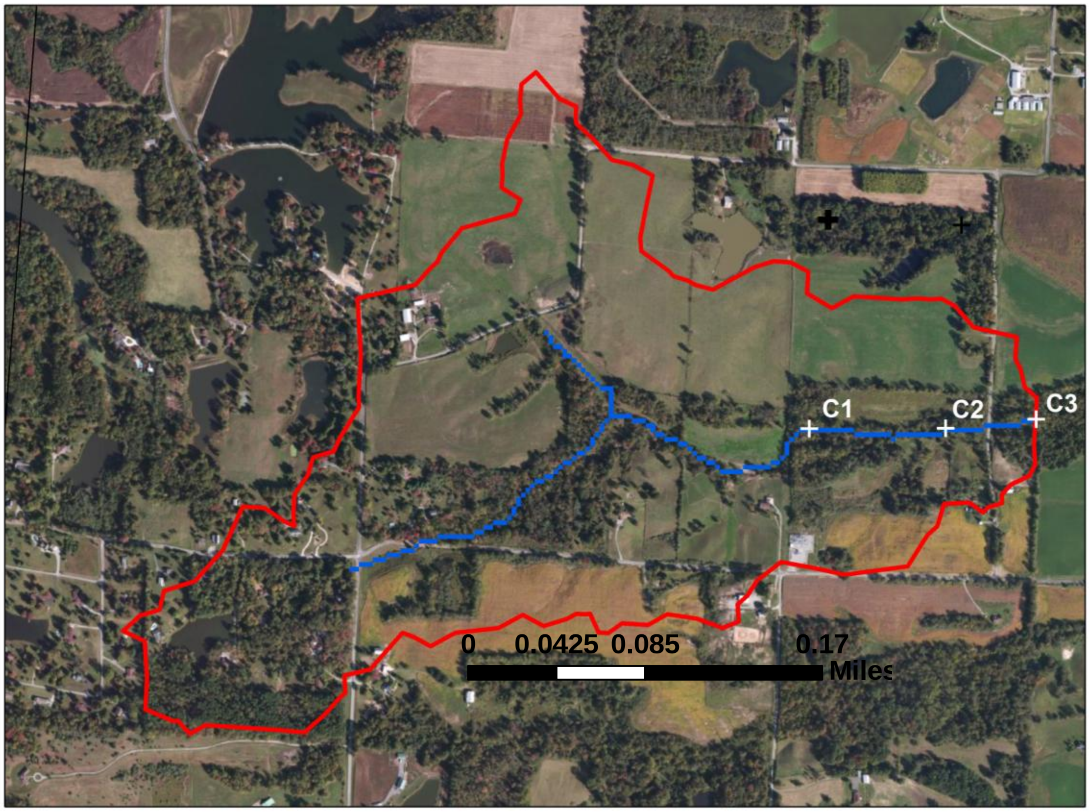

Figure 4 Stream reach locations C1, C2 and C3

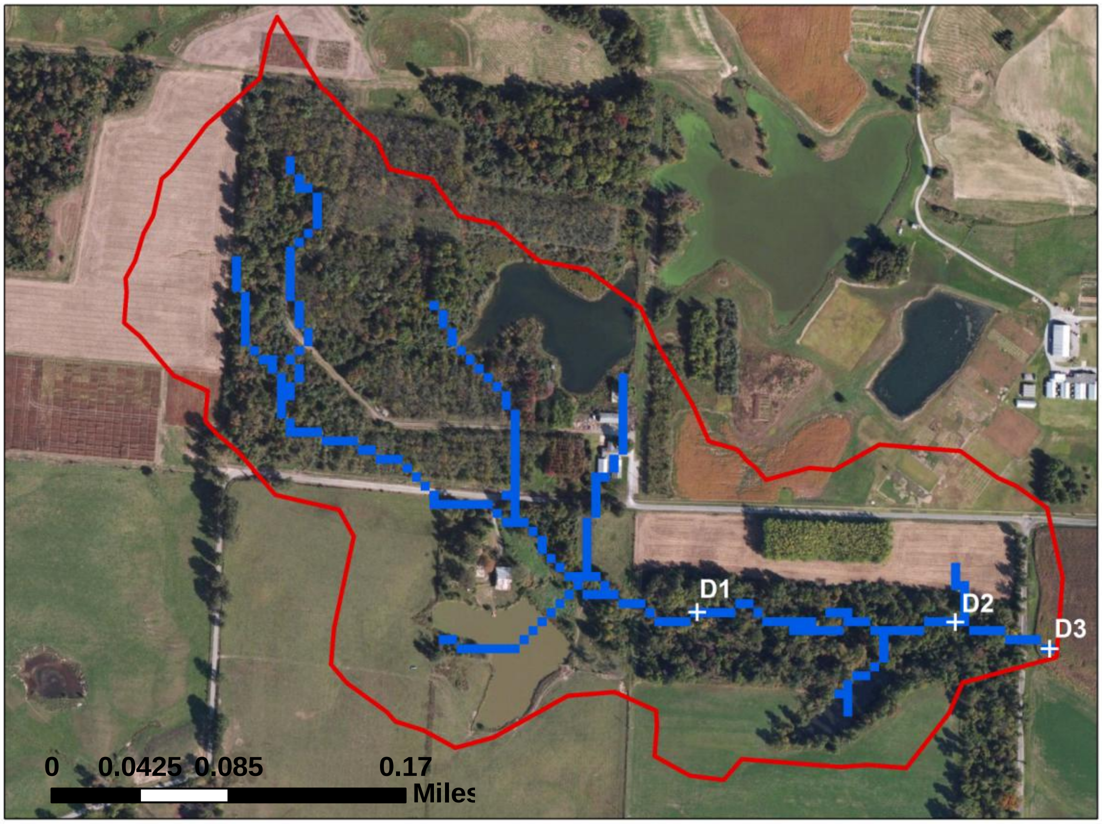

Figure 5 Stream reach locations D1, D2, and D3

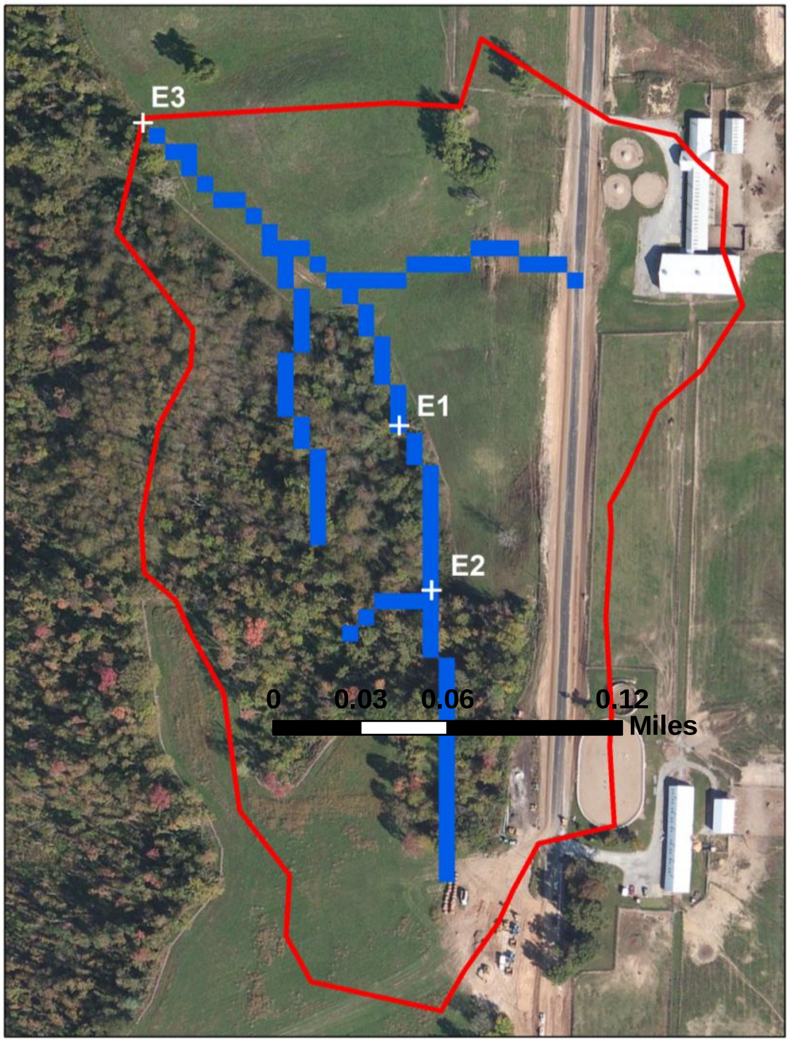

Figure 6 Stream reach locations E1, E2 and E3

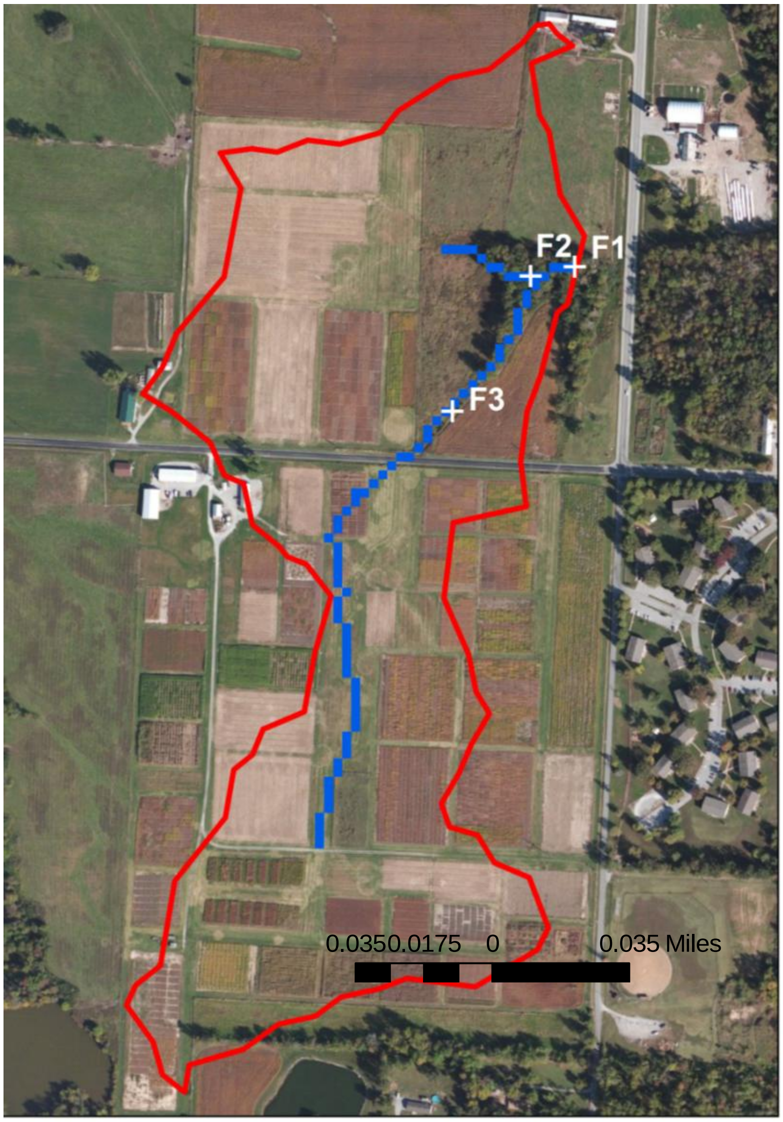

Figure 7 Stream reach locations F1, F2 and F3

2.1.1 Soils

The soils of the stream reaches are silt and clay loams with 0-18% slopes. These soils are well-moderately drained, and the depth to the water table is generally >2.03 m below the surface in the uplands (USDA, 2014). In some of the upper reaches, there is exposed bedrock in the stream channels showing a thin soil profile. In the majority of the investigated study reaches and the lower reaches of these streams with bedrock found in the channel, the stream channels are actively eroding the residual soils, alluvium, or Pleistocene lake clays.

2.1.2 Data Sources Section

Land use data from 1995 were acquired from the Illinois Department of Natural Resources Geospatial Data Clearinghouse (Homer et al. 2004) and the county digital soil data map was obtained from the USDA (2014). Watershed delineation was completed using hydrology tools in ArcGIS 10 (Appendix 1). The 1/3-arc-second digital elevation model (DEM) which is based on the D8 method (O'Callaghan and Mark, 1984) was acquired from USGS National Elevation Database (Gesch, 2007; USGS, 2014) and was in the UTM 1983 coordinate system. Precipitation data for the study period were obtained from NOAA's National Climatic Data Center Climate website (NOAA, 2014) at the Carbondale Airport weather station.

2.1.3 Study Stream Selection

Selecting stream reaches that incorporated each flow permanence class was critical to meet the study objectives. To meet these objectives, land use, watershed and stream mapping, in addition to field reconnaissance, were employed in this study. Digital watershed boundaries and stream delineation were undertaken using ArcGIS employing a 1/3-arc-second (10 m) DEM of Jackson County to determine each streams watershed boundary. The land cover data were masked to each watershed to determine the land use composition.

Streams with watersheds that had >70% agriculture land use on Southern Illinois University farm property where selected for field screening. In these watersheds, drainage basin area was used to determine which specific study reaches were to be evaluated as stream reaches for the demarcation between ephemeral, intermitted, and perianal streams. Site visits were undertaken to each study reach to ensure the physical site characteristics were consistent with the intended stream permanence class to be monitored and classified.

Drainage basin area for the selected study reaches where between 0.93-31.45 acres. Rural grassland and cropland (winter wheat, corn and soybeans) were the dominant agricultural land uses in study basins (Table 2). Most of the stream reaches were affected by channel modifications in the form of culverts, ditches, or impoundments (Table 3). Impoundments in the form of retention basins and farm ponds collect and slow down water from reaching the basin's outlet (Menerey 1999) and affect stream permanence if water is slowly being released; for each stream reach basin the total surface area of impoundments was totaled. Ditches decrease the length of the flow path that precipitation takes to reach the basin outlet. Culverts used primarily for water to flow under roads alter flow path since scour holes directly above or directly below the culvert often form and has the same effect as an impoundment that traps and slowly releases water into the stream (Menery 1999).

