CORRELATING STREAM BIOLOGY WITH BUFFER QUALITY

Final Report

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TABLE OF CONTENTS

LIST OF TABLES AND FIGURES

TABLES

FIGURES

EXECUTIVE SUMMARY

Field studies were conducted in 14 of the coastal plain watersheds where the riparian assessment method originally was developed to examine relationships between riparian zone quality and stream water quality (as indicated by stream biology). Evaluations included riparian assessments, field water quality variables (water temperature, dissolved oxygen concentrations, specific conductivity, and pH), and stream biology as reflected by benthic macroinvertebrates with emphasis on the biotic index (BI) and the species of Ephemeroptera, Plecoptera, and Trichoptera (EPT taxa).

The Cumulative Function Score and most of the individual metrics that comprised the coastal plain riparian assessment method correlated very poorly with stream biology (EPT and BI) and water quality field variables. Similarly, the Total Score and individual metrics of the DWQ stream habitat assessment method correlated poorly with stream biology and water quality field variables. These results indicated clearly that summary scores and most individual metrics comprising either of these techniques were not good indicators of water quality or stream biology and should not be used for this purpose. Two individual riparian assessment metrics that specifically described stream habitat conditions (Pollution Affecting the Stream and Stream Bank Stability) had somewhat higher correlations with stream biology or field water quality variables than the summary scores. This suggested that weighting of the coastal plain riparian assessment method more heavily toward these stream metrics might improve correlations with water quality and stream biology.

Two individual stream metrics from the coastal plain riparian assessment method were modified by DWQ biologists and used in 17 piedmont and mountain watersheds to examine the possibility for application to those physiographic provinces. In the modified protocols, In-Stream Woody Structure was renamed Habitat Types and was split into two equal subcategories, Major Habitats and Minor Habitats. Similarly, Sediment Regime was renamed Substrate Structure and was split into two equal subcategories, Embeddedness and Riffle Makeup. The purpose of the modification was to include stream conditions that were deemed to be appropriate for piedmont or mountain streams. It is crucial to understand that the indicators used in this modified protocol were not based on the extensive reference system such as that used for the development of the coastal plain riparian assessment method. Therefore, the modified protocol should not be construed as even an approximate equivalent of the former method. Summary and individual metrics of this modified protocol as well as those in the DWQ stream habitat assessment form correlated very poorly with either water quality field variables or with stream biology. One individual metric of the modified protocol, Substrate Structure, correlated slightly better with water quality field variables and stream biology than summary scores.

Factors that have the most influence on water quality and stream biology also are quite different in the coastal plain than in the piedmont and mountains. The coastal plain riparian assessment technique is not appropriate for and should not be applied to watersheds in the piedmont and mountains. Riparian assessment techniques for non-coastal plain watershed will have to be developed and calibrated against a full range of reference conditions from poorest to highest quality for low and high order streams in both rural and urban watersheds in the piedmont and mountains before they can be applied to watersheds in those physiographic provinces. Therefore, application of the slightly modified version of the coastal plain riparian assessment method for use outside the coastal plain is not appropriate and should not be used.

The results of this study indicated clearly that neither riparian assessments nor stream habitat assessments relate well to water quality or stream biology in small watersheds or catchments. Riparian assessments provide valid, general descriptions of environmental conditions existing within larger watersheds and can be used to compare conditions among larger watersheds. However, these assessment techniques cannot assess or pinpoint specific water quality problems originating within a small watershed or an individual catchment and should not be considered for this purpose. More in-depth, detailed evaluations are needed to locate and evaluate problems originating within a small watershed or catchment that may be of sufficient magnitude to affect adversely the biological integrity of the larger watershed. Application of this procedure beyond its designated purpose (e.g., as a water quality assessment tool for small watersheds or catchments) is inappropriate and may yield inaccurate and misleading results.

INTRODUCTION

Riparian buffers provide important ecological functions affecting the quality and quantity of groundwater and surface water runoff entering the streams of a watershed (Scott et al. 2002, Qualls et al. 2000). High quality, intact buffers can reduce anthropogenic nonpoint source pollution by filtering and treating stormwater runoff before it flows into streams (Uusi-Kamppa et al. 1997, Parsons et al 1994). These buffers also provide sites for nitrification and denitrification and, thus, reduce nitrogen loading into streams *via* the groundwater (Spruill 2004, Lowrance 1992, Groffman et al. 1991). Consequently, the Division of Water Quality (DWQ) in the NC Department of Environment and Natural Resources (NCDENR) has implemented buffer rules in several river basins to reduce nonpoint source pollution of the state's streams and rivers.

Recently, Professor Mark Brinson at East Carolina University (ECU) and his colleagues developed a method to evaluate the quality of the riparian zone of low (1st and 2nd) and high (3rd and 4th) order coastal plain streams in both rural and urban settings (Brinson et al. 2006, Rheinhardt et al. in press). This technique incorporates Riparian Zone Width and several physical and biological field assessments into metrics that collectively form an index of stream network condition. Each stream network chosen for assessment includes several randomly sited reaches that cover approximately 10 percent of the stream length in that network. Reaches are 300 feet in length and extend outward for 90 feet perpendicular to each stream bank. The riparian reach is subdivided into 30-foot blocks. Vegetative cover and type and other associated metrics then are calculated for each riparian zone reach and the associated stream channel. The technique was developed primarily as an assessment of the riparian zone as an ecosystem and, consequently, focuses primarily on the physical and biological integrity of the riparian zone and the associated stream channel.

Briefly, the riparian assessment method (Rheinhardt et al. in press) includes nine individual metrics (eight for rural low order streams) that are incorporated into two summary scores, which collectively form indicators of the quality of the riparian zone (Riparian Zone Condition) and the stream channel (Channel Condition). Four individual metrics (Riparian Zone Cover, Channel-Riparian Zone Connection, Factors Affecting the Riparian Zone, and Habitat Quality of the Riparian Zone) are used in calculations associated with the riparian zone evaluation, and six (Near-Stream Cover, In-Stream Woody Structure, Sediment Regime, Channel-Riparian Zone Connection, Pollution Affecting the Stream, and Stream Bank Stability) are used in those associated with the evaluation of the stream channel. These summary scores then are averaged to produce a final score (Cumulative Function Score) that describes the overall conditions existing within an individual reach (see Appendix A for an example of his field assessment form, which gives a complete discussion of the logic behind each of the metrics used in the coastal plain riparian assessment method, shows how individual metrics are weighted, and provides details of the calculations).

The NC Ecosystem Enhancement Program (EEP) currently is using the riparian assessment method in the NC coastal plain. Audience discussions following presentations by Dr. Brinson to several state agencies have suggested that his riparian assessment method might be applied statewide as an inexpensive tool to predict water quality of streams in a watershed based on buffer quality, which also could be used as a premise for future mitigation through preserving and restoring riparian buffers. This idea is based on the concept that the existence of a good buffer along a stream protects water quality. However, the interrelationships between stream water quality and riparian buffer quality are very complex. This raises concern about the appropriateness of adopting new methodology without adequately testing the assumption that buffer quality is well correlated with stream water quality. Even if field data clearly substantiate the relationships between riparian buffer quality and stream water quality, a technique developed for use in the coastal plain still may not be applicable to other physiographic provinces in the state without significant modification.

Benthic macroinvertebrate populations, particularly insect larvae, are useful and reliable indicators of stream water quality (Carmago et al. 2004, Lenat 1988, Armitage et al. 1983, Hilsenhoff 1977). These organisms effectively integrate water quality over time and provide a more cost-effective and reliable assessment of long-term conditions existing within a stream than periodic water sampling for chemical analysis. The NCDENR uses benthic macroinvertebrate diversity as one metric in determining the relative quality of streams and for rating streams as "impaired" or "unimpaired" (NC Division of Water Quality Biological Assessment Unit. 2003).

This project was funded by a Section 319 grant to examine the coastal plain riparian assessment method in terms of stream biology. The relationships between individual and summary metrics of the riparian assessment protocols and stream water quality were examined using benthic macroinvertebrate populations as indicators. The potential for using a modified version of these protocols in the piedmont and mountain physiographic provinces also was evaluated. Coastal plain riparian assessment metrics were compared with metrics of the DWQ stream habitat assessment method. We also examined the relationships between individual and summary metrics of the DWQ stream habitat assessment protocols (NC Division of Water Quality Biological Assessment Unit. 2003) and stream water quality using benthic macroinvertebrate populations as indicators.