Table 2 Study reach watershed area and basin land use composition

Study reach	Watershed area acres	Basin Land Use
A1	16.83	57% rural grassland 41% crops
A2	26.79	1% Surface water 53% rural grassland 46% crops
B1	24.83	55% rural grassland 15% crops 11% upland
B2	31.38	59% rural grassland 16% crops 13% coniferous and upland, 7% Floodplain Forest
B3	31.45	58% rural grassland 17% crops 21% floodplain forest, coniferous, and upland
C1	21.56	61% rural grassland 20% crops 16% Floodplain Forest, Coniferous, and upland
C2	29.7	61% rural grassland 19% crops 15% Floodplain Forest coniferous and upland
C3	31.31	2% Surface water 57% rural grassland 41% crops
D1	7.18	71% rural grassland 14% crops 4% surface water
D2	9.24	65% rural grassland 14% crops 14% surface water floodplain forest and upland
D3	24.5	66% rural grassland 14% crops 14% surface water floodplain forest and upland
E1	1.47	50% rural grassland 30% crops 16% upland
E2	0.93	37% rural grassland 37% crops 21% upland
E3	3.69	59% rural grassland 20% upland 17% crops
F1	7.88	58% rural grassland 42% crops
F2	2.31	60% crops 39% rural grassland
F3	4.93	65% rural grassland 35% crops

Table 3 Stream channel modifications

Stream Channel Modifications				
Stream Reach	Ditched length upstream of sensor	Impoundments affecting stream reach perimeter (m)	Culverts	Notes
A1	682 m	23.87	1	
A2	1214 m	23.87	1	
B1	138	601.2	3	
B2	625.2 m	601.2	3	
B3	633.8 m	601.2	3	
C1	0	538	0	
C2	274.7m	538	0	
C3	416.3m	538	1	
D1	0.0	1101.6	1	
D2	0.0	1101.6	1	
D3	0.0	1400.8	1	23m to culvert
E1	0.0	202.9	1	
E2	0.0	202.9	1	
E3	227.8	202.9	1	
F1	239.3	639.6	1	
F2	239.3	0.0	1	
F3	106.1	0.0	1	61m to culvert

2.2 Flow Permanence Assessment Methods

Each stream reach was evaluated for its flow permanence class (ephemeral, intermittent, or perennial) using three separate methodologies. The approaches employed were the Observation Method (OM), the Direct Measurement Method (DMM) and the Identification Methods for the Origins of Intermittent and Perennial streams (NC method). In this study, the NC method was compared to the OM and the DMM. This study took place a little over a year from January 2013 through March 2014. DMM water sensors where installed and checked on for the entire year, and observations for the OM where taken twice a month for the entire year.

2.2.1 Observation Method (OM)

For this method, each stream reach was visited twice a month in order to record the presence or absence of stream flow. If the stream was found not to be flowing, the presence or absence of pooled water in the stream channel was also noted. Following the stream flow permanence protocols of Fritz et al. (2013) perennial reaches had flowing water during each visit. Intermittent reaches had flowing water during the wet season, but dry or had standing pools during the dry season. Ephemeral reaches were dry or contained standing water year round.

2.2.2 Instrument Methods (DMM)

DMM employed water sensors where continuously monitored for the presence of stream flow using the protocol established by Fritz et al. (2006). Water sensors where installed in the middle of the 30 meter study reach. As defined by Fritz et al. (2013) study reaches were classified as perennial if they had flowing water throughout the year. Study reaches which had dry periods and had a maximum period of flow greater than 29 days were classified as intermittent. A study reach was classified as ephemeral if the maximum period of flow was less than or equal to 29 days.

2.2.3 Methodology for Identification of Intermittent and Perennial Streams and Their Origins version 4.11 (NC Method)

Each study reach was also placed into a flow permanence category using the 26 geomorpholgy, hydrology, and biology indicators employed by the NC method (Table 1). A soil auger, small net, GPS, tape measure, and stadia rod where employed to collect the data to make stream permanence determinations. The date, project site, county, latitude, longitude are indicated on the form. In this study, stream flow permanence determinations were made along a 60 m reach centered on the location of the water sensor (i.e., 30 m above and 30 m below the water sensor) as the representative study reach. Each stream characteristic was then marked as absent, weak, moderate, or strong based on the degree of occurrence of each characteristic using the scoring guide provided in the NC method manual to determine scores for each individual characteristic score (Table 1). After NC method characteristics were scored, they were added up and the study reach was placed into a flow permanence category: ephemeral if less than 19, intermittent if greater than or equal to 19, perennial if greater than or equal to 30 (North Carolina Division of Water Quality, 2010).

Table 4 Guide to scoring categories for the NC method

Category	Description
Absent	The character is not observed
Weak	The character is present but you have to search intensely (i.e., ten or more minutes) to find
Moderate	The character is present and observable with mild (i.e., one or two minutes) searching
Strong	The character is easily observable

2.3 Data Analysis

2.3.1 Permanence Class Analysis

Two analyses were performed to determine the accuracy of the DDM and NC method stream permanence classification. The first analysis was a direct comparison of each method's flow permanence class prediction. For the second analysis intermittent and perennial where combined to assess if the DDM and NC method categorized each study reach accurately between perennial and non-perennial. The purpose of this second analysis was to assess the accuracy of using the DDM and NC method for regulatory determinations under sections 401 and 404 of the CWA.

2.3.2 Principal Component Analysis

SPSS statistical software (v22) was used to perform a Principle Component Analysis (PCA). PCA is useful to test redundancy between variables in a data sets; in this case redundancy means that some of the variables are correlated with one another, possibly because they are measuring the same construct (here, same stream characteristic O'Rourke and Hatcher, 2013). PCA reduces a data set with a large amount of variables into a new data set containing fewer new variables when redundancy occurs (Wilks, 2006). The new variables are linear combinations of the original ones, and are chosen to represent the maximum possible fraction of the variability contained in the original data (Wilks, 2006).

Each characteristic on the NC method form was placed into an Excel spreadsheet table along with its score for each score obtained. The factor analyses were selected from the dimension reduction analyses. Each variable was placed into a Factor Analysis dialogue box, and in the Factor Analysis: Descriptives box the initial solution, coefficients, reproduced, anti-image, and KMO and Barlett's test of sphericity where selected. In The Factor Analysis: Extraction box the correlation matrix, un-rotated factor solution, scree plot, based on eigenvalue >1 options where all selected, and the maximum iterations for convergence where set to 25. In the Factor Analysis: Factor Score the save as variables and regression options where selected. The Factor Analysis: Options box was selected and the option to exclude cases. Listwise was checked along with Sorted by size and Suppress small coefficients and the Factor Analysis: Options box absolute value was set to .3.

2.3.3 Regression Models for the Assessment of Stream Permanence

SPSS statistical software (v22) was used to develop linear- regression and multiple-linear regression models to predict stream-flow permanence using the NC method score. Multiple-linear regression is useful to determine the correlation between several independent variables with a single dependant variable. In this case the independent variables were watershed area, upslope grass, upslope surface-water area, bankfull width, row-crops, average-accumulative slope and upstream ditched length. The independent variables watershed area, upslope grass, upslope surface-water area, row-crops, average-accumulative slope and upstream ditched length where derived using land use and DEM layers in combination with ArcGIS described in section 2.1.3. The Independent variable bankfull depth was measured at each stream reach in the field. Each characteristic was placed into a table with its associated value, and that table was used in SPSS using the multiple-regression analysis tool. The basic command regression followed by linear allow you to enter as many characteristics as desired. From there the descriptive box is checked in order to acquire all of the necessary read-outs to analyze the models accuracy including the R square, adjusted R square, standard deviation and significance.

CHAPTER 3

RESULTS

3.1 Assessment of Precipitation during Study Period

Precipitation during the study period was analyzed to determine if the stream permanence data collected was significantly different than average years. Comparison of monthly precipitation within the study period condition with NWS average monthly precipitation data from Southern Illinois Airport (i.e., NWS 2014) revealed above normal precipitation was observed four out of twelve months, below normal five out of twelve months and about normal three out of twelve months. In 2013 March, April, May, June, July, October, November and December were all above normal precipitation amounts. Below normal precipitation amounts were recorded for August and September in 2013 and January, February and March in 2014. However, the annual total precipitation for March 2013 through March 2014 was near normal (Figure 8) (NOAA 2014).

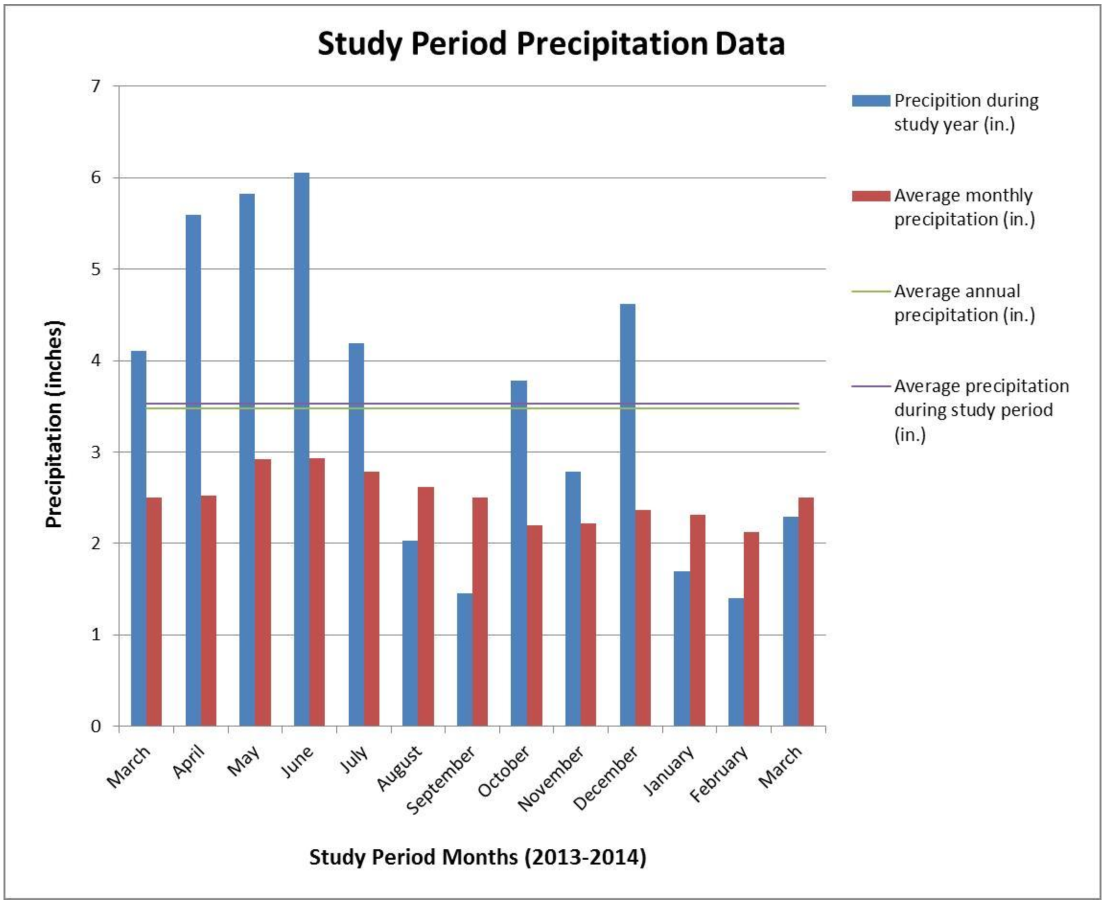

Figure 8 Precipitation Data for the study period (Base Period: 1901-2000)

3.2 Stream Permanence Assessment Results

The OM compared to the DMM had three instances where flow permanence classes did not agree. In all three cases the DMM labeled the stream intermittent where the OM labeled the stream as perennial. The OM was used as the standard reference in further analysis because the DMM was often found to be recording inaccurate data; sensors sometimes would be full of sediment, sometimes the stream would shift and the sensor would be logging dry when there actually was flow in the channel, and sometimes the sensors where tampered with by animals.

Table 5 The OM compared to the DMM in discriminating flow permanence class

Direct Measurement Method	Observation Method	Agree/disagree
Intermittent	Intermittent	Agree
Intermittent	Perennial	Disagree
Intermittent	Intermittent	Agree
Intermittent	Intermittent	Agree
Intermittent	Perennial	Disagree
N/A	Intermittent	N/A
N/A	Intermittent	N/A
Intermittent	Perennial	Disagree
Intermittent	Intermittent	Agree
N/A	Ephemeral	N/A
Perennial	Perennial	Agree
Ephemeral	ephemeral	Agree
Ephemeral	ephemeral	Agree
Intermittent	Intermittent	Agree
Intermittent	Intermittent	Agree
Ephemeral	Ephemeral	Agree
Intermittent	Intermittent	Agree
	Percent Disagreement	21
	Percent agreement	79

The standard reference for the NC method was the OM. There was 82% agreement between the OM and the NC method flow permanence class determinations. There were three cases of disagreement, twice the NC method categorized the stream as intermittent when the stream was determined by the OM to be perennial and in one case the NC method categorized the stream as perennial when the stream was determined by the OM to be intermittent (Table 6). When comparing the OM to the NC score to distinguishing between intermittent and perennial study reaches from ephemeral reaches there was no disagreement.

Table 6 NC method compared to the OM in distinguishing ephemeral, intermittent, and perennial

Study reach	NC method Score	NC method Flow Permanence Class	OM Permanence Class	Distinguish Ephemeral, Intermittent, and Perennial
A1	22.0	Intermittent	Intermittent	Agree
A2	36.5	Perennial	Perennial	Agree
B1	28.0	Intermittent	Intermittent	Agree
B2	29.0	Intermittent	Intermittent	Agree
B3	37.0	Perennial	Perennial	Agree
C1	29.5	Intermittent	Intermittent	Agree
C2	30.0	Perennial	Intermittent	Disagree
C3	36.5	Perennial	Perennial	Agree
D1	24.7	Intermittent	Intermittent	Agree
D2	18.0	Ephemeral	Ephemeral	Agree
D3	25.0	Intermittent	Perennial	Disagree
E1	17.5	Ephemeral	Ephemeral	Agree
E2	17.5	Ephemeral	Ephemeral	Agree
E3	22.5	Intermittent	Intermittent	Agree
F1	31.5	Perennial	Intermittent	Disagree
F2	18.0	Ephemeral	Ephemeral	Agree
F3	25.0	Intermittent	Intermittent	Agree
		Percent Disagreement		**18%**
		Percent Agreement		**82%**

Comparing the NC method to the DDM revealed disagreement 29% of the time (Table 7). There were three instances where the NC method overestimated the study reaches' flow permanence class and classified it as perennial instead of intermittent. There was one case were the NC method underestimated the flow permanence class and classified the reach as intermittent instead of perennial. When comparing the NC method to the DDM distinguishing ephemeral from intermittent and perennial there was no disagreement.

Table 7 NC method compared to the DDM in distinguishing ephemeral, intermittent and perennial.

Study reach	NC Method Score	NC method Flow Permanence Class	Direct Measure flow Class	Distinguish Ephemeral, Intermittent, and Perennial
A1	22	Intermittent	Intermittent	Agree
A2	36.5	Perennial	Intermittent	Disagree
B1	28	Intermittent	Intermittent	Agree
B2	29	Intermittent	Intermittent	Agree
B3	37	Perennial	Perennial	Agree
C1	29.5	Intermittent	N/A	N/A
C2	30	Perennial	N/A	N/A
C3	36.5	Perennial	Intermittent	Disagree
D1	24.75	Intermittent	Intermittent	Agree
D2	18	Ephemeral	N/A	N/A
D3	25	Intermittent	Perennial	Disagree
E1	17.5	Ephemeral	Ephemeral	Agree
E2	17.5	Ephemeral	Ephemeral	Agree
E3	22.5	Intermittent	Intermittent	Agree
F1	31.5	Perennial	Intermittent	Disagree
F2	18	Ephemeral	Ephemeral	Agree
F3	25	Intermittent	Intermittent	Agree
			Percent disagreement:	29%
			Percent agreement	71%

3.3 Comparison of Physical Stream Parameters as Predictors for Stream Permanence

The linear-regression models were developed to assess physical stream characteristics as predictors of flow permanence. Previous studies have found that bankfull width, watershed area and bankfull depth have significant and strong correlation with flow permanence (Fritz et al. 2008, Fritz et al. 2013). The NC method score, and the DMM percent time flowing where the dependent variables and bankfull width and watershed area where the independent variables.

Analysis shows that with 95% confidence levels watershed area has a significant positive linear correlation with the DMM percent flow with p-value .024 and accounts for 34% of the variance (R^2 0.34) in the NC scores. Watershed area has a strong positive linear correlation with the NC method scores with a p-value of 1.83E-4 and explained 62% of the variance (R^2 0.62). Bankfull width also had a strong positive linear correlation with the NC score and explained 65% of the variance (R^2 0.65). Bankfull Depth had a significant linear correlation with the NC method scores and explained 29% of the variance (R^2 0.29); Table 3.3.1).

Table 8 Linear correlation between watershed parameters watershed area (WA), Bankfull width (BW) and the NC score (NC), and Direct Measurement Method (DMM). Significant correlations are in bold.

	WA vs. DM	BW vs DMM	BD vs DMM	WA vs. NC Score	BW vs. NC Score	BD vs. NC Score
R2 Value	0.34	0.26	0.02	0.62	0.65	0.29
P-value	0.02	0.06	0.67	1.83E-4	9.1E-05	0.02
Significance	0.03	0.06	0.67	1.83E-4	9.12E-05	0.02

3.4 Principal Component Analysis on the NC Method Flow Characteristics

Principle Component Analysis (PCA) was performed to test the redundancy between the individual flow characteristics on the NC method forms (Table 10). Strong relationships between characteristics would suggest a redundancy within the NC form at these particular stream reaches. To determine how many components where significant the Scree Plot Method was used analyzing the eigenvalues against the Principle Components; any components below the elbow of the plot are considered to be insignificant (table 9).

Components with correlations less than 0.3 were considered weak, components between 0.3-0.5 were considered acceptable and anything above 0.5 was considered strong. The first principle component has four characteristics that acceptably correlated with each component: continuity channel bed and bank active/relict floodplain, depositional bars or benches, and recent alluvial deposits; each of those characteristics where all geomorphology characteristics. Principle Component two has three characteristics that trend positively together and one characteristic that trends negatively. Base flow, macrobenthos, and leaf litter all trend positively with each other, and sinuosity varies negatively with the other characteristics. Macrobenthos was the only strong characteristic in principle component two and the rest where acceptable.

Table 9 PCA Analyses: Scree Plot, Eigenvalues plotted against the principle Components

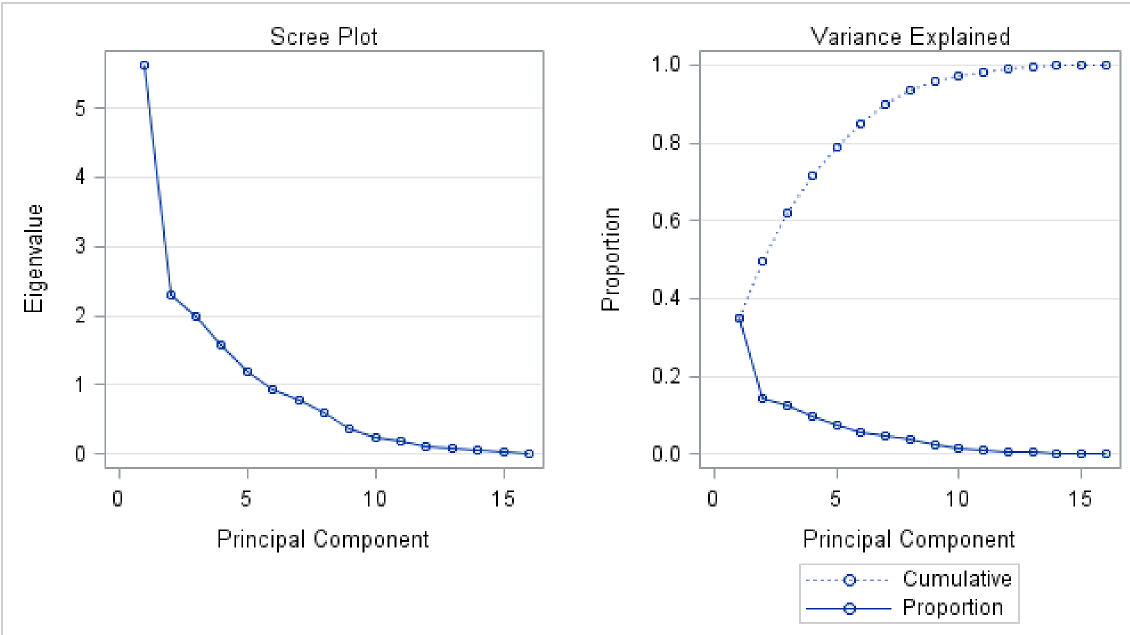

Table 10 PCA Analyses: Eigenvalues of the Ivenvector Principle Component Analysis

	Principle component 1	Principle component 2
continuity of channel bed and bank	**0.31**	0.04
sinuosity	0.15	**-0.47**
in-channel structure	0.30	-0.22
particle size of stream stubstrate	0.28	-0.16
active/relict floodplain	**0.37**	-0.19
depositional bars or benches	**0.35**	-0.02
recent alluvial deposits	**0.33**	0.03
natural valley	0.02	-0.26
base flow	0.25	**0.31**
leaf litter	0.24	**0.37**
sediment on plants or debris	0.29	-0.07
organic debris lines or piles	0.20	0.03
fibrous roots in streambed	0.15	-0.01
rooted upland plants in streambed	0.24	0.03
macrobenthos	0.09	**0.53**
algae	0.13	0.28

3.5 Regression models for the prediction of stream-flow permanence

Several linear- and multiple- linear regression models where created to assess which stream characteristics best explained the variance in stream-flow permanence. The two models with the best explanatory power were a linear regression model using just watershed area and a multiple-linear-regression model comprised of bankfull width, upslope surface water area and upslope grassland. The watershed area linear regression model explained 61%

of the variance in stream-flow permanence (Table 11). The multiple-linear-regression model comprised of bankfull width, upslope surface water area, and upslope grassland area explained 69% of the variance in the NC method stream permanence score.   The other models assessed had lower predictive powers, and where most were found to be not significant at the 95% confidence interval (Appendix D).

Table 11 models predicting flow permanence 1. Watershed area and 2. Bankfull Width), Upslope surface water area, upslope grassland

Model	Adjusted R-Square	Significance
Watershed Area	0.612	0.001
Bankfull Width, Upslope Surface Water Area and Upslope Grassland Area	0.697	0.001

CHAPTER 4

DISCUSSION

Headwater streams make up a majority of watershed networks, but are often poorly delineated and classified on topographical maps and in geospatial datasets used in environmental decision making. Due to the poor delineation and classification, headwater streams are often neglected in environmental policies and decision making (Fritz 2013, Lowe and Likens 2005; Lassaletta et al. 2010; Taylor et al. 2011). Currently in Illinois, practitioners of the CWA use the National Hydrography Dataset (NHD) and USGS topographical maps to make 401 and 404 permit determinations (ILDNR 2014). NHD and USGS maps often underestimate stream length and subsequently flow permanence (Drummond 1974; Gardner and Archfield 2002).

There is a need for more accurate methods for determining flow permanence, particularly in agricultural watersheds. Flow permanence determination methods have been developed for forested watersheds in several states including Oregon, Kentucky and North Carolina. Fritz et al. (2013) and Fritz et al. (2008) have developed and tested a robust methodology for forested watersheds in North Carolina and South Carolina. In this study, we employed the NC method to evaluate stream permanence in Southern Illinois watersheds where agriculture is the dominate land use. Agriculture alters the land and ultimately affects the way water moves through it. There are currently no rapid assessment protocols in Illinois and it is hoped this study is a useful step in developing a rapid protocol for agricultural streams in Illinois.

In this study, the NC method was compared with the OM study reach and the DMM. These comparisons revealed NC method and OM agreed 83% and DDM and OM agreed 72% of the time. The reasons why the OM was used as the reference for stream permanence instead of the DMM are as follows. In a few incidents, water sensors where found to be recording stream flow inaccurately; scouring occurred around the water sensor and it was not recording the presence of stream flow when it was present. In addition, the water sensors would often be disturbed or washed away during heavy precipitation events. Some sensors were damaged by animals or humans. This study supports findings in previous studies that the NC method can distinguish ephemeral from intermittent and perennial streams (i.e., Fritz et al. 2008 and Fritz et al. 2013). As in previous studies the NC method is not consistent in differentiating between intermittent and perennial study reaches (Fritz et al. 2008 and Fritz et al. 2013). In two of the cases that the NC method did not accurately differentiate between intermittent and perennial the scores where 30 and 31.5 which is right on the threshold of being in the intermittent or perennial, and one case the score was 5 points from being in the correct category.

There were many sites affected by culverts, drainage ditches, and impoundments (Table 2.2). At stream reach D3 there was a culvert with a scour hole directly below it that would impound water and slowly release water producing more flow in the channel than what would otherwise occur; in cases where there where culverts farther away from the stream reach there were no observed impacts; the NC method categorized D3 as intermittent instead of perennial. At stream reach F1 there is a low lying retention area directly downstream that would often fill with water after precipitation events and retain the water for a significant amount of time. It is hypothesized that this water would raise the height of the local water table which produced more perennial flow than what would normally be there; The NC method categorized F1 as Perennial instead of Intermittent. Stream reach C2 is in an area that is ditched and has a low lying retention area relatively close upstream of it. The NC form categorized C2 as perennial instead of intermittent.

When analyzing flow characteristics on the NC method form using PCA analyses suggested there were no significant correlations between characteristics at these particular stream reaches. Based on the results from this study, there would not be any recommended changes to stream characteristics and associated weights on the NC method form. However, the results of the PCA analyses suggested showed that there were some minor redundancies between…, but were all >0.5 which is considered relatively insignificant. It is important to point out here there were only 17 stream reaches assessed in this study, which is relatively small sample size. The small sample size could be responsible for the lack of significance in the PCA analysis performed here.

Watershed area and bankfull width have been used in several studies as a surrogate of flow permanence, and has been recommended in past studies that it be included on assessment protocols (Fritz et al. 2013). This study also supports the findings in Fritz et. al 2013 that watershed area and bankfull width could benefit the NC method and possibly make it more robust. Watershed area and bankfull depth were found to be very helpful in pre-screening study reaches as a rough estimator of flow permanence.

Several linear- and multiple- linear regression models where created in this study to assess which stream characteristics best explained the variance in stream-flow permanence. Only two of the models had a substantial amount of explanatory power and were statistical significant at the 95% confidence interval. The two models were a linear regression model using watershed area as the predictor of stream permanence and a multiple-linear-regression model comprised of bankfull width, upslope surface water area and upslope grassland as the predictor of stream permanence. These models explained 61% and 69% of the variance in the NC method stream-permanence score, respectively. While these regression models are not capable of explicitly modeling stream-permanence a NC score for a given location with a high degree of accuracy, they are useful for guiding stream- permanence study-site selection.

Currently in Illinois there are no rapid assessment protocols for the region, and future research is needed to develop stream permanence determination protocol in Illinois. Stream reach D3 was located 23 m from a culvert with a large scour hole that slowly released water into the stream which resulted in perennial flow. In cases where culverts where farther upstream from stream reaches the slowly released flow did not affect stream reach permanence. More research is needed to determine the distance from a culvert that assessment protocols are still accurate.