PURPOSE AND GOALS

The objectives of this study were: 1) to examine the relationships between riparian zone quality and stream water quality (as indicated by stream biology) at sites in the coastal plain where the riparian assessment technique was developed; 2) to determine if and how this method can be applied to piedmont and mountain streams; and 3) to use the information gained in this study to develop new buffer policies and measurement techniques that may be used by the DWQ and other local, state, or federal agencies to protect NC streams from nonpoint runoff; and 4) to provide guidance to the NC Ecosystem Enhancement Program's (EEP) policy for stream and riparian buffer mitigation.

DELIVERABLES

The following deliverables were required by the 319 grant.

- Final report describing the results, conclusions, and recommendations from this study

- Presentation of the results of our study at a professional meeting (to be presented at the Annual Meeting of the Southeastern Water Pollution Biologists Association, Cordele, GA, November 16, 2006).

METHODOLOGY

Field and Laboratory Procedures

The primary objective was to examine the relationship between water quality and the metrics used in the coastal plain riparian assessment protocols. Consequently, the initial studies focused on watersheds in the coastal plain (Figure 1), which were part of the original research used in calibrating the metrics in the coastal plain riparian assessment protocols (Brinson et al. 2006).

Stream Biology. Benthic macroinvertebrates were collected between August 31 and September 2, 2005, using the DWQ Qual 4 methodology (NC Division of Water Quality Biological Assessment Unit 2003) at fourteen sites in six watersheds in the coastal plain (Table 1) and were immediately preserved in the field with 100% ethanol. Low-order coastal plain streams often stop flowing or are entirely dry under the summer climatic conditions. This presents problems for biological assessments made during these time, particularly those which make inferences based on EPT taxa (Davis et al. 2003). To avoid this situation and facilitate relevant comparisons, only streams which had discernible flow on the dates of collection were used in this study. All macroinvertebrate collection sites except for Phillipi Branch were located at or just below points in which the riparian assessment method had been applied previously to characterize riparian zone quality (see Appendix B for coordinates of all riparian assessment reaches). There was at least one 300-foot riparian assessment reach immediately upstream from each of our macroinvertebrate collection sites. Subsequently, with the assistance of Dr. Brinson and his graduate students, a riparian assessment was conducted at Phillipi Branch at the site of benthic macroinvertebrate collection.

In the laboratory, all macroinvertebrates collected at each site were identified to the lowest feasible taxon (genus and species, whenever possible). A biotic Index (BI) was calculated for each collection site using tolerance values (Lenat 1993) and DWQ protocols (NC Division of Water Quality Biological Assessment Unit 2003). Tolerance values reflect the relative sensitivities of different taxa to environmental stressors. High values represent species that are widely tolerant of many environmental stressors, whereas low values represent species that are sensitive and which are good indicators of environmental stressors. The primary taxonomic references for identification of benthic macroinvertebrates included Epler (1996, 2001), Kathman and Brinkhurst (1999), and Brigham et al. (1982).

Water Quality and Other Field Procedures. Water temperature, dissolved oxygen concentration (DO), and specific conductivity were measured *in situ* with a YSI Model 85 meter, and pH was measured with an Accumet AP61 portable pH meter. All of these are routine field measurements used by DWQ at all stream assessment sites. Specific conductivity is of particular interest as it often reflects the presence of physicochemical stressors within a watershed that have significant effects on the benthic macroinvertebrates in a stream (Pond and Passmore, no date). Digital photographs (upstream and downstream) were taken, and a DWQ stream habitat assessment form was completed for a 300-foot reach immediately above each benthic macroinvertebrate collection site to see how well different DWQ metrics might correspond to metrics used in the riparian assessment technique.

Application of a Modified Version of the Coastal Plain Riparian Assessment Method to Piedmont and Mountain Watersheds

Site Selection. A secondary objective was to determine whether a modified version of the riparian assessment protocols developed by Dr. Brinson and his colleagues (Rheinhardt et al. in press) might also be applied to piedmont and mountain watersheds. Consequently, our subsequent study focused largely on sites in the piedmont and, to a limited extent, in the mountain physiographic provinces (Figure 1). Sites were selected in rural and urban settings where recent (2000 or later) benthic macroinvertebrate data already were available (Table 1) from the DWQ Biological Assessment Unit (BAU). Each of these piedmont and mountain riparian assessment sites included a 300-ft. reach immediately above the BAU benthic macroinvertebrate collection site and one to several additional 300-ft. reaches upstream within the watershed above each macroinvertebrate collection site to facilitate a more complete assessment than would be possible using only a single reach per watershed (see Appendix B for coordinates of all riparian assessment reaches). The additional reaches were sited primarily on the basis of accessibility from road crossings to avoid in so far as possible any conflicts with private landowners. Preliminary reconnaissance then was conducted to determine the actual accessibility and the suitability of each site. Riparian zone quality subsequently was evaluated on a total of fifty-eight (58) 300-ft. reaches (including 16 reaches at BAU macroinvertebrate collection sites) within the piedmont and mountain physiographic provinces (Table 1) using the modification of the riparian assessment technique discussed below. Benthic macroinvertebrates were collected from one additional piedmont site, Hatcher’s Run, using Qual 4 methodology. Each site was photographed digitally, a DWQ stream habitat assessment form was filled out for all reaches, and field water quality variables were measured within each reach when flowing water was present.

Modification of the Riparian Assessment Protocols. Riffles (including the boulders and cobbles and, in some cases, riprap) and pool sequences are the primary habitats for benthic macroinvertebrates in piedmont and mountains streams. The Major Habitats available for benthic macroinvertebrates in coastal plain streams, however, are large woody debris and root mats. True true riffles with boulders and cobbles occur only rarely and were absent at all of the relatively unaltered sites in the coastal plain. The two individual metrics in the riparian assessment protocol that evaluated stream habitat quality, specifically In-Stream Woody Structure and Sediment Regime, were not really appropriate for application to piedmont and mountain streams. Accordingly, and in consultation with Dr. Brinson, these two metrics were modified to make them more appropriate for evaluation of habitat quality in piedmont and mountain streams (Table 2). Unlike the coastal plain protocols, these metrics were not calibrated with reference sites along a gradient of alteration, but were based on best professional judgment that these metrics (e.g., Embeddedness and Riffle Makeup) were indicative of piedmont and mountain stream conditions.

For piedmont and mountain watersheds, In-Stream Woody Structure became Habitat Types; this was split into two equal subcategories to include Major Habitats (riffles, pools, and riprap) and Minor Habitats [root mats, leaf packs, sticks, large ($\geq$ 4 inches diameter) woody debris, and macrophytes]. Each subcategory scored 0 to 50 points, for a total of 100 points maximum for the modified metric, Habitat Types. For piedmont and mountain watersheds, Sediment Regime became Substrate Structure and was split into two equal subcategories to include Embeddedness and Riffle Makeup (which evaluated the relative mix of boulders, cobbles, gravel, sand, etc. in the stream bed). Each subcategory also scored 0 to 50 points, for a total of 100 points maximum for the modified metric Substrate Structure. These two metrics were considered approximately equivalent to the respective two original metrics from the original protocols developed for the coastal plain. These two modified metrics received the same total weight in the modified version of the riparian assessment techniques as the two original metrics in the method as originally developed for the coastal plain. All of the other metrics of the original coastal plain riparian assessment protocols seemed to be appropriate regardless of physiographic province and remained unmodified. Thus, the total possible score for a mountain or piedmont assessment was the same as the total possible score for a coastal plain assessment, which potentially would facilitate some comparability among physiographic provinces. This modification of the coastal plain method for the piedmont and mountains is analogous to the differences in the two versions of the stream habitat forms that DWQ uses for the piedmont/mountains vs. the coastal plain streams.

Data Analyses and Statistical Procedures

Grouping of Data for Analyses. The data were separated into two basic groups: a) data from the specific reaches associated with macroinvertebrate collections (hereafter called “biology reaches”); and b) all data available from throughout a specific watershed or catchment, including that from the biology reach and all additional reaches assessed upstream from a specific biology reach (hereafter called watershed data). The logic in doing so was based on the premises that water quality at a particular point in a watershed or catchment (e.g., at a specific biology reach) integrates everything that occurs upstream from that point and that data collected throughout the watershed or catchment should be more representative of the conditions in that specific watershed or catchment than stream habitat data or riparian assessment data collected at the biology reach alone. For the purpose of statistical analysis, the watershed data are averages of each of the riparian assessment metrics or each of the DWQ stream habitat assessment metrics from all reaches upstream of and including the associated biology reach. All comparisons of the riparian assessment data from the coastal plain were analyzed separately from the combined data collected from the piedmont and mountain provinces. The logic in doing this was based on the fact that the modified riparian assessment protocols used in the piedmont and mountains had not been calibrated against a range of reference conditions (from best to worst possible) for urban and rural high and low order streams in these physiographic provinces.