There are several variables including drainage tile, buffers, and physiographic provinces that need long term monitoring in order to understand how they affect flow permanence and if the NC method forms need to be adjusted. Corrugated drain tile is becoming more popular in agriculture and drains surface water quickly off the field and into the nearest stream; there were no drain tiles in the basins in this study. There is a need for more long-term monitoring on how drain tiles affect flow permanence in order to develop a rapid assessment form Illinois.

CHAPTER 5

CONCLUSION

The NC method was successful in distinguishing ephemeral streams from intermittent and perennial streams. However, the NC method had a slightly lower fidelity for the demarcation of ephemeral and intermittent study reach. The results of this study suggest the NC method would be useful for determining which streams should be protected under the CWA in Southern Illinois agricultural basins.

Drainage area and bankfull width were two parameters that are not included in the NC method but determined to have a significant positive correlation with a streams' flow permanence classes in the Southern Illinois agricultural watersheds studied here. These parameters could be used to enhance the predicative capability of NC method for similar watersheds. In addition, theses data could be used to prescreen stream reaches for the selection of stream permanence stream reaches. Another finding from this study was the inaccuracy of the DMM; the data loggers/water sensors where often found recording inaccurate data during site visits due to shifts in sediment, clogged sensors, and tampering from animals and determined to be inefficient.

Linear- and multiple- linear regression models where employed to model NC method stream scores and stream-flow permanence. Only two of the models developed had a substantial amount of explanatory power and were statistical significant at the 95% confidence interval. The two models were a linear regression model using watershed area as the predictor of stream permanence and a multiple-linear-regression model comprised of bankfull width, upslope surface water area and upslope grassland as the predictor of stream permanence. These models explained 61% and 69% of the variance in the NC method stream-permanence score, respectively. With their limited explanatory power, these regression models are not capable of reproducing the accuracy of field based stream permanence determination methods assessed here. However, these regression models would be useful for guiding stream- permanence study-site selection.

This study was the first to test the NC method in agricultural basins. In 2010, 27-million acres or 75% of the total land area of Illinois was agriculture (Illinois Department of Agriculture, 2014). If this form were to be considered for regulatory use in Illinois it would be recommended that it be tested in more agricultural headwaters stream reaches in central and northern Illinois which differ slightly in physical settings then the streams assessed here. For example, provinces in northern and central Illinois were affected by the most recent glaciation (Wisconsin Glacial Period; ~25,000 to ~12,000 years before present) and have more widely varying layers of glacial, glaciofluvial and aeolian deposits resulting in different soil types and characteristics. Different soil types have different infiltration and surface storage properties which alter the hydrologic properties of the soil (Leonard and Andrieux, 1998; Van Dijck, 2000) affecting stream permanence and consequently the accuracy of the NC method. In addition, most of the stream reaches in this study had vegetated buffers. In future studies, stream buffers need to be more rigorously evaluated for their importance for flow permanence. Additional direct long-term monitoring would also be beneficial in determining the weights of each stream characteristic.

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APPENDICES

Appendix A

ArcGIS 10 hydrology tools

To calculate the drainage area of each water sensor the 10 meter DEM was downloaded from the Illinois GIS data Clearing House.
Fill (fills any holes in the DEM)>Flowdirection>Flow length (adjust the classification to fit field observations)>Flow accumulation
A new shapefile was created in ArcCatalog to add a point where the sensor was located. The shapefile was added and edited to create a point in combination with the coordinates tool where each water sensor was located.
Watershed tool (flow direction layer, new pour point layer) provides all cells flowing to the pour point (drainage area).
The attribute has a total count of 10mx10m units are flowing to the sensor which m^2 is then converted to acres.

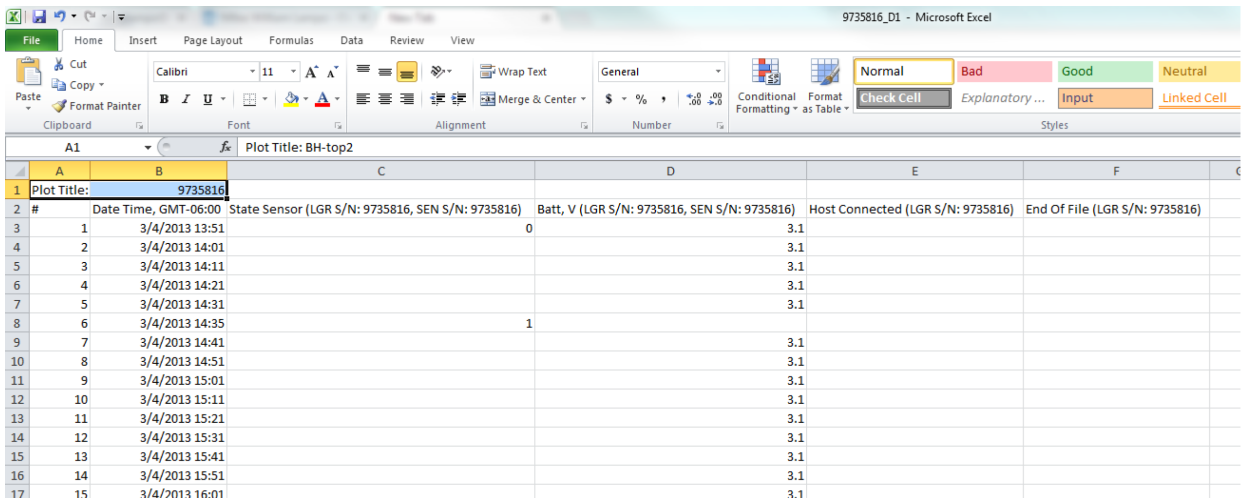
Land Use

The land use layer was downloaded from the USGS database. To identify the land use of each water sensor the land use layer was masked to each sites drainage basin, and then the percent of each land use category was calculated based on 10x10 meter area.

Appendix B

Water Sensor Data

In the state sensor column 1's are considered periods where the stream was wet and 0's were dry periods. In the Date Time column the time indicated how long the sensor was logging each state (wet or dry).

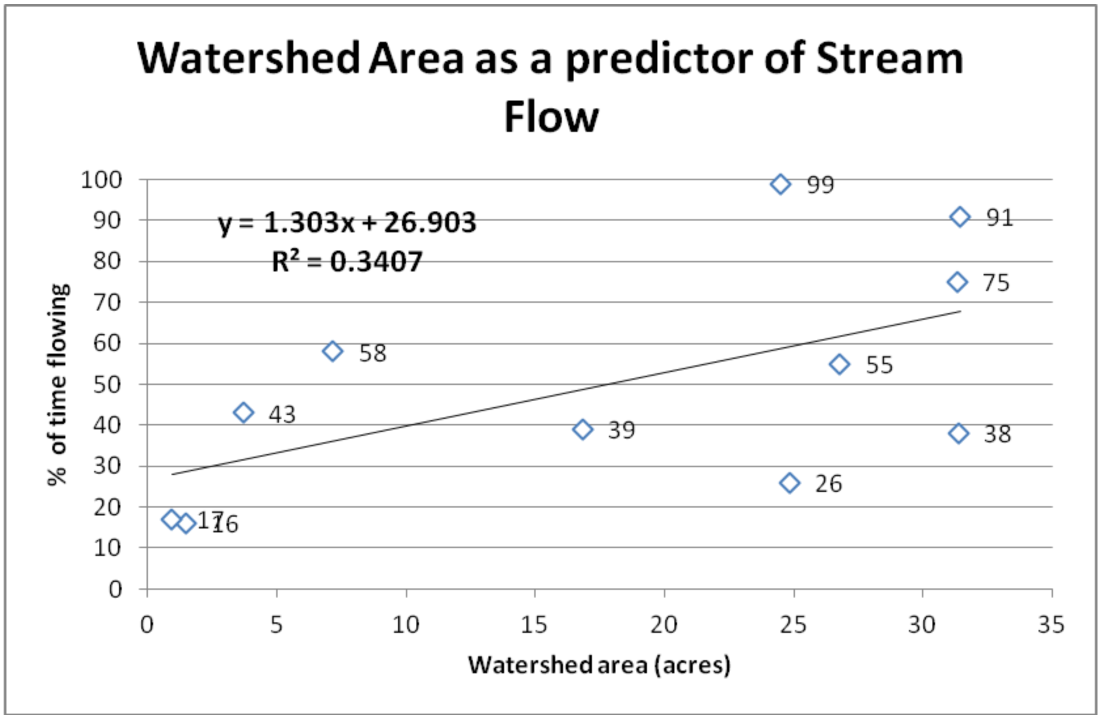


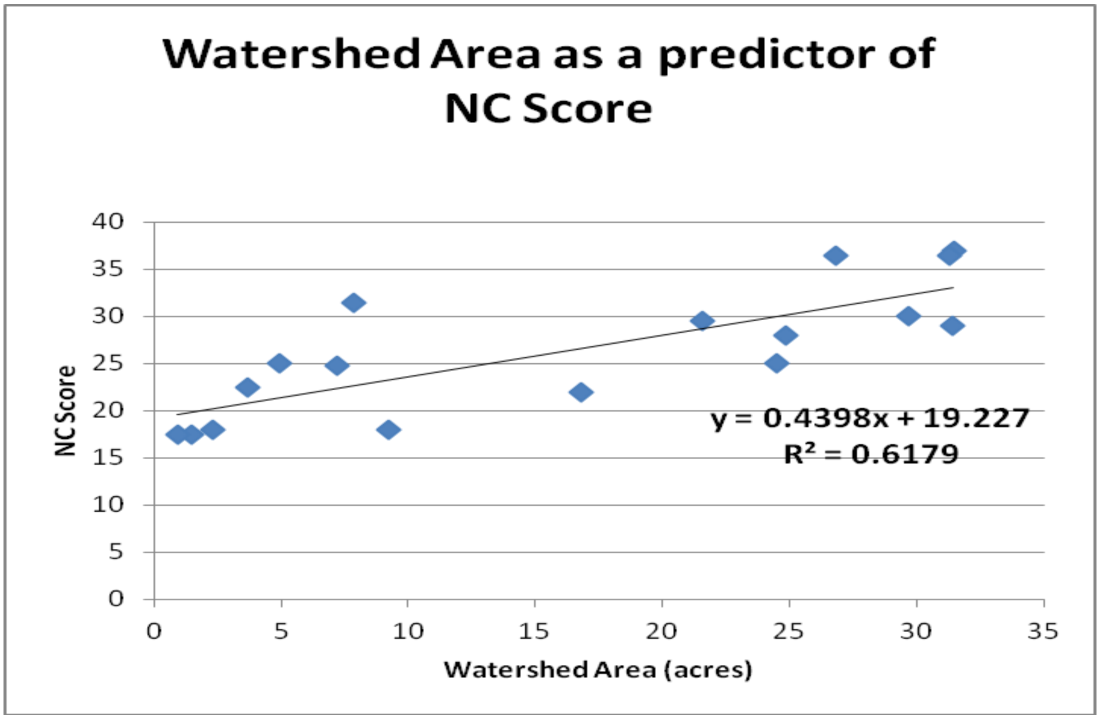
	A	B	C	D	E	F
1	Plot Title:	9735816				
2	#	Date Time, GMT-06:00	State Sensor (LGR S/N: 9735816, SEN S/N: 9735816)	Batt, V (LGR S/N: 9735816, SEN S/N: 9735816)	Host Connected (LGR S/N: 9735816)	End Of File (LGR S/N: 9735816)
3	1	3/4/2013 13:51	0	3.1		
4	2	3/4/2013 14:01		3.1		
5	3	3/4/2013 14:11		3.1		
6	4	3/4/2013 14:21		3.1		
7	5	3/4/2013 14:31		3.1		
8	6	3/4/2013 14:35	1			
9	7	3/4/2013 14:41		3.1		
10	8	3/4/2013 14:51		3.1		
11	9	3/4/2013 15:01		3.1		
12	10	3/4/2013 15:11		3.1		
13	11	3/4/2013 15:21		3.1		
14	12	3/4/2013 15:31		3.1		
15	13	3/4/2013 15:41		3.1		
16	14	3/4/2013 15:51		3.1		
17	15	3/4/2013 16:01		3.1		

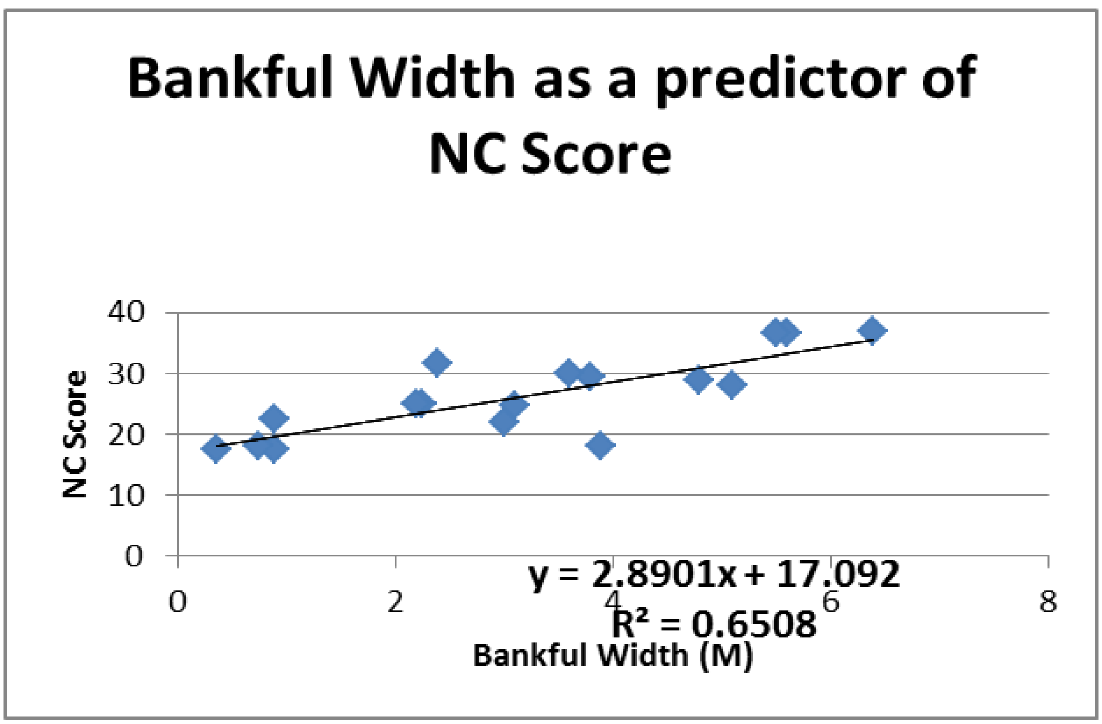
To convert that data into days:
Delete row one, then Ctrl A>data tab>filter button>state sensor (drop down) uncheck blanks
Copy data to a new page "paste values"
In D2 =(B1-B2)*24, apply to entire column
Copy all data, paste "values only" to new sheet
Delete last line
Total days=sum (D:D)
Total Dry Days=Sumif (C:C,0,D:D)
Total Wet days=Sumif(C:C,1,D:D)

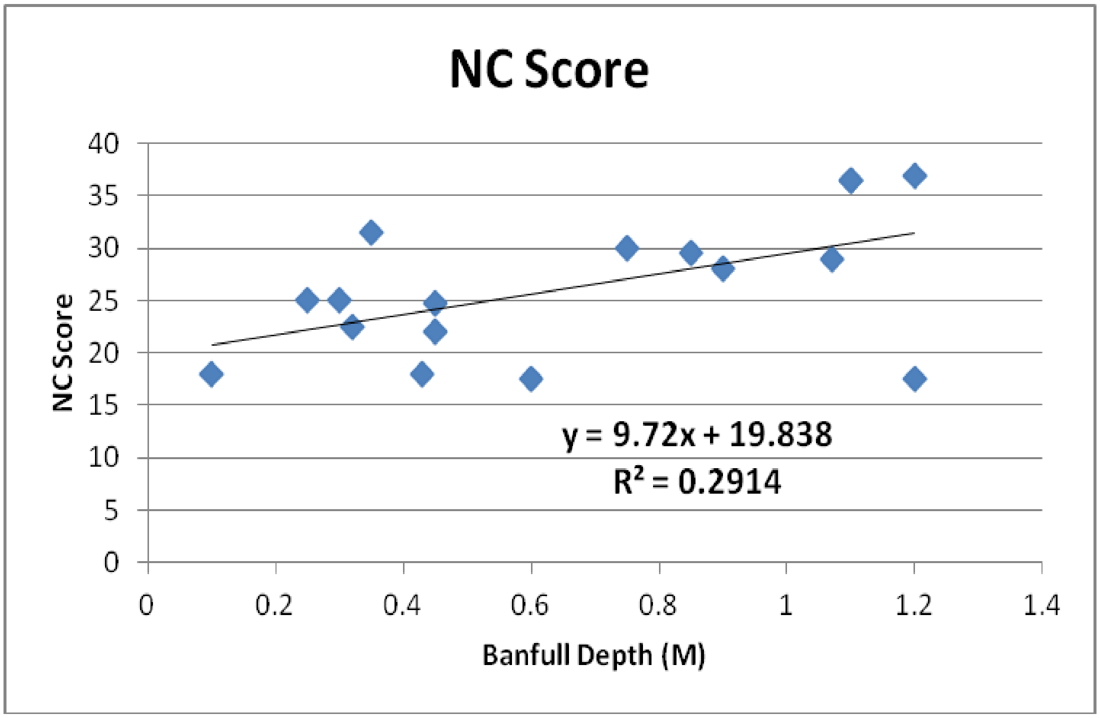
Appendix C

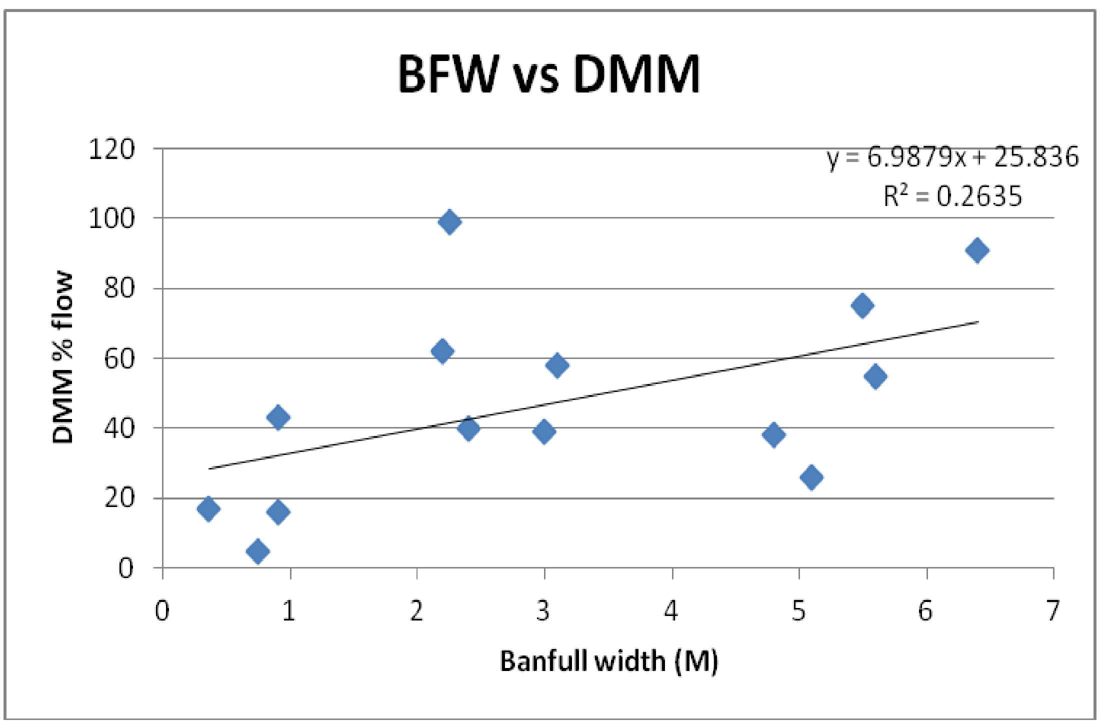
Correlation analyses




Watershed Area as a predictor of NC Score
NC Score
Watershed Area (acres)
y = 0.4398x + 19.227
R² = 0.6179
0
5
10
15
20
25
30
35
40


Bankful Width as a predictor of NC Score
NC Score
Bankful Width (M)
y = 2.8901x + 17.092
R² = 0.6508
0
10
20
30
40
2
4
6
8


NC Score
40
35
30
25
20
15
10
5
0
NC Score
y = 9.72x + 19.838
R² = 0.2914
0
0.2
0.4
0.6
0.8
1
1.2
1.4
Banfull Depth (M)


BFW vs DMM
120
100
80
60
40
20
0
DMM % flow
y = 6.9879x + 25.836
R² = 0.2635
0
1
2
3
4
5
6
7
Banfull width (M)

Appendix D

NC DWQ Stream Identification Form Version 4.11

Date:	Project/Site: A1	Latitude:
Evaluator:	County:	Longitude:
Total Points: *Stream is at least intermittent if ≥ 19 or perennial if ≥ 30** 22	Stream Determination (circle one) Ephemeral Intermittent Perennial	Other *e.g. Quad Name:*

A. Geomorphology (Subtotal = 7)	Absent	Weak	Moderate	Strong
1[a]. Continuity of channel bed and bank	0	1	2	3
2. Sinuosity of channel along thalweg	0	1	2	3
3. In-channel structure: ex. riffle-pool, step-pool, ripple-pool sequence	0	1	2	3
4. Particle size of stream substrate	0	1	2	3
5. Active/relict floodplain	0	1	2	3
6. Depositional bars or benches	0	1	2	3
ch 7. Recent alluvial deposits	3	[illegible]	2	3
8. Headcuts	0	1	2	3
9. Grade control	0	0.5	1	1.5
10. Natural valley	0	0.5	1	1.5
11. Second or greater order channel	No = 0		Yes = 3	

[a] artificial ditches are not rated; see discussions in manual

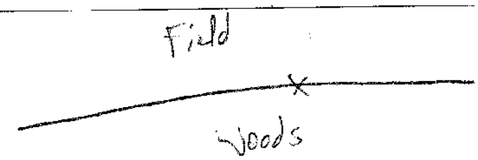
B. Hydrology (Subtotal = 7)	Absent	Weak	Moderate	Strong
12. Presence of Baseflow	0	1	2	3
13. Iron oxidizing bacteria	0	1	2	3
14. Leaf litter	1.5	1	0.5	0
15. Sediment on plants or debris	0	0.5	1	1.5
16. Organic debris lines or piles	0	0.5	1	1.5
17. Soil-based evidence of high water table?	No = 0		Yes = 3	

C. Biology (Subtotal = 6)	Absent	Weak	Moderate	Strong
18. Fibrous roots in streambed	3	2	1	0
19. Rooted upland plants in streambed	3	2	1	0
20. Macrobenthos (note diversity and abundance)	0	1	2	3
21. Aquatic Mollusks	0	1	2	3
22. Fish	0	0.5	1	1.5
23. Crayfish	0	0.5	1	1.5
24. Amphibians	0	0.5	1	1.5
25. Algae	0	0.5	1	1.5
26. Wetland plants in streambed	FACW = 0.75; OBL = 1.5 Other = 0			

*perennial streams may also be identified using other methods. See p. 35 of manual.

Notes: Ditch, lower scores in Geomorph

Sketch:



NCWQ Stream Identification Form Version 4.11

Date:	Project/Site: A2	Latitude:
Evaluator:	County:	Longitude:
Total Points: Stream is at least intermittent if ≥ 19 or perennial if ≥ 30* 36.5	Stream Determination (circle one) Ephemeral Intermittent Perennial	Other e.g. Quad Name:

A. Geomorphology (Subtotal = 22.5)	Absent	Weak	Moderate	Strong
1[a] Continuity of channel bed and bank	0	1	2	3
2. Sinuosity of channel along thalweg	0	1	2	3
3. In-channel structure: ex. riffle-pool, step-pool, ripple-pool sequence	0	1	2	3
4. Particle size of stream substrate	0	1	2	3
5. Active/relict floodplain	0	1	2	3
6. Depositional bars or benches	0	1	2	3
7. Recent alluvial deposits	0	1	2	3
8. Headcuts	0	1	2	3
9. Grade control	0	0.5	2	3
10. Natural valley	0	0.5	1	1.5
11. Second or greater order channel	No = 0		Yes = 3	

[a] artificial ditches are not rated; see discussions in manual

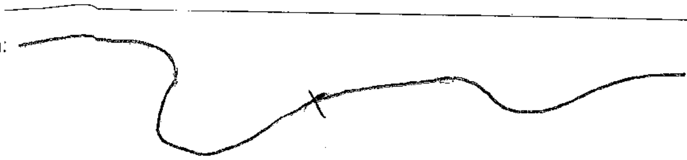
B. Hydrology (Subtotal = 9)	Absent	Weak	Moderate	Strong
12. Presence of Baseflow	0	1	2	3
13. Iron oxidizing bacteria	0	1	2	3
14. Leaf litter	1.5	1	0.5	0
15. Sediment on plants or debris	0	0.5	1	1.5
16. Organic debris lines or piles	0	0.5	1	1.5
17. Soil-based evidence of high water table?	No = 0		Yes = 3	

C. Biology (Subtotal = 5)	Absent	Weak	Moderate	Strong
18. Fibrous roots in streambed	3	2	1	0
19. Rooted upland plants in streambed	3	2	1	0
20. Macrobenthos (note diversity and abundance)	0	1	2	3
21. Aquatic Mollusks	0	1	2	3
22. Fish	0	0.5	1	1.5
23. Crayfish	0	0.5	1	1.5
24. Amphibians	0	0.5	1	1.5
25. Algae	0	0.5	1	1.5
26. Wetland plants in streambed	FACW = 0.75; OBL = 1.5 Other = 0			

*perennial streams may also be identified using other methods. See p. 35 of manual.

Notes:

Sketch:



NC DWQ Stream Identification Form Version 4.11

Date:	Project/Site: B1	Latitude:
Evaluator:	County:	Longitude:
Total Points: *Stream is at least intermittent if ≥ 19 or perennial if ≥ 30** 28	Stream Determination (circle one) Ephemeral Intermittent Perennial	Other *e.g. Quad Name*:

A. Geomorphology (Subtotal = 20)	Absent	Weak	Moderate	Strong
1ª. Continuity of channel bed and bank	0	1	2	3
2. Sinuosity of channel along thalweg	0	1	2	3
3. In-channel structure: ex. riffle-pool, step-pool, ripple-pool sequence	0	1	2	3
4. Particle size of stream substrate	0	1	2	3
5. Active/relict floodplain	0	1	2	3
6. Depositional bars or benches	0	1	2	3
7. Recent alluvial deposits	0	1	2	3
8. Headcuts	0	1	2	3
9. Grade control	0	0.5	1	1.5
10. Natural valley	0	0.5	1	1.5
11. Second or greater order channel	No = 0		Yes = 3	

ª artificial ditches are not rated; see discussions in manual

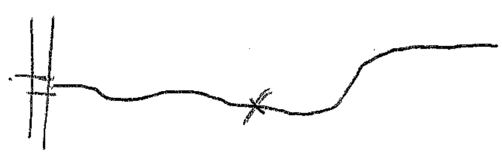
B. Hydrology (Subtotal = 4)				
12. Presence of Baseflow	0	1	2	3
13. Iron oxidizing bacteria	0	1	2	3
14. Leaf litter	1.5	1	0.5	0
15. Sediment on plants or debris	0	0.5	1	1.5
16. Organic debris lines or piles	0	0.5	1	1.5
17. Soil-based evidence of high water table?	No = 0		Yes = 3	

C. Biology (Subtotal = 4)				
18. Fibrous roots in streambed	3	2	1	0
19. Rooted upland plants in streambed	3	2	1	0
20. Macrobenthos (note diversity and abundance)	0	1	2	3
21. Aquatic Mollusks	0	1	2	3
22. Fish	0	0.5	1	1.5
23. Crayfish	0	0.5	1	1.5
24. Amphibians	0	0.5	1	1.5
25. Algae	0	0.5	1	1.5
26. Wetland plants in streambed	FACW = 0.75; OBL = 1.5 Other = 0			

*perennial streams may also be identified using other methods. See p. 35 of manual.