Statistical Procedures. Since different watersheds and catchments may vary substantially in size, different benthic macroinvertebrate sampling methods may be used, depending on the specific watershed’s drainage area. This poses a problem for direct comparisons among watersheds where different collection procedures were used. To avoid this issue in so far as possible, all coastal plain benthic macroinvertebrate collections used the Qual 4 method regardless of stream size. The Qual 4 method normally is used for small streams having a total drainage area of less than 3 square miles. The BAU collected and assessed stream biology in all of our mountain sites and in all but one of the piedmont sites (Hatcher's Run) and used different field collection and assessment methods (full scale, Qual 5, Qual 4, and EPT) based on watershed size. The BI (which is based on all taxa, not just EPT taxa) was not used for the piedmont and mountain streams, because of the multiple collection protocols would not provide valid comparisons. All biology data from Qual 5, Qual 4, and EPT collection protocols were normalized to the equivalent of the full-scale assessment using a correction factor of 1.15 x EPT taxa (Eaton and Lenat 1991). This corrected (i.e. normalized) EPT value was used in correlation analyses and all subsequent statistical procedures that included influences of other variables on stream biology.

Simple correlation analysis was used for the initial evaluation of our data sets to look for possible interrelationships between individual and summary riparian assessment metrics and our indicators of water quality, including biology (EPT) and field water quality measurements (temperature, dissolved oxygen, specific conductivity, and pH). DWQ metrics were similarly compared with the riparian assessment metrics and with field water quality indicators using simple correlations. All correlations which had a significance value (P) $\leq$ 0.100 and had a correlation coefficient $\geq$ 0.50 or $\leq$ - 0.50 were accepted as **potentially useful** because of the relatively small size of the data set and the inherent variability of this type of environmental assessment data. It is very difficult to sort out pertinent relationships from a series of correlation coefficients and significance probabilities. Correlation does not prove cause and effect relationships but rather suggests that two variables may be related in some manner. Many apparently strong positive or negative correlations produced in an analysis of this nature are products of indirect relationships that have no real physicochemical or biological significance. Hence one must not rely heavily on this type of data analysis. Consequently, correlation analysis was used only as an initial cut to eliminate data relationships that were without any doubt totally unrelated. For further evaluation, recursive partitioning analysis was used to elucidate which riparian assessment metrics had the most influence on EPTs and on each of our field water quality variables. This procedure partitions data according to relationship between X and Y values, creating a partition tree (SAS Institute 2005). It finds a set of groupings of X values that best predict a Y value by searching all possible groupings. Similarly, recursive partitioning analysis was used to examine the influences of DWQ metrics and field water quality variables influence on EPTs.

RESULTS AND DISCUSSION

Correlating the Riparian Assessment Procedure with Stream Biology and Water Quality in the Coastal Plain

Stream Biology. Both individual and summary metrics of the riparian assessment technique correlated very poorly with stream biology in the coastal plain. Two of these metrics, Near-Stream Cover and Pollution Affecting the Stream, correlated slightly with EPT taxa when only the immediately adjacent biology reach was included in the analysis (Table 3). There were no acceptable correlations between any of the individual metrics or summary metrics and stream biology when watershed data were analyzed. None of the summary metrics fell within the acceptable ranges (P $\leq$ 0.100 and r $\geq$ 0.50) and were not considered further. Among the individual metrics, Pollution Affecting the Stream had the highest correlations at both watershed and biology reach levels but was significant ($P \leq 0.100$ and $r \geq 0.5$) only when examined at the level of the biology reach. Higher values of this metric indicate that there are few or no obvious pollution sources entering the reach directly or entering within 600 ft upstream of the reach. At the biology reach level, Near-Stream Cover also fell within our acceptable ranges. The inverse relationship between Near-Stream Cover and EPT taxa probably was a reflection of the high abundance of Baetid mayflies in reaches where little to no cover was present. Three to five species of Baetid mayflies usually are abundant in most North Carolina coastal plain streams having flow during the warmer months.

Recursive partitioning analyses suggested that Habitat Quality of the Riparian Zone was the single riparian assessment metric that contributed the most toward explaining the variability of the EPT data for the coastal plain (Figure 2) when the biology reaches were examined alone. On a watershed basis, however, Pollution Affecting the Stream contributed the most toward the EPT variability in the coastal plain (Figure 3).

Water Quality. Stream Bank Stability was the only riparian assessment metric that correlated highly and significantly with any of the water quality field variables at the biological reach level, and then only with temperature (Table 4). At the watershed level of analysis, Riparian Zone Cover, Near-Stream Cover, and Habitat Quality of the Riparian Zone had acceptable correlations with temperature; Stream Bank Stability also correlated very strongly with conductivity (Table 4). We are not sure why the correlations of Near-Stream Cover and Riparian Zone Cover with temperature were positive; this seems counterintuitive, as increasing vegetative cover would be expected to insulate the stream somewhat from sunlight and result in lower temperatures than would be expected in streams with little cover. A strong negative correlation of temperature with Habitat Quality of the Riparian Zone seems to reflect the extent of vegetative cover within the riparian zone. Decreasing Stream Bank Stability also would increase the loading of dissolved salts in the water and, hence increase the specific conductivity.

Recursive partitioning suggested that In-Stream Woody Structure was the only riparian assessment metric that accounted for any substantial part of the variation in specific conductivity when analyzed at either the level of biology reaches (Figure 4) or watershed (Figure 5). We are uncertain why there might be a relationship between this metric and conductivity, unless the metric possibly reflects a unrelated relationship with another riparian assessment metric that does influence conductivity. Partitionings that would help explain the variation in dissolved oxygen or temperature revealed no strong pattern.

Comparison of Correlations with DWQ and Riparian Assessment Summary Scores. Summary scores from the DWQ stream habitat assessment form (Total Score) and the riparian assessment technique (Cumulative Function Score) are used as overall descriptors of habitat quality in streams and riparian zones, respectively. High summary scores on either assessment (both summary scores range from 0 to 100) should indicate high quality habitat. In the present study, both the DWQ Total Score and the riparian assessment Cumulative Function Score correlated very poorly with field water quality variables and stream biology in coastal plain streams (Table 5). Even when the Cumulative Function Scores were averaged over the watersheds, correlations did not improve. These data showed clearly that the summary scores from either field procedure might be useful indicators of habitat quality but definitely were not indicative of water quality within the streams.

Correlating the Modified Riparian Assessment Procedure with Stream Biology and Water Quality in the Piedmont and Mountains

Stream Biology. In the piedmont and mountains (data combined due to small number of mountain sites), none of the correlations between EPT and the riparian assessment metrics fell within our acceptable ranges when we included only the biology reaches in the analysis (the two highest correlations are shown in Table 6). Analyses on a watershed or catchment basis revealed that three riparian assessment metrics (Near-Stream Cover, Riparian Zone Cover, and Pollution Affecting the Stream) were both significant and had correlations $\geq$ 0.50 or $\leq$ -0.50 (Table 6). Stream Bank Stability also had a significant correlation ($P < 0.058$) and $r = 0.48$, which is just below our accepted value. It is interesting to note also that Pollution Affecting the Stream also was the factor with the highest correlation for the biology reaches in the piedmont and mountains as well as in both the biology reaches and the watersheds for the coastal plain. Pollution Affecting the Stream also had the highest correlations and significance when we examined the data combined over all physiographic provinces.

Recursive partitioning analysis on the piedmont and mountain streams at the biology reach level suggested that Pollution Affecting the Stream was the major factor influencing EPT variability, followed by Habitat Quality of the Riparian Zone (Figure 6). At the watershed level analysis, Stream Bank Stability was most important, followed by Substrate Structure - a modified riparian assessment metric (Figure 7). When all physiographic provinces were included in this analysis, Pollution Affecting the Stream and Near-Stream Cover were the top two factors in the biology reaches (Figure 8) as well as at the watershed level (Figure 9).

Water Quality. More water quality variables and riparian assessment metrics had acceptable correlations in the piedmont and mountains than in the coastal plain biological reaches and watersheds. This observation suggests that the relationships between water quality and riparian zone quality in the piedmont and mountains either may be considerably more complex than those in coastal plain watersheds or more predictable and, therefore, less random. At both the biology reach and watershed levels, three riparian assessment metrics (Stream Bank Stability, Riparian Zone Cover, and Near-Stream Cover) appeared consistently associated with one or several water quality variables (Table 7). The fact that significant correlations of these same three riparian assessment metrics with water quality variables also occurred in the coastal plain (Table 4) suggested that several of the metrics from the original method for the coastal plain possibly may have application with minimal modification outside of the coastal plain. Considerably more data are needed to verify this with a more rigid degree of certainty, however. A difference we noted was that, unlike the coastal plain, at the watershed level, there were no significant correlations between Habitat Quality of the Riparian Zone and any of the water quality variables in the piedmont and mountain systems. This suggests that this riparian assessment metric may have greater influence on water quality in the coastal plain than in the piedmont and mountains.

In the piedmont and mountain provinces, recursive partitioning suggested that Stream Bank Stability was the overriding factor explaining specific conductivity, especially at the watershed level (Figures 10 and 11). When conductivity was examined over all physiographic provinces combined, Substrate Structure (Sediment Regime for coastal plain) and Pollution Affecting the Stream were the primary factors for the biology reaches alone (Figure 12), but Stream Bank Stability was still the major contributing factor at the watershed level followed by Near-Stream Cover (Figure 13).

<u>Comparison of Correlations with DWQ and Riparian Assessment Summary Scores</u>. The DWQ Total Score and the riparian assessment Cumulative Function Score (using the modified version of metrics) for piedmont and mountain watersheds (Table 8) were even more poorly correlated poorly with field water quality variables and stream biology in the piedmont and mountain watersheds than occurred in the coastal plain (Table 5). These extremely poor correlations further reinforce the conclusion that summary scores from either the DWQ stream habitat assessment protocol or the riparian assessment protocols (including our current modification for the mountains and piedmont) do not correlate well with water quality within the streams.

Relationships Between Riparian Assessment Metrics and DWQ Metrics

Examination of coastal plain field data revealed that, with a few notable exceptions, individual and summary metrics used in the riparian assessment procedure were very poorly correlated with the metrics used in the DWQ stream habitat assessment form. One DWQ metric, Riparian Zone Width, was positively correlated with six individual and four summary riparian assessment metrics (Table 9). Light Penetration was correlated positively with two individual and three summary riparian assessment metrics, and Bottom Substrate was negatively correlated with Pollution Affecting the Stream (Table 9). All of the individual metrics correlating well with Riparian Zone Width and Light Penetration are functions of the overall quality and intactness of the riparian zone. The DWQ metric, Bottom Substrate, reflects water flow and sediment movement into and within the stream channel. Pollution Affecting the Stream is the primary riparian assessment metric that encompasses these phenomena. High scores for either of these metrics theoretically would indicate good conditions. We are uncertain why these scores were negatively correlated.

Relationships Among DWQ Metrics, Stream Biology, and Water Quality

A total of seven individual metrics comprise the Total Score of the DWQ habitat assessment form for coastal plain streams and eight metrics for the mountain and piedmont streams. There were no acceptable correlations between any of the individual DWQ metrics or Total Score and stream biology (EPT). Kathy Herring (formerly of the DWQ BAU) examined BAU benthic macroinvertebrate and habitat data from more than 300 streams and similarly found that benthic macroinvertebrate data correlated poorly with the DWQ stream habitat assessment Total Score (unpublished memorandum, BAU, February 2000). She attributed this to the fact that stream macroinvertebrate populations are influenced by conditions within the watershed as well as by physical habitat. She found that some individual metrics, including In-Stream Habitat and the riffle metrics, correlated well with the biological data "because they are generally the most productive habitat areas." In the current study, we found that In-Stream

Habitat had the highest correlation with EPTs of any of the individual DWQ metrics. Even though this correlation was significant, the value r = 0.46 indicates that the correlation still was not high. In our study, we found very poor, non-significant correlations of EPTs with other riffle/pool metrics.

Field water quality variables also correlated poorly with most DWQ habitat metrics. There were only three significant correlations (Table 10), and all had only marginally acceptable r values (~ -0.50). Water quality at any point within a stream will reflect conditions in the entire watershed or catchment above the sampling point. However, the DWQ habitat assessment metrics reflect only conditions observed within 100-meter reaches. Our inclusion of several habitat evaluation reaches in each stream watershed data set should have provided a more valid assessment than would have occurred from a single downstream reach where biological and/or water quality data were collected. Even averaging data from multiple reaches, however, only provides a partial description of conditions within the watershed. Entrance of pollutants at points above and/or between the assessed reaches may have a major impact on downstream water quality and stream biology. Consequently, correlations between the DWQ stream habitat metrics and either water quality variables or stream biology often are not strong.

Correlations between biology (EPT) and the field water quality variables we measured were very poor (Table 11). Only three were significant, and all of these had r values outside of our stated acceptable range. Of these three, specific conductivity was the one variable that was most likely influenced least by conditions occurring immediately within the individual reaches where we conducted the DWQ habitat assessments. Our data suggest strongly that EPTs are being influenced by very complex interactions among several habitat and water quality factors, including most likely many variables that we did not measure in the present study. The input of pollutants above and between our assessed reaches also would be involved.

Other Concerns

During the course of this study, several ideas surfaced that potentially could improve the utility of the riparian assessment method, particularly if the protocols were revised for piedmont and mountain watersheds. The first is the separation of rural from urban watersheds, which seems to be somewhat arbitrary. Dr. Brinson (personal communication) has indicated that one of the current projects with the EEP is to determine whether and how this might be done. It also was unclear how dense a suburban development had to be before an adjacent watershed became "urban". Further, it seemed that the change from a rural watershed to an urban watershed (e.g., Phillipi Branch to Greens Mill Run flowing through the ECU campus) represented a continuum of conditions and gradual increments, rather than an abrupt change with a single definitive breakpoint. The connection between riparian zone quality and stream water quality (at least as reflected by stream biology) might be clearer if future revisions of the riparian assessment methods treated the rural to urban transition as a continuous process. The urban assessment protocols seem to incorporate most of the conditions of the rural protocols and possibly could be usable for this purpose, at least with some modifications. This needs further consideration.

Another issue that could be addressed if the riparian assessment method were revised was the separation of smaller watersheds from larger ones on the basis stream order. Stream order determination currently is based on the branching pattern of the stream irrespective of the total length of stream channel or the total drainage area. Although any other stream size and flow classification system would have its problems, it is obvious that a 3rd order stream formed from a series of many small branching 1st order streams is not the hydrological and ecological equivalent of a 3rd order stream formed by a few ditched natural streams with a large number of zero order ditches draining additional land above them. The former scenario seems to have streams much more prone to drying than similar order streams in the latter scenario. Stream sizes and flow regimes are continuous variables that are functions of the total drainage areas more so than of the patterns and frequency of stream branching within their respective watersheds. A confounding factor within the coastal plain is that drainage areas of a stream often are more affected by ditch connections than by elevation. The use of some other indicator, such as watershed size (i.e. **actual** drainage area) or shape (Smith 2001) might prove to be a more quantitative and consistent measure of a stream's size and flow characteristics than order.

CONCLUSIONS

- The generally poor correlations of the riparian assessment method and the DWQ stream habitat assessment method with either stream biology or field water quality variables in the coastal plain indicates that assessments of riparian zone or stream habitat quality are not good predictors of water quality or stream biology.

- Several individual metrics of the riparian assessment method that describe stream habitat conditions (Pollution Affecting the Stream, Stream Bank Stability, and the modified metric, Substrate Structure) had somewhat higher correlations with stream biology or water quality than the summary scores. This suggests that weighting of the riparian assessment method more heavily toward these stream metrics might improve correlations with water quality and stream biology.

- Riparian assessments provide a valid, general description of environmental conditions existing within a large watershed but may not effectively assess or pinpoint specific problems originating in a small watershed or an individual catchment. A more detailed evaluation is needed to locate and evaluate problems originating within a small watershed or individual catchment that are of sufficient magnitude to affect adversely the biological integrity of the larger watershed.

- The results of this study suggest that factors having the most influence on water quality and stream biology may be quite different in the coastal plain than in the piedmont and mountains.

- The modified version of the coastal plain riparian assessment technique applied to the piedmont and mountain watersheds in this study should not be used until all metrics have been clearly deemed appropriate for these physiographic provinces. This will necessitate substantial further research to calibrate each metric against a full range of reference conditions from poorest to highest quality for low and high order streams in both rural and urban watersheds in the piedmont and mountains.