Notes:

Sketch:



NC DWQ Stream Identification Form Version 4.11

Date:	Project/Site: B2	Latitude:
Evaluator:	County:	Longitude:
Total Points: *Stream is at least intermittent if ≥ 19 or perennial if ≥ 30** 29	Stream Determination (circle one) Ephemeral Intermittent Perennial	Other *e.g. Quad Name:*

A. Geomorphology (Subtotal = 15)	Absent	Weak	Moderate	Strong
1[a] Continuity of channel bed and bank	0	1	2	3
2. Sinuosity of channel along thalweg	0	1	2	3
3. In-channel structure: ex. riffle-pool, step-pool, ripple-pool sequence	0	1	2	3
4. Particle size of stream substrate	0	1	2	3
5. Active/relict floodplain	0	1	2	3
6. Depositional bars or benches	0	1	2	3
7. Recent alluvial deposits	0	1	2	3
8. Headcuts	0	1	2	3
9. Grade control	0	0.5	1	1.5
10. Natural valley	0	0.5	1	1.5
11. Second or greater order channel	No = 0		Yes = 3	

[a] artificial ditches are not rated; see discussions in manual

B. Hydrology (Subtotal = 10)				
12. Presence of Baseflow	0	1	2	3
13. Iron oxidizing bacteria	0	1	2	3
14. Leaf litter	1.5	1	0.5	0
15. Sediment on plants or debris	0	0.5	1	1.5
16. Organic debris lines or piles	0	0.5	1	1.5
17. Soil-based evidence of high water table?	No = 0		Yes = 3	

C. Biology (Subtotal = 4)				
18. Fibrous roots in streambed	3	2	1	0
19. Rooted upland plants in streambed	3	2	1	0
20. Macrobenthos (note diversity and abundance)	0	1	2	3
21. Aquatic Mollusks	0	1	2	3
22. Fish	0	0.5	1	1.5
23. Crayfish	0	0.5	1	1.5
24. Amphibians	0	0.5	1	1.5
25. Algae	0	0.5	1	1.5
26. Wetland plants in streambed	FACW = 0.75; OBL = 1.5 Other = 0			

*perennial streams may also be identified using other methods. See p. 35 of manual.

Notes:

Sketch:

NC DWQ Stream Identification Form Version 4.11

Date:	Project/Site: B3	Latitude:
Evaluator:	County:	Longitude:
Total Points: *Stream is at least intermittent if ≥ 19 or perennial if ≥ 30** 37	Stream Determination (~~circle one~~) Ephemeral Intermittent Perennial	Other *e.g. Quad Name:*

A. Geomorphology (Subtotal = 22.5)	Absent	Weak	Moderate	Strong
1[a] Continuity of channel bed and bank	0	1	2	3
2. Sinuosity of channel along thalweg	0	1	2	3
3. In-channel structure: ex. riffle-pool, step-pool, ripple-pool sequence	0	1	2	3
4. Particle size of stream substrate	0	1	2	3
5. Active/relict floodplain	0	1	2	3
6. Depositional bars or benches	0	1	2	3
7. Recent alluvial deposits	0	1	2	3
8. Headcuts	0	1	2	3
9. Grade control	0	0.5	1	1.5
10. Natural valley	0	0.5	1	1.5
11. Second or greater order channel		No = 0	Yes = 3	

[a] artificial ditches are not rated; see discussions in manual

B. Hydrology (Subtotal = 10)				
12. Presence of Baseflow	0	1	2	3
13. Iron oxidizing bacteria	0	1	2	3
14. Leaf litter	1.5	1	0.5	0
15. Sediment on plants or debris	0	0.5	1	1.5
16. Organic debris lines or piles	0	0.5	1	1.5
17. Soil-based evidence of high water table?		No = 0	Yes = 3	

C. Biology (Subtotal = 4.5)				
18. Fibrous roots in streambed	3	2	1	0
19. Rooted upland plants in streambed	3	2	1	0
20. Macrobenthos (note diversity and abundance)	0	1	2	3
21. Aquatic Mollusks	0	1	2	3
22. Fish	0	0.5	1	1.5
23. Crayfish	0	0.5	1	1.5
24. Amphibians	0	0.5	1	1.5
25. Algae	0	0.5	1	1.5
26. Wetland plants in streambed		FACW = 0.75; OBL = 1.5	Other = 0	

*perennial streams may also be identified using other methods. See p. 35 of manual.

Notes:

Sketch:

NC DWQ Stream Identification Form Version 4.11

Date:	Project/Site: C2	Latitude:
Evaluator:	County:	Longitude:
Total Points: *Stream is at least intermittent if ≥ 19 or perennial if ≥ 30** 30	Stream Determination (circle one) Ephemeral Intermittent Perennial	Other *e.g. Quad Name:*

A. Geomorphology (Subtotal = 15.5)	Absent	Weak	Moderate	Strong
1[a]. Continuity of channel bed and bank	0	1	2	3
2. Sinuosity of channel along thalweg	0	1	2	3
3. In-channel structure: ex. riffle-pool, step-pool, ripple-pool sequence	0	1	2	3
4. Particle size of stream substrate	0	1	2	3
5. Active/relict floodplain	0	1	2	3
6. Depositional bars or benches	0	1	2	3
7. Recent alluvial deposits	0	1	2	3
8. Headcuts	0	1	2	3
9. Grade control	0	0.5	1	1.5
10. Natural valley	0	0.5	1	1.5
11. Second or greater order channel	No = 0		Yes = 3	

[a] artificial ditches are not rated; see discussions in manual

B. Hydrology (Subtotal = 6.5)				
12. Presence of Baseflow	0	1	2	3
13. Iron oxidizing bacteria	0	1	2	3
14. Leaf litter	1.5	1	0.5	0
15. Sediment on plants or debris	0	0.5	1	1.5
16. Organic debris lines or piles	0	0.5	1	1.5
17. Soil-based evidence of high water table?	No = 0		Yes = 3	

C. Biology (Subtotal = 8)				
18. Fibrous roots in streambed	3	2	1	0
19. Rooted upland plants in streambed	3	2	1	0
20. Macrobenthos (note diversity and abundance)	0	1	2	3
21. Aquatic Mollusks	0	1	2	3
22. Fish	0	0.5	1	1.5
23. Crayfish	0	0.5	1	1.5
24. Amphibians	0	0.5	1	1.5
25. Algae	0	0.5	1	1.5
26. Wetland plants in streambed	FACW = 0.75; OBL = 1.5 Other = 0			

*perennial streams may also be identified using other methods. See p. 35 of manual.

Notes:

Sketch:

NC DWQ Stream Identification Form Version 4.11

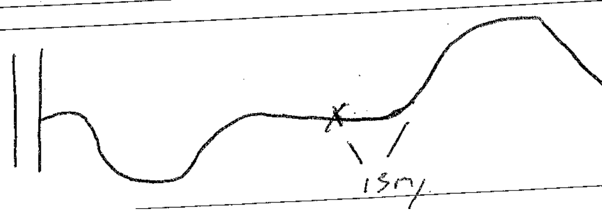
Date:	Project/Site: C3	Latitude:
Evaluator:	County:	Longitude:
Total Points: *Stream is at least intermittent if ≥ 19 or perennial if ≥ 30** 36.5	Stream Determination (circle one) Ephemeral Intermittent Perennial	Other *e.g. Quad Name:*

	Absent	Weak	Moderate	Strong
A. Geomorphology (Subtotal = 18.5)				
1[a] Continuity of channel bed and bank	0	1	2	3
2. Sinuosity of channel along thalweg	0	1	2	3
3. In-channel structure: ex. riffle-pool, step-pool, ripple-pool sequence	0	1	2	3
4. Particle size of stream substrate	0	1	2	3
5. Active/relict floodplain	0	1	2	3
6. Depositional bars or benches	0	1	2	3
7. Recent alluvial deposits	0	1	2	3
8. Headcuts	0	1	2	3
9. Grade control	0	0.5	1	1.5
10. Natural valley	0	0.5	1	1.5
11. Second or greater order channel		No = 0		Yes = 3
[a] artificial ditches are not rated; see discussions in manual				
B. Hydrology (Subtotal = 7.5)				
12. Presence of Baseflow	0	1	2	3
13. Iron oxidizing bacteria	0	1	2	3
14. Leaf litter	1.5	1	0.5	0
15. Sediment on plants or debris	0	0.5	1	1.5
16. Organic debris lines or piles	0	0.5	1	1.5
17. Soil-based evidence of high water table?		No = 0		Yes = 3
C. Biology (Subtotal = 9.5)				
18. Fibrous roots in streambed	3	2	1	0
19. Rooted upland plants in streambed	3	2	1	0
20. Macrobenthos (note diversity and abundance)	0	1	2	3
21. Aquatic Mollusks	0	1	2	3
22. Fish	0	0.5	1	1.5
23. Crayfish	0	0.5	1	1.5
24. Amphibians	0	0.5	1	1.5
25. Algae	0	0.5	1	1.5
26. Wetland plants in streambed		FACW = 0.75; OBL = 1.5 Other = 0		

*perennial streams may also be identified using other methods. See p. 35 of manual.

Notes:

Sketch:



NC DWQ Stream Identification Form Version 4.11

Date:	Project/Site: D1	Latitude:
Evaluator:	County:	Longitude:
Total Points: *Stream is at least intermittent if ≥ 19 or perennial if ≥ 30** 24.75	Stream Determination (circle one) Ephemeral Intermittent Perennial	Other *e.g. Quad Name:*

A. Geomorphology (Subtotal = 17)	Absent	Weak	Moderate	Strong
1[a] Continuity of channel bed and bank	0	1	2	3
2. Sinuosity of channel along thalweg	0	1	2	3
3. In-channel structure: ex. riffle-pool, step-pool, ripple-pool sequence	0	1	2	3
4. Particle size of stream substrate	0	1	2	3
5. Active/relict floodplain	0	1	2	3
6. Depositional bars or benches	0	1	2	3
7. Recent alluvial deposits	0	1	2	3
8. Headcuts	0	1	2	3
9. Grade control	0	0.5	1	1.5
10. Natural valley	0	0.5	1	1.5
11. Second or greater order channel	No = 0		Yes = 3	

[a] artificial ditches are not rated; see discussions in manual

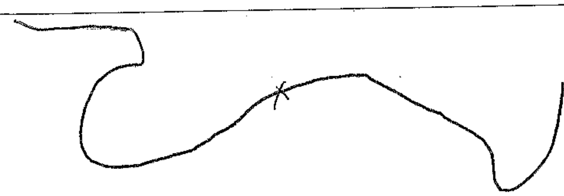
B. Hydrology (Subtotal = 4)	Absent	Weak	Moderate	Strong
12. Presence of Baseflow	0	1	2	3
13. Iron oxidizing bacteria	0	1	2	3
14. Leaf litter	1.5	1	0.5	0
15. Sediment on plants or debris	0	0.5	1	1.5
16. Organic debris lines or piles	0	0.5	1	1.5
17. Soil-based evidence of high water table?	No = 0		Yes = 3	

C. Biology (Subtotal = 3.75)	Absent	Weak	Moderate	Strong
18. Fibrous roots in streambed	3	2	1	0
19. Rooted upland plants in streambed	3	2	1	0
20. Macrobenthos (note diversity and abundance)	0	1	2	3
21. Aquatic Mollusks	0	1	2	3
22. Fish	0	0.5	1	1.5
23. Crayfish	0	0.5	1	1.5
24. Amphibians	0	0.5	1	1.5
25. Algae	0	0.5	1	1.5
26. Wetland plants in streambed		FACW = 0.75; OBL = 1.5 Other = 0		

*perennial streams may also be identified using other methods. See p. 35 of manual.

Notes:

Sketch:



NC DWQ Stream Identification Form Version 4.11

Date:	Project/Site: D2	Latitude:
Evaluator:	County:	Longitude:
Total Points: *Stream is at least intermittent if ≥ 19 or perennial if ≥ 30** 18	**Stream Determination (circle one)** Ephemeral Intermittent Perennial	**Other** *e.g. Quad Name:*

A. Geomorphology (Subtotal = 8.5)	Absent	Weak	Moderate	Strong
1[a] Continuity of channel bed and bank	0	1	2	3
2. Sinuosity of channel along thalweg	0	1	2	3
3. In-channel structure: ex. riffle-pool, step-pool, ripple-pool sequence	0	1	2	3
4. Particle size of stream substrate	0	1	2	3
5. Active/relict floodplain	0	1	2	3
6. Depositional bars or benches	0	1	2	3
7. Recent alluvial deposits	0	1	2	3
8. Headcuts	0	1	2	3
9. Grade control	0	0.5	1	1.5
10. Natural valley	0	0.5	1	1.5
11. Second or greater order channel	No = 0		Yes = 3	

[a] artificial ditches are not rated; see discussions in manual

B. Hydrology (Subtotal = 6)				
12. Presence of Baseflow	0	1	2	3
13. Iron oxidizing bacteria	0	1	2	3
14. Leaf litter	1.5	1	0.5	0
15. Sediment on plants or debris	0	0.5	1	1.5
16. Organic debris lines or piles	0	0.5	1	1.5
17. Soil-based evidence of high water table?	No = 0		Yes = 3	

C. Biology (Subtotal = 3.5)				
18. Fibrous roots in streambed	3	2	1	0
19. Rooted upland plants in streambed	3	2	1	0
20. Macrobenthos (note diversity and abundance)	0	1	2	3
21. Aquatic Mollusks	0	1	2	3
22. Fish	0	0.5	1	1.5
23. Crayfish	0	0.5	1	1.5
24. Amphibians	0	0.5	1	1.5
25. Algae	0	0.5	1	1.5
26. Wetland plants in streambed		FACW = 0.75; OBL = 1.5	Other = 0	

*perennial streams may also be identified using other methods. See p. 35 of manual.