- The separation of rural from urban watersheds in a riparian assessment procedure seems arbitrary, as riparian quality represents a continuum ranging from the best conditions (e.g., a rural forested watershed) to worst (e.g., large expanses of pavement in an urban watershed) irrespective of its setting. The connection between riparian zone quality and stream water quality might be clearer if the riparian assessment procedure considered the rural to urban transition as a continuous process rather than as separate, discrete entities. This possibly could be done by modifying the urban protocols.

- Stream order is an inexact measure of stream size and does not reflect clearly the actual flow regime of the stream. The use of another indicator, such as drainage area, might prove to be a more quantitative and accurate measure of a stream's size and flow characteristics than stream order.

RECOMMENDATIONS

- Assessments of riparian zone quality and stream habitat quality are not reflected in stream biology and should not be used as predictors of stream water quality.

- Existing protocols could be modified somewhat to place heavier weighting on stream metrics and possibly improve correlations between the coastal plain riparian assessment method and water quality as reflected by stream biology.

- The modified coastal riparian assessment technique in its current format is not appropriate and should not be used for application to mountain and piedmont watersheds.

- Assessments of riparian zone quality need to be treated as one continuum from best conditions to worst conditions irrespective of the watershed's setting (i.e. rural or urban).

- Future revisions of the coastal plain riparian assessment technique, as well as any protocol developed for the piedmont and mountains, should consider actual drainage area (including contributing ditches that cross the natural watershed boundaries) as the measure of stream size and flow regime.

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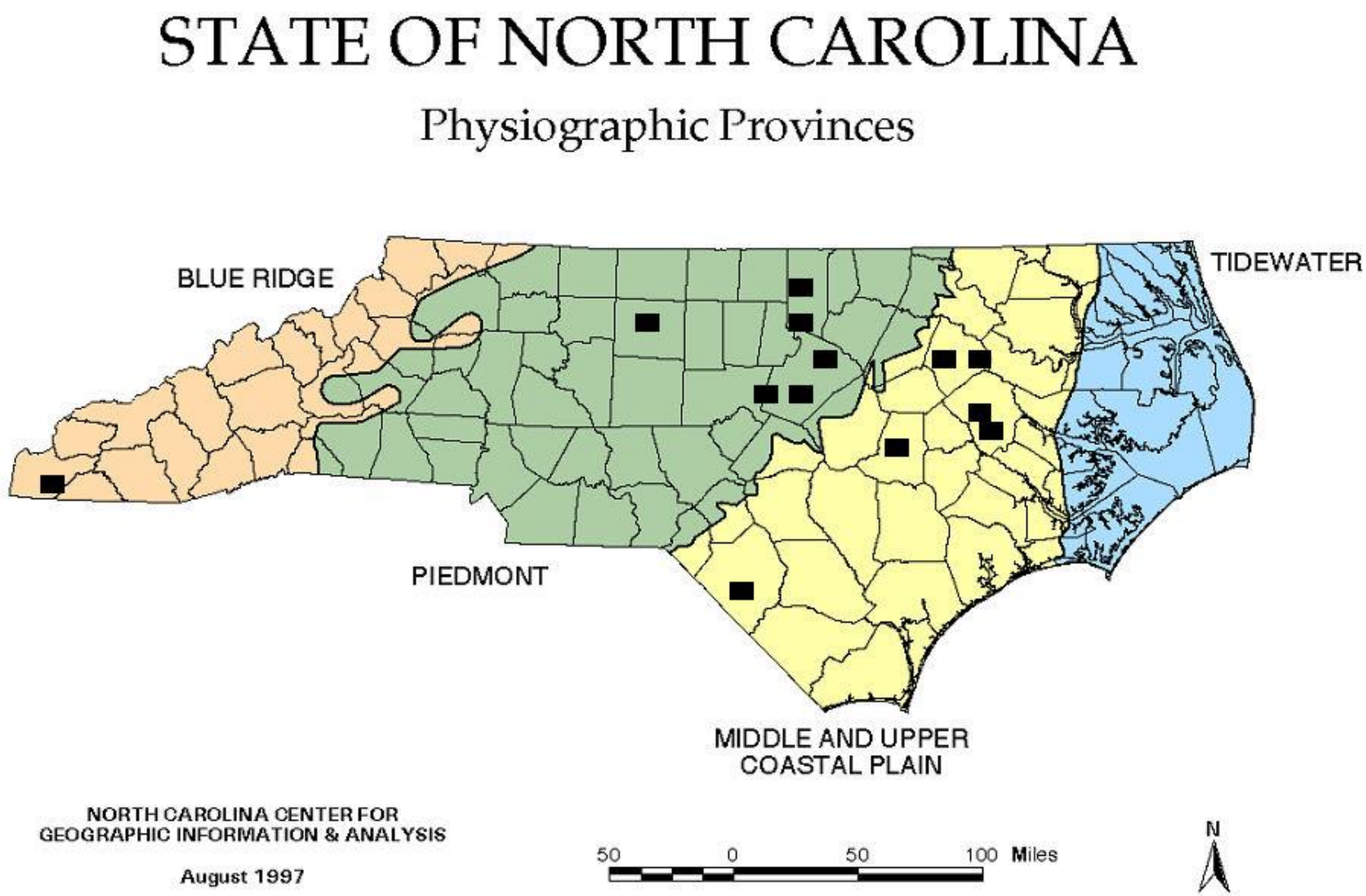


Figure 1. Locations of watersheds included in the present study.

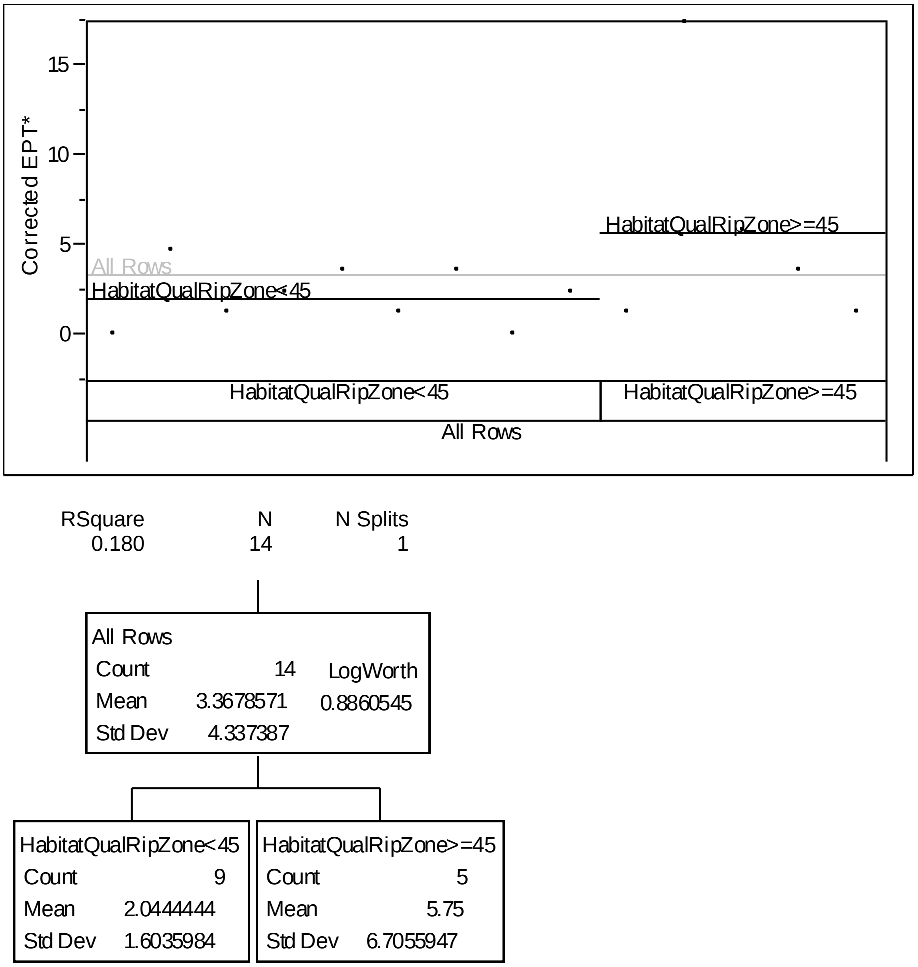
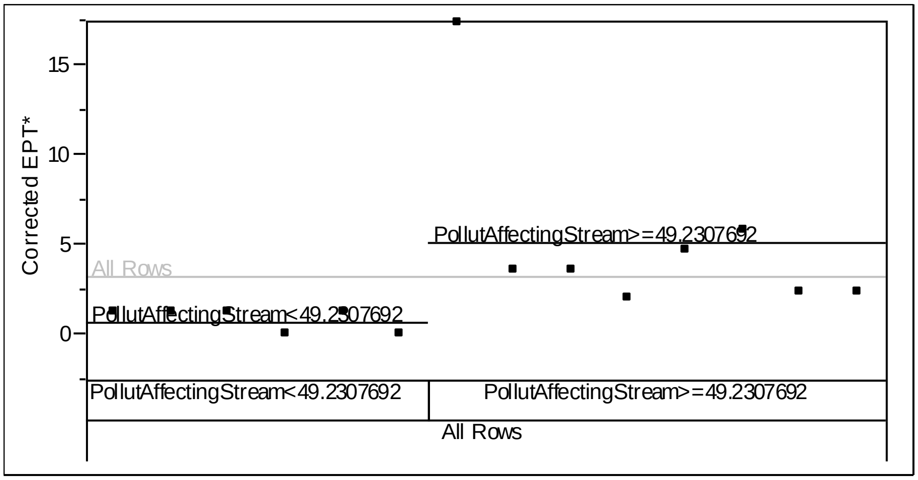


Figure 2. Recursive partitioning analysis of stream biology against riparian assessment metrics at biology reaches in the coastal plain.



RSquare	N	N Splits
0.264	14	1

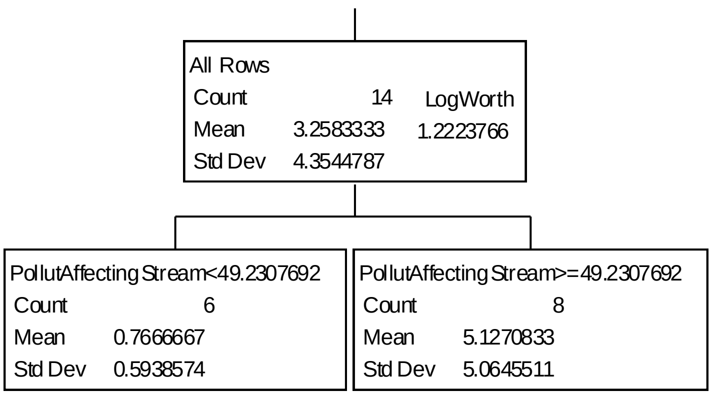
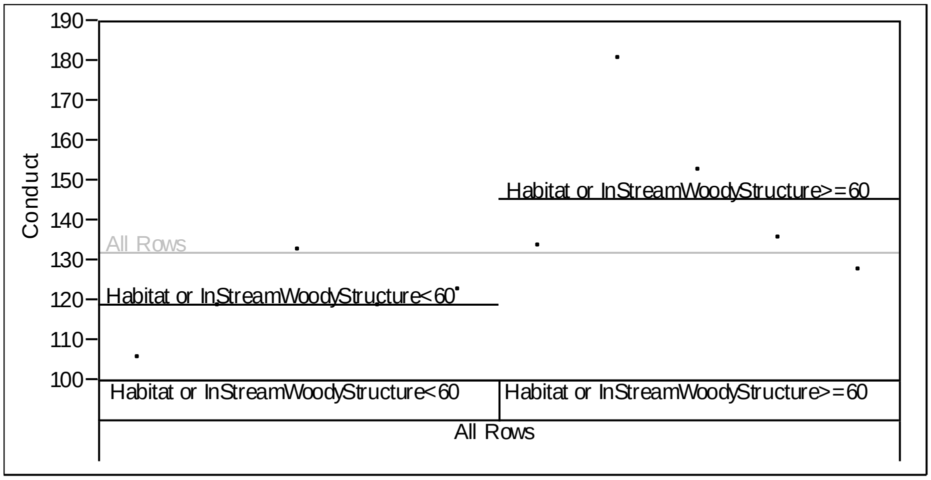


Figure 3. Recursive partitioning analysis of stream biology against riparian assessment metrics over watersheds in the coastal plain.



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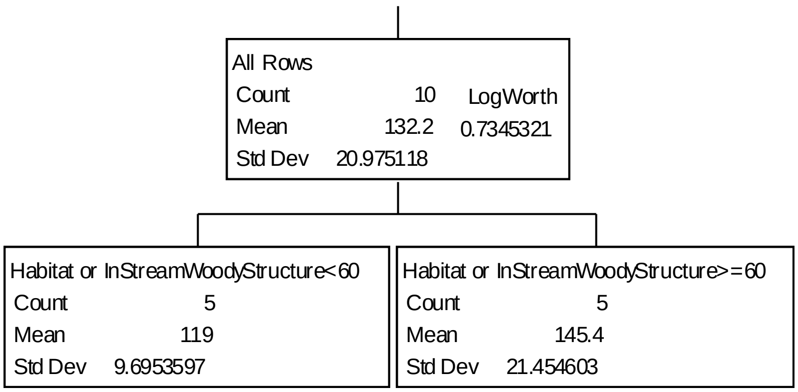


Figure 4. Recursive partitioning analysis of specific conductivity against riparian assessment metrics at biology reaches in the coastal plain.

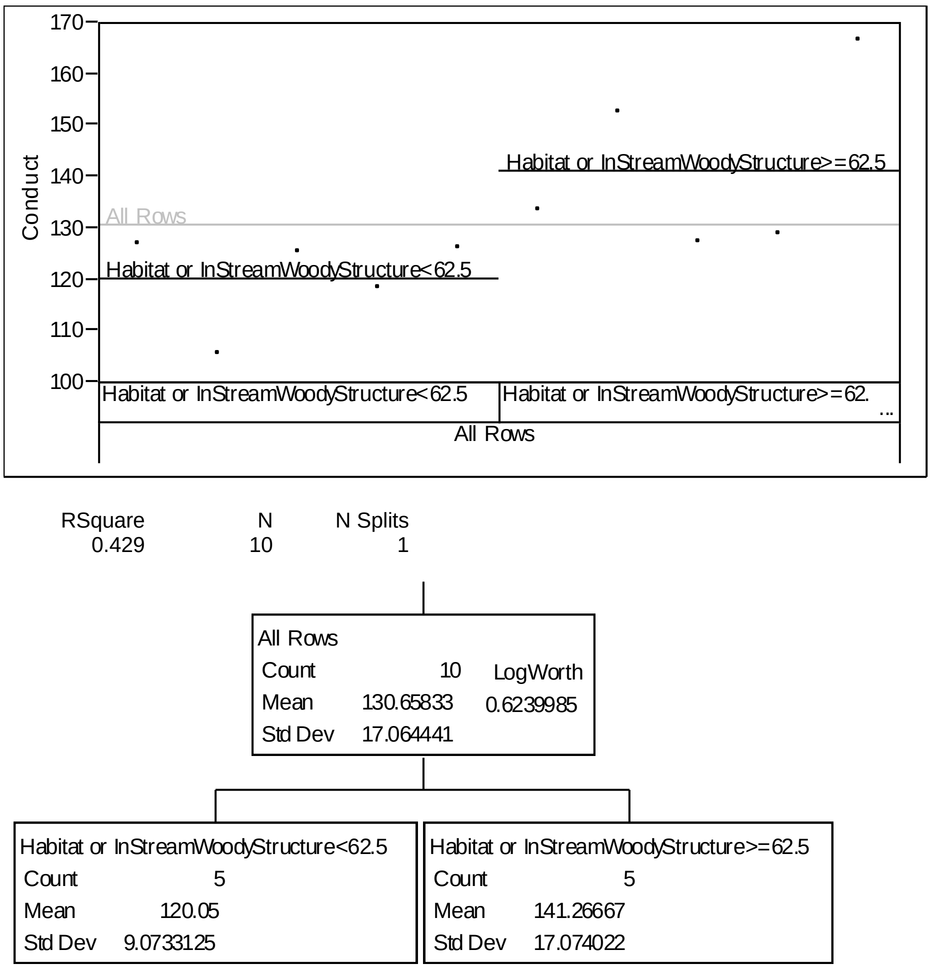


Figure 5. Recursive partitioning analysis of specific conductivity against riparian assessment metrics over watersheds in the coastal plain.