Notes: went from I to E, stream working through legacy sediment

Sketch:

15.2/15

NC DWQ Stream Identification Form Version 4.11

Date:	Project/Site: D3	Latitude:
Evaluator:	County:	Longitude:
Total Points: *Stream is at least intermittent if ≥ 19 or perennial if ≥ 30** 25	Stream Dete~~rmination~~ (circle one) Ephemeral Intermittent Perennial	Other *e.g. Quad Name*:

A. Geomorphology (Subtotal = 9)	Absent	Weak	Moderate	Strong
1[a.] Continuity of channel bed and bank	0	1	2	3
2. Sinuosity of channel along thalweg	0	1	2	3
3. In-channel structure: ex. riffle-pool, step-pool, ripple-pool sequence	0	1	2	3
4. Particle size of stream substrate	0	1	2	3
5. Active/relict floodplain	0	1	2	3
6. Depositional bars or benches	0	1	2	3
7. Recent alluvial deposits	0	1	2	3
8. Headcuts	0	1	2	3
9. Grade control	0	0.5	1	1.5
10. Natural valley	0	0.5	1	1.5
11. Second or greater order channel	No = 0		Yes = 3	

[a] artificial ditches are not rated; see discussions in manual

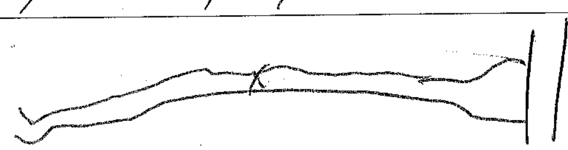
B. Hydrology (Subtotal = 9.5)				
12. Presence of Baseflow	0	1	2	3
13. Iron oxidizing bacteria	0	1	2	3
14. Leaf litter	1.5	1	0.5	0
15. Sediment on plants or debris	0	0.5	1	1.5
16. Organic debris lines or piles	0	0.5	1	1.5
17. Soil-based evidence of high water table?	No = 0		Yes = 3	

C. Biology (Subtotal = 6.5)				
18. Fibrous roots in streambed	3	2	1	0
19. Rooted upland plants in streambed	3	2	1	0
20. Macrobenthos (note diversity and abundance)	0	1	2	3
21. Aquatic Mollusks	0	1	2	3
22. Fish	0	0.5	1	1.5
23. Crayfish	0	0.5	1	1.5
24. Amphibians	0	0.5	1	1.5
25. Algae	0	0.5	1	1.5
26. Wetland plants in streambed	FACW = 0.75; OBL = 1.5 Other = 0			

*perennial streams may also be identified using other methods. See p. 35 of manual.

Notes: Below large culvert, grassy buffer, no trees.

Sketch:



NC DWQ Stream Identification Form Version 4.11

Date:	Project/Site: E1	Latitude:
Evaluator:	County:	Longitude:
Total Points: *Stream is at least intermittent if ≥ 19 or perennial if ≥ 30** 17.5	Stream Determination (circle one) Ephemeral Intermittent Perennial	Other *e.g. Quad Name:*

A. Geomorphology (Subtotal = 9)	Absent	Weak	Moderate	Strong
1[a] Continuity of channel bed and bank	0	1	2	3
2. Sinuosity of channel along thalweg	0	1	2	3
3. In-channel structure: ex. riffle-pool, step-pool, ripple-pool sequence	0	1	2	3
4. Particle size of stream substrate	0	1	2	3
5. Active/relict floodplain	0	1	2	3
6. Depositional bars or benches	0	1	2	3
7. Recent alluvial deposits	0	1	2	3
8. Headcuts	0	1	2	3
9. Grade control	0	0.5	1	1.5
10. Natural valley	0	0.5	1	1.5
11. Second or greater order channel		No = 0		Yes = 3

[a] artificial ditches are not rated; see discussions in manual

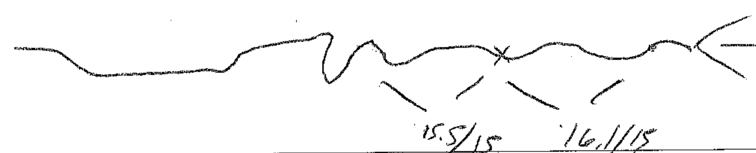
B. Hydrology (Subtotal = 6)				
12. Presence of Baseflow	0	1	2	3
13. Iron oxidizing bacteria	0	1	2	3
14. Leaf litter	1.5	1	0.5	0
15. Sediment on plants or debris	0	0.5	1	1.5
16. Organic debris lines or piles	0	0.5	1	1.5
17. Soil-based evidence of high water table?		No = 0		Yes = 3

C. Biology (Subtotal = 2)				
18. Fibrous roots in streambed	3	2	1	0
19. Rooted upland plants in streambed	3	2	1	0
20. Macrobenthos (note diversity and abundance)	0	1	2	3
21. Aquatic Mollusks	0	1	2	3
22. Fish	0	0.5	1	1.5
23. Crayfish	0	0.5	1	1.5
24. Amphibians	0	0.5	1	1.5
25. Algae	0	0.5	1	1.5
26. Wetland plants in streambed		FACW = 0.75; OBL = 1.5		Other = 0

*perennial streams may also be identified using other methods. See p. 35 of manual.

Notes: legacy sediment working stream through valley

Sketch:



NC DWQ Stream Identification Form Version 4.11

Date:	Project/Site: F 2	Latitude:
Evaluator:	County:	Longitude:
Total Points: *Stream is at least intermittent if ≥ 19 or perennial if ≥ 30** 17.5	Stream Determination (circle one) Ephemeral Intermittent Perennial	Other *e.g. Quad Name:*

A. Geomorphology (Subtotal = 11.5)	Absent	Weak	Moderate	Strong
1[a]. Continuity of channel bed and bank	0	1	2	3
2. Sinuosity of channel along thalweg	0	1	2	3
3. In-channel structure: ex. riffle-pool, step-pool, ripple-pool sequence	0	1	2	3
4. Particle size of stream substrate	0	1	2	3
5. Active/relict floodplain	0	1	2	3
6. Depositional bars or benches	0	1	2	3
7. Recent alluvial deposits	0	1	2	3
8. Headcuts	0	1	2	3
9. Grade control	0	0.5	1	1.5
10. Natural valley	0	0.5	1	1.5
11. Second or greater order channel	No = 0		Yes = 3	

[a] artificial ditches are not rated; see discussions in manual

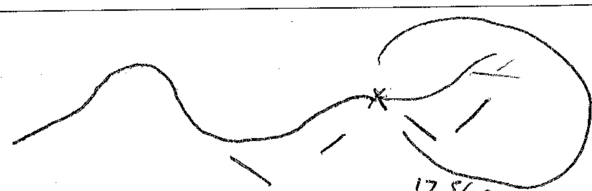
B. Hydrology (Subtotal = 2.5)	Absent	Weak	Moderate	Strong
12. Presence of Baseflow	0	1	2	3
13. Iron oxidizing bacteria	0	1	2	3
14. Leaf litter	1.5	1	0.5	0
15. Sediment on plants or debris	0	0.5	1	1.5
16. Organic debris lines or piles	0	0.5	1	1.5
17. Soil-based evidence of high water table?	No = 0		Yes = 3	

C. Biology (Subtotal = 3.5)	Absent	Weak	Moderate	Strong
18. Fibrous roots in streambed	3	2	1	0
19. Rooted upland plants in streambed	3	2	1	0
20. Macrobenthos (note diversity and abundance)	0	1	2	3
21. Aquatic Mollusks	0	1	2	3
22. Fish	0	0.5	1	1.5
23. Crayfish	0	0.5	1	1.5
24. Amphibians	0	0.5	1	1.5
25. Algae	0	0.5	1	1.5
26. Wetland plants in streambed	FACW = 0.75; OBL = 1.5 Other = 0			

*perennial streams may also be identified using other methods. See p. 35 of manual.

Notes:

Sketch:



21.8/18

1.3

NC DWQ Stream Identification Form Version 4.11

Date:	Project/Site: E3	Latitude:
Evaluator:	County:	Longitude:
Total Points: *Stream is at least intermittent if ≥ 19 or perennial if ≥ 30** 22.5	Stream Determination (circle one) Ephemeral Intermittent Perennial	Other *e.g. Quad Name:*

A. Geomorphology (Subtotal = 13)	Absent	Weak	Moderate	Strong
1[a] Continuity of channel bed and bank	0	1	2	3
2. Sinuosity of channel along thalweg	0	1	2	3
3. In-channel structure: ex. riffle-pool, step-pool, ripple-pool sequence	0	1	2	3
4. Particle size of stream substrate	0	1	2	3
5. Active/relict floodplain	0	1	2	3
6. Depositional bars or benches	0	1	2	3
7. Recent alluvial deposits	0	1	2	3
8. Headcuts	0	1	2	3
9. Grade control	0	0.5	1	1.5
10. Natural valley	0	0.5	1	1.5
11. Second or greater order channel	No = 0		Yes = 3	

[a] artificial ditches are not rated; see discussions in manual

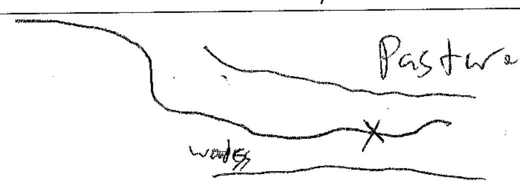
B. Hydrology (Subtotal = 7)				
12. Presence of Baseflow	0	1	2	3
13. Iron oxidizing bacteria	0	1	2	3
14. Leaf litter	1.5	1	0.5	0
15. Sediment on plants or debris	0	0.5	1	1.5
16. Organic debris lines or piles	0	0.5	1	1.5
17. Soil-based evidence of high water table?	No = 0		Yes = 3	

C. Biology (Subtotal = 2.5)				
18. Fibrous roots in streambed	3	2	1	0
19. Rooted upland plants in streambed	3	2	1	0
20. Macrobenthos (note diversity and abundance)	0	1	2	3
21. Aquatic Mollusks	0	1	2	3
22. Fish	0	0.5	1	1.5
23. Crayfish	0	0.5	1	1.5
24. Amphibians	0	0.5	1	1.5
25. Algae	0	0.5	1	1.5
26. Wetland plants in streambed	FACW = 0.75; OBL = 1.5 Other = 0			

*perennial streams may also be identified using other methods. See p. 35 of manual.

Notes: incised stream half wooded / half grass buffer

Sketch:



NC DWQ Stream Identification Form Version 4.11

Date: 3/14	Project/Site: F1	Latitude:
Evaluator:	County:	Longitude:
Total Points: *Stream is at least intermittent if ≥ 19 or perennial if ≥ 30** 31.5	Stream Determination (circle one) Ephemeral Intermittent Perennial	Other *e.g. Quad Name:*

A. Geomorphology (Subtotal = 16)	Absent	Weak	Moderate	Strong
1[a]. Continuity of channel bed and bank	0	1	2	3
2. Sinuosity of channel along thalweg	0	1	2	3
3. In-channel structure: ex. riffle-pool, step-pool, ripple-pool sequence	0	1	2	3
4. Particle size of stream substrate	0	1	2	3
5. Active/relict floodplain	0	1	2	3
6. Depositional bars or benches	0	1	2	3
7. Recent alluvial deposits	0	1	2	3
8. Headcuts	0	1	2	3
9. Grade control	0	0.5	1	1.5
10. Natural valley	0	0.5	1	1.5
11. Second or greater order channel	No = 0		Yes = 3	

[a] artificial ditches are not rated; see discussions in manual

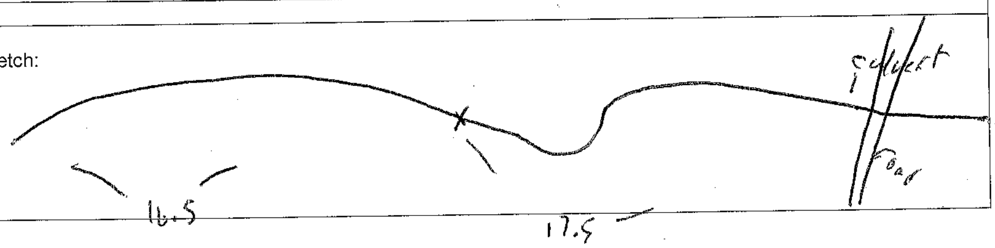
B. Hydrology (Subtotal = 10.5)	Absent	Weak	Moderate	Strong
12. Presence of Baseflow	0	1	2	3
13. Iron oxidizing bacteria	0	1	2	3
14. Leaf litter	1.5	1	0.5	0
15. Sediment on plants or debris	0	0.5	1	1.5
16. Organic debris lines or piles	0	0.5	1	1.5
17. Soil-based evidence of high water table?	No = 0		Yes = 3	

C. Biology (Subtotal = 5)	Absent	Weak	Moderate	Strong
18. Fibrous roots in streambed	3	2	1	0
19. Rooted upland plants in streambed	3	2	1	0
20. Macrobenthos (note diversity and abundance)	0	1	2	3
21. Aquatic Mollusks	0	1	2	3
22. Fish	0	0.5	1	1.5
23. Crayfish	0	0.5	1	1.5
24. Amphibians	0	0.5	1	1.5
25. Algae	0	0.5	1	1.5
26. Wetland plants in streambed	FACW = 0.75; OBL = 1.5 Other = 0			

*perennial streams may also be identified using other methods. See p. 35 of manual.