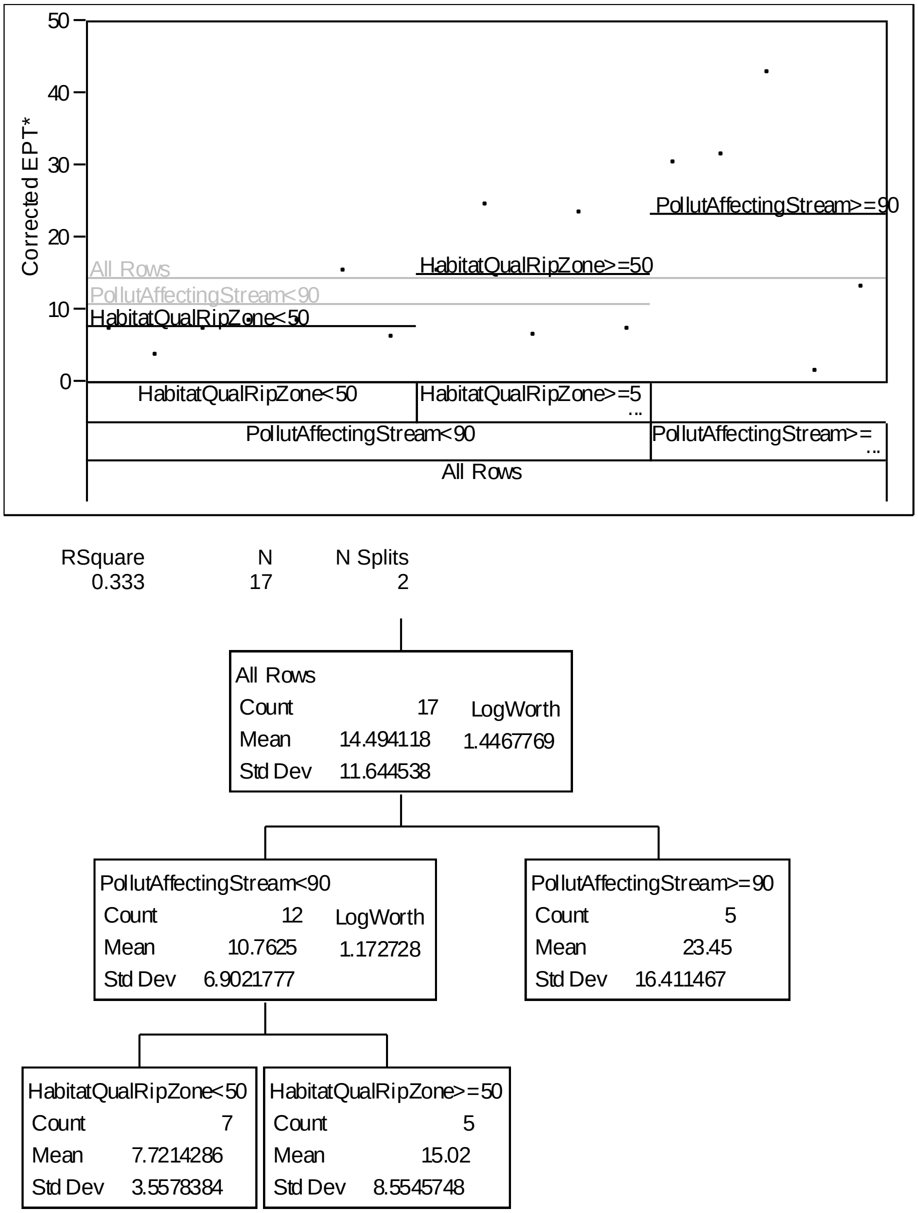
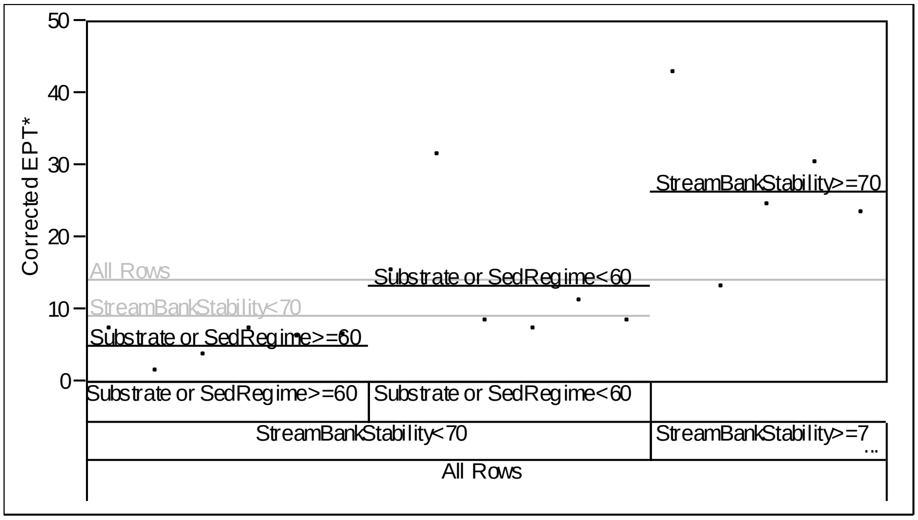


Figure 6. Recursive partitioning analysis of stream biology against riparian assessment metrics (modified version) at biology reaches in the piedmont and mountains.



RSquare	N	N Splits
0.577	17	2

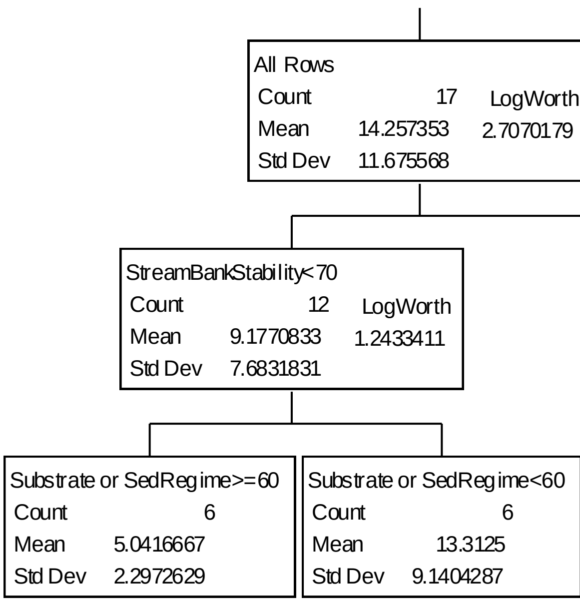
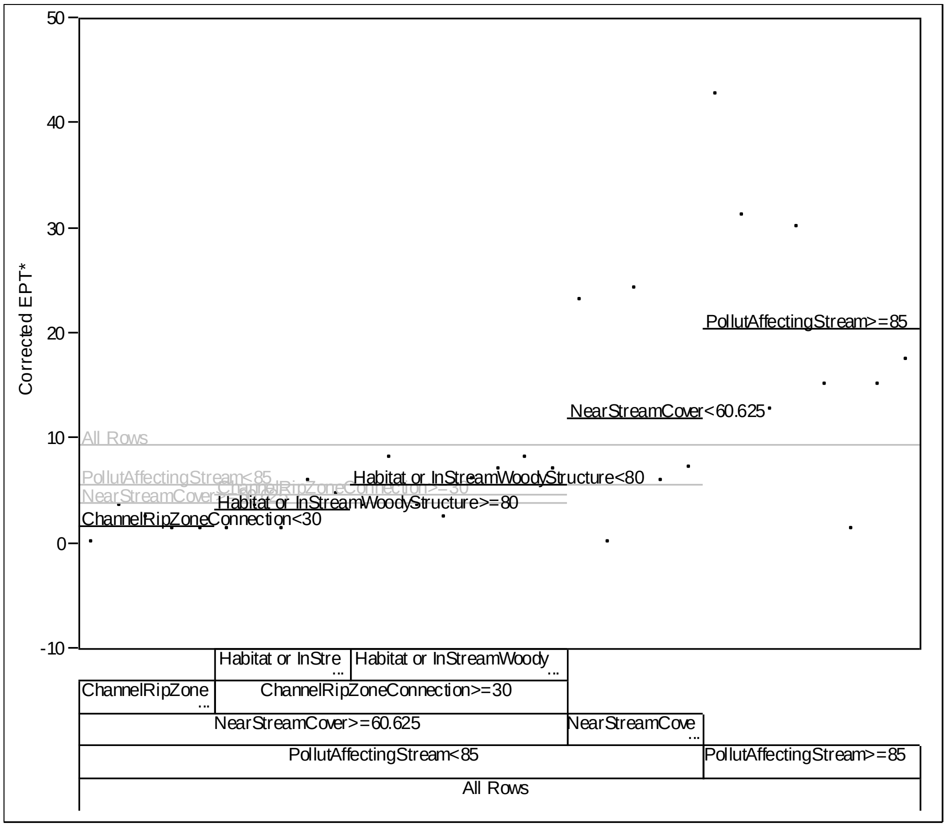


Figure 7. Recursive partitioning analysis of stream biology against riparian assessment metrics (modified version) over watersheds in the piedmont and mountains.