Notes:

Sketch:



15 17.5m
16.5M

silty clay
organic debris

NC DWQ Stream Identification Form Version 4.11

Date:	Project/Site: F2	Latitude:
Evaluator:	County:	Longitude:
Total Points: *Stream is at least intermittent if ≥ 19 or perennial if ≥ 30** 18	Stream Determination (circle one) Ephemeral Intermittent Perennial	Other *e.g. Quad Name:*

A. Geomorphology (Subtotal = 9)	Absent	Weak	Moderate	Strong
1[a] Continuity of channel bed and bank	0	1	2	3
2. Sinuosity of channel along thalweg	0	1	2	3
3. In-channel structure: ex. riffle-pool, step-pool, ripple-pool sequence	0	1	2	3
4. Particle size of stream substrate	0	1	2	3
5. Active/relict floodplain	0	1	2	3
6. Depositional bars or benches	0	1	2	3
7. Recent alluvial deposits	0	1	2	3
8. Headcuts	0	1	2	3
9. Grade control	0	0.5	1	1.5
10. Natural valley	0	0.5	1	1.5
11. Second or greater order channel	No = 0		Yes = 3	

[a] artificial ditches are not rated; see discussions in manual

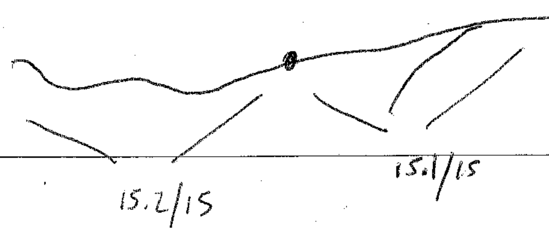
B. Hydrology (Subtotal = 8)				
12. Presence of Baseflow	0	1	2	3
13. Iron oxidizing bacteria	0	1	2	3
14. Leaf litter	1.5	1	0.5	0
15. Sediment on plants or debris	0	0.5	1	1.5
16. Organic debris lines or piles	0	0.5	1	1.5
17. Soil-based evidence of high water table?	No = 0		Yes = 3	

C. Biology (Subtotal = 1)				
18. Fibrous roots in streambed	3	2	1	0
19. Rooted upland plants in streambed	3	2	1	0
20. Macrobenthos (note diversity and abundance)	0	1	2	3
21. Aquatic Mollusks	0	1	2	3
22. Fish	0	0.5	1	1.5
23. Crayfish	0	0.5	1	1.5
24. Amphibians	0	0.5	1	1.5
25. Algae	0	0.5	1	1.5
26. Wetland plants in streambed	FACW = 0.75; OBL = 1.5 Other = 0			

*perennial streams may also be identified using other methods. See p. 35 of manual.

Notes:

Sketch:



NC DWQ Stream Identification Form Version 4.11

Date:	Project/Site: F3	Latitude:
Evaluator:	County:	Longitude:
Total Points: *Stream is at least intermittent if ≥ 19 or perennial if ≥ 30** 25	Stream Determination (circle one) Ephemeral Intermittent Perennial	Other *e.g. Quad Name:*

A. Geomorphology (Subtotal = 10.5)	Absent	Weak	Moderate	Strong
1[a] Continuity of channel bed and bank	0	1	2	3
2. Sinuosity of channel along thalweg	0	1	2	3
3. In-channel structure: ex. riffle-pool, step-pool, ripple-pool sequence	0	1	2	3
4. Particle size of stream substrate	0	1	2	3
5. Active/relict floodplain	0	1	2	3
6. Depositional bars or benches	0	1	2	3
7. Recent alluvial deposits	0	1	2	3
8. Headcuts	0	1	2	3
9. Grade control	0	0.5	1	1.5
10. Natural valley	0	0.5	1	1.5
11. Second or greater order channel	No = 0		Yes = 3	

— 2 drain ditches;

[a] artificial ditches are not rated; see discussions in manual

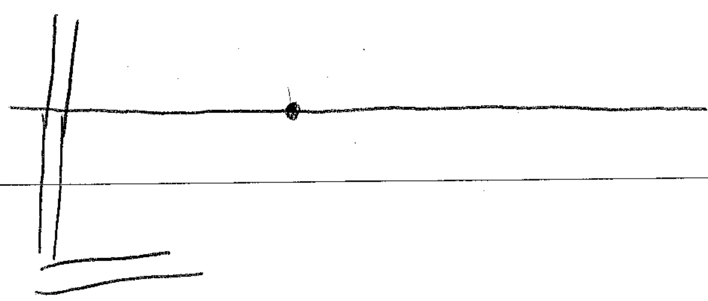
B. Hydrology (Subtotal = 8.5)				
12. Presence of Baseflow	0	1	2	3
13. Iron oxidizing bacteria	0	1	2	3
14. Leaf litter	1.5	1	0.5	0
15. Sediment on plants or debris	0	0.5	1	1.5
16. Organic debris lines or piles	0	0.5	1	1.5
17. Soil-based evidence of high water table?	No = 0		Yes = 3	

C. Biology (Subtotal = 6)				
18. Fibrous roots in streambed	3	2	1	0
19. Rooted upland plants in streambed	3	2	1	0
20. Macrobenthos (note diversity and abundance)	0	1	2	3
21. Aquatic Mollusks	0	1	2	~~3~~
22. Fish	0	0.5	1	1.5
23. Crayfish	0	0.5	1	1.5
24. Amphibians	0	0.5	1	1.5
25. Algae	0	0.5	1	1.5
26. Wetland plants in streambed	FACW = 0.75; OBL = 1.5 Other = 0			

*perennial streams may also be identified using other methods. See p. 35 of manual.

Notes: Ditch, if not ditched ~~not~~ intermittent, likely no channel

Sketch:



Appendix E

Linear Regression

2 potential models approximating the NC score

1 watershed area only

2 width water grass

Results table showing those associated scores

Dependent: NC Score

Independent: watershed area average slope rowcrop grass water width

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.883[a]	.779	.647	3.99373

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.883[a]	.779	.647	3.99373

a. Predictors: (Constant), Width, AverageSlope, Water, Grass, WatershedArea, Rowcrop

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	562.619	6	93.770	5.879	.007[a]
	Residual	159.499	10	15.950		
	Total	722.118	16			

a. Predictors: (Constant), Width, AverageSlope, Water, Grass, WatershedArea, Rowcrop

b. Dependent Variable: NCScore

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-1.895	26.144		-.072	.944
	WatershedArea	.000	.001	.228	.566	.584
	AverageSlope	.021	1.680	.005	.013	.990
	Rowcrop	12.745	25.769	.253	.495	.632
	Grass	29.502	25.243	.401	1.169	.270
	Water	-162.790	131.836	-.385	-1.235	.245
	Width	2.319	1.448	.644	1.601	.140

a. Dependent Variable: NCScore

Dependent: NC Score

Independent: watershed area, average slope

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.810[a]	.656	.607	4.20996

a. Predictors: (Constant), AverageSlope, WatershedArea

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	473.985	2	236.992	13.371	.001[a]
	Residual	248.133	14	17.724		
	Total	722.118	16			

a. Predictors: (Constant), AverageSlope, WatershedArea
b. Dependent Variable: NCScore

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	21.486	2.672		8.040	.000
	WatershedArea	.001	.000	.788	5.021	.000
	AverageSlope	-.660	.724	-.143	-.912	.377

a. Dependent Variable: NCScore

Dependent: NC Score

Independent: watershed area, Rowcrop

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.809[a]	.654	.605	4.22386

a. Predictors: (Constant), Rowcrop, WatershedArea

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	472.344	2	236.172	13.238	.001[a]
	Residual	249.774	14	17.841		
	Total	722.118	16			

a. Predictors: (Constant), Rowcrop, WatershedArea
b. Dependent Variable: NCScore

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	17.404	3.093		5.627	.000
	WatershedArea	.001	.000	.864	4.932	.000
	Rowcrop	7.570	8.829	.150	.857	.406

a. Dependent Variable: NCScore

Dependent: NC Score

Independent: watershed area, Grass

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.799[a]	.639	.587	4.31517

a. Predictors: (Constant), Grass, WatershedArea

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	461.428	2	230.714	12.390	.001[a]
	Residual	260.690	14	18.621		
	Total	722.118	16			

a. Predictors: (Constant), Grass, WatershedArea
b. Dependent Variable: NCScore

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	17.084	7.560		2.260	.040
	WatershedArea	.001	.000	.779	4.589	.000
	Grass	4.293	12.490	.058	.344	.736

a. Dependent Variable: NCScore

Dependent: NC Score

Independent: watershed area, water

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.804[a]	.646	.596	4.27016

a. Predictors: (Constant), Water, WatershedArea

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	466.839	2	233.419	12.801	.001[a]
	Residual	255.279	14	18.234		
	Total	722.118	16			

a. Predictors: (Constant), Water, WatershedArea
b. Dependent Variable: NCScore

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	20.157	1.929		10.452	.000
	WatershedArea	.001	.000	.804	5.050	.000
	Water	-43.483	67.305	-.103	-.646	.529

a. Dependent Variable: NCScore

Dependent: NC Score

Independent: watershed area, bankfull width

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.818[a]	.670	.622	4.12856

a. Predictors: (Constant), Width, WatershedArea

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	483.487	2	241.743	14.183	.000[a]
	Residual	238.631	14	17.045		
	Total	722.118	16			

a. Predictors: (Constant), Width, WatershedArea
b. Dependent Variable: NCScore

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	18.084	2.109		8.573	.000
	WatershedArea	.001	.000	.432	1.258	.229
	Width	1.474	1.235	.409	1.193	.253

a. Dependent Variable: NCScore

Dependent: NC Score

Independent: watershed area, ditched upstream

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.814[a]	.662	.614	4.17486

a. Predictors: (Constant), ditched, WatershedArea

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	478.105	2	239.052	13.715	.001[a]
	Residual	244.013	14	17.429		
	Total	722.118	16			

a. Predictors: (Constant), ditched, WatershedArea
b. Dependent Variable: NCScore

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	19.489	1.699		11.471	.000
	WatershedArea	.001	.000	.685	3.620	.003
	ditched	.004	.004	.197	1.041	.316

a. Dependent Variable: NCScore

Dependent: nc score

Independent: watershed area

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.797[a]	.636	.612	4.18640

a. Predictors: (Constant), WatershedArea

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	459.228	1	459.228	26.203	.000[a]
	Residual	262.890	15	17.526		
	Total	722.118	16			

a. Predictors: (Constant), WatershedArea
b. Dependent Variable: NCScore

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	19.611	1.700		11.539	.000
	WatershedArea	.001	.000	.797	5.119	.000

a. Dependent Variable: NCScore

Dependent: NC score

Independent: bankfull width, average slope, water, ditched upstream, grass, rowcrop

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.879[a]	.772	.668	3.86839

a. Predictors: (Constant), Width, AverageSlope, Water, Grass, Rowcrop

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	557.509	5	111.502	7.451	.003[a]
	Residual	164.609	11	14.964		
	Total	722.118	16			

a. Predictors: (Constant), Width, AverageSlope, Water, Grass, Rowcrop
b. Dependent Variable: NCScore

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.775	24.907		.031	.976
	AverageSlope	-.131	1.606	-.028	-.082	.936
	Rowcrop	8.530	23.895	.169	.357	.728
	Grass	27.784	24.274	.377	1.145	.277
	Water	-197.843	112.732	-.468	-1.755	.107
	Width	3.009	.757	.836	3.973	.002

a. Dependent Variable: NCScore

Dependent: Nc Score

Independent: width, water, grass, rowcrop

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.879[a]	.772	.696	3.70482

a. Predictors: (Constant), Rowcrop, Width, Water, Grass

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	557.409	4	139.352	10.153	.001[a]
	Residual	164.709	12	13.726		
	Total	722.118	16			

a. Predictors: (Constant), Rowcrop, Width, Water, Grass
b. Dependent Variable: NCScore

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-1.000	11.699		-.085	.933
	Width	3.047	.568	.846	5.363	.000
	Water	-191.638	79.830	-.453	-2.401	.033
	Grass	29.115	17.247	.396	1.688	.117
	Rowcrop	10.269	10.448	.204	.983	.345

a. Dependent Variable: NCScore

Dependent: NC score

Independent: width, water, grass

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.868[a]	.754	.697	3.69997

a. Predictors: (Constant), Grass, Width, Water

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	544.150	3	181.383	13.250	.000[a]
	Residual	177.967	13	13.690		
	Total	722.118	16			

a. Predictors: (Constant), Grass, Width, Water
b. Dependent Variable: NCScore

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	7.258	8.130		.893	.388
	Width	2.915	.551	.810	5.287	.000
	Water	-199.262	79.348	-.471	-2.511	.026
	Grass	20.314	14.721	.276	1.380	.191

a. Dependent Variable: NCScore

Dependent: DMM

Independent: bankfull width average slope, water, ditched upstream, grass, watershed area, rowcrop

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.798[a]	.637	.214	24.72274

a. Predictors: (Constant), Width, AverageSlope, Water, ditched, Grass, WatershedArea, Rowcrop

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	6440.147	7	920.021	1.505	.317[a]
	Residual	3667.282	6	611.214		
	Total	10107.429	13			

a. Predictors: (Constant), Width, AverageSlope, Water, ditched, Grass, WatershedArea, Rowcrop
b. Dependent Variable: DMM

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	212.184	244.574		.868	.419
	WatershedArea	-.004	.007	-.778	-.637	.548
	ditched	.032	.044	.404	.717	.500
	AverageSlope	-17.719	14.905	-1.010	-1.189	.279
	Rowcrop	-297.983	264.700	-1.492	-1.126	.303
	Grass	-54.305	216.215	-.188	-.251	.810
	Water	-828.233	985.503	-.461	-.840	.433
	Width	4.159	13.649	.305	.305	.771

a. Dependent Variable: DMM

VITA

Graduate School
Southern Illinois University

Miles W. Lampo

mileslampo@gmail.com (permanent email address after graduation)

Southern Illinois University Carbondale
Masters of Science, Geography, June 2014

Southern Illinois University Carbondale
Master of Science in Education, Curriculum and Instruction, June 2014

Thesis Paper Title:
A VALIDATION STUDY OF THE NORTH CAROLINA RAPID FIELD-BASED RATING SYSTEM FOR DISCRIMINATING FLOW PERMANENCE CLASSES OF HEADWATER STREAMS IN AGRICULTURE BASINS IN SOUTHERN ILLINOIS

Major Professor: Dr. Jonathan Remo