RSquare	N	N Splits
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Figure 8. Recursive partitioning analysis of stream biology against riparian assessment metrics (modified version used for the piedmont and mountain reaches) at biology reaches for all provinces combined.

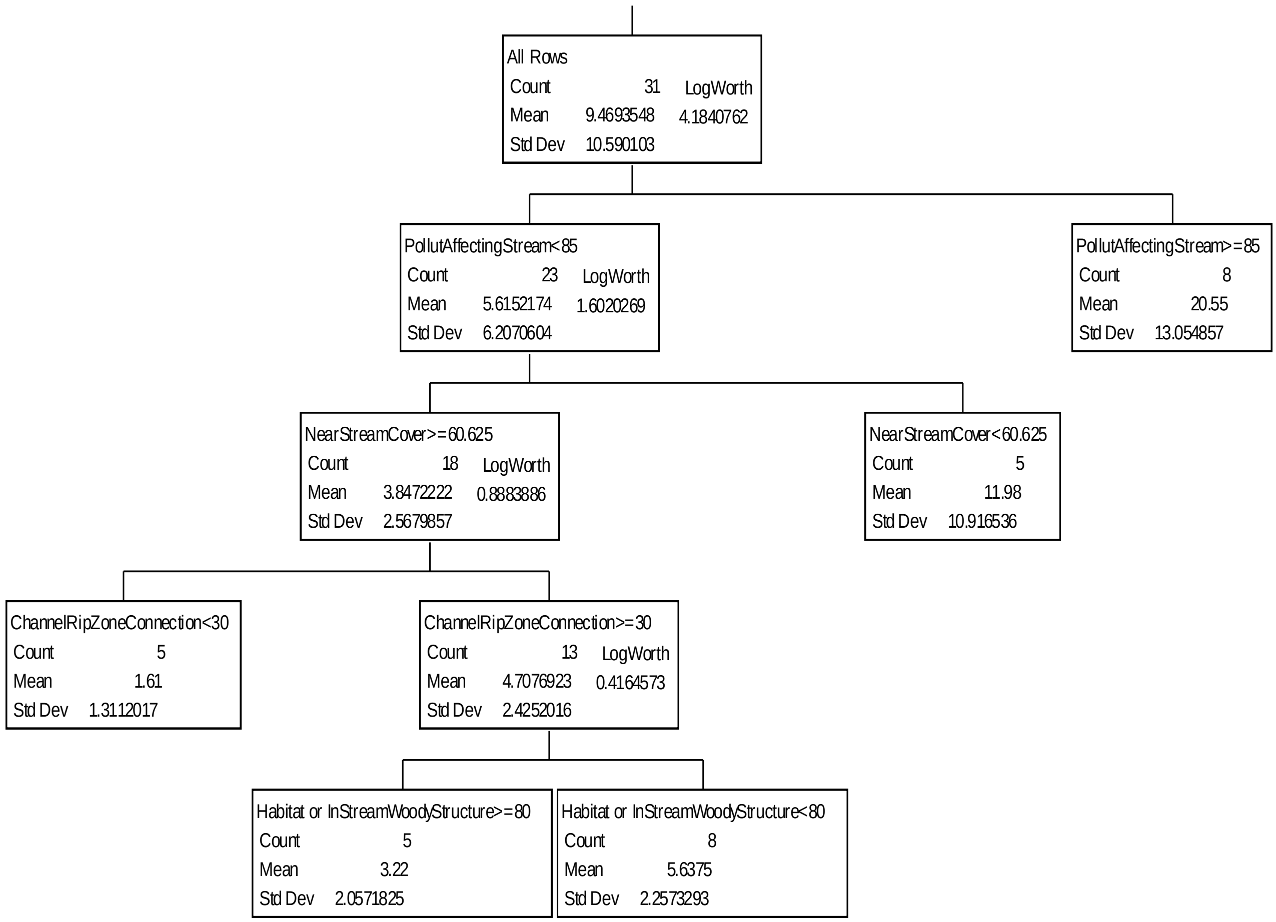

Figure 8, continued.

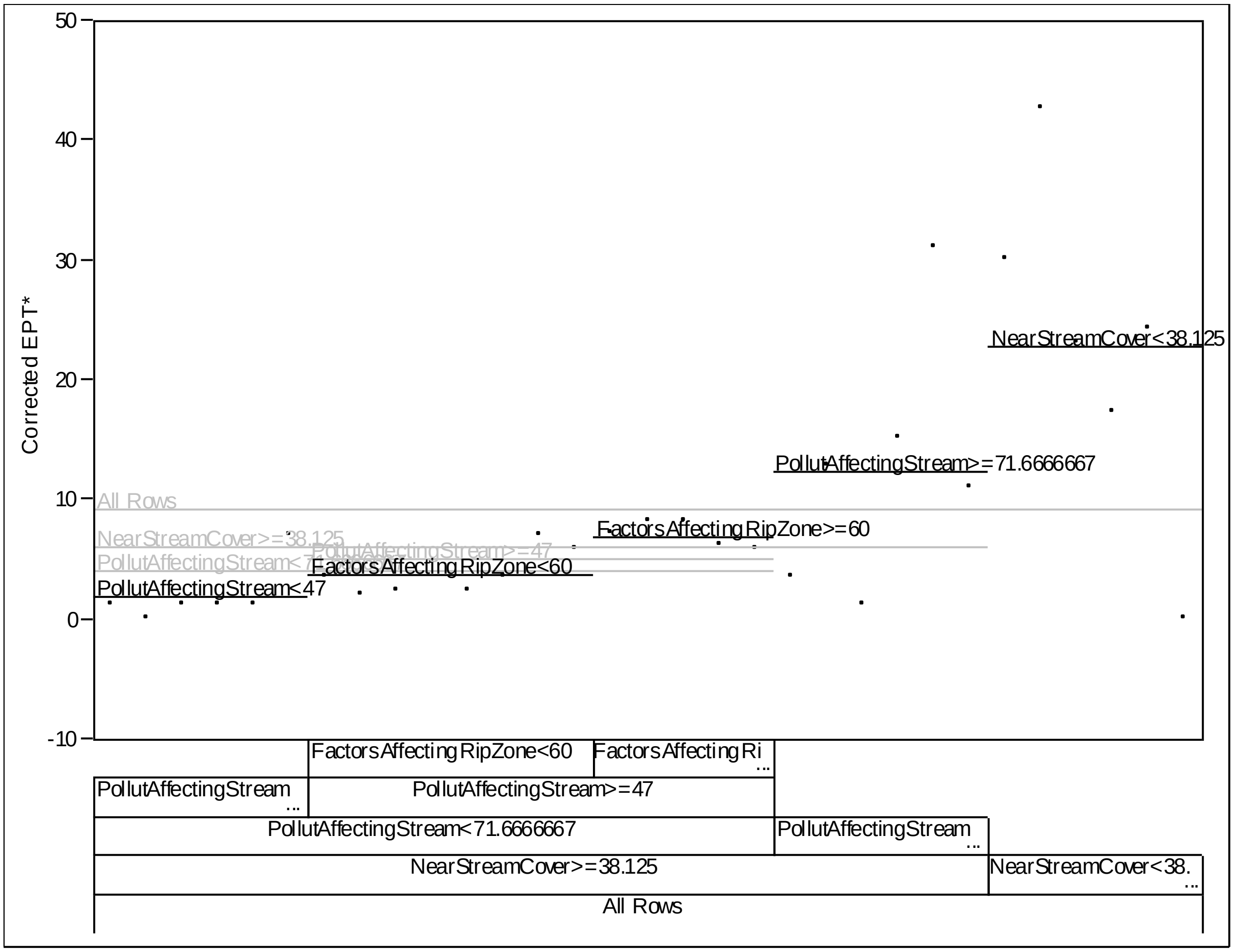

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Figure 9. Recursive partitioning analysis of stream biology against riparian assessment metrics (modified version used for the piedmont and mountains) over watersheds for all provinces combined.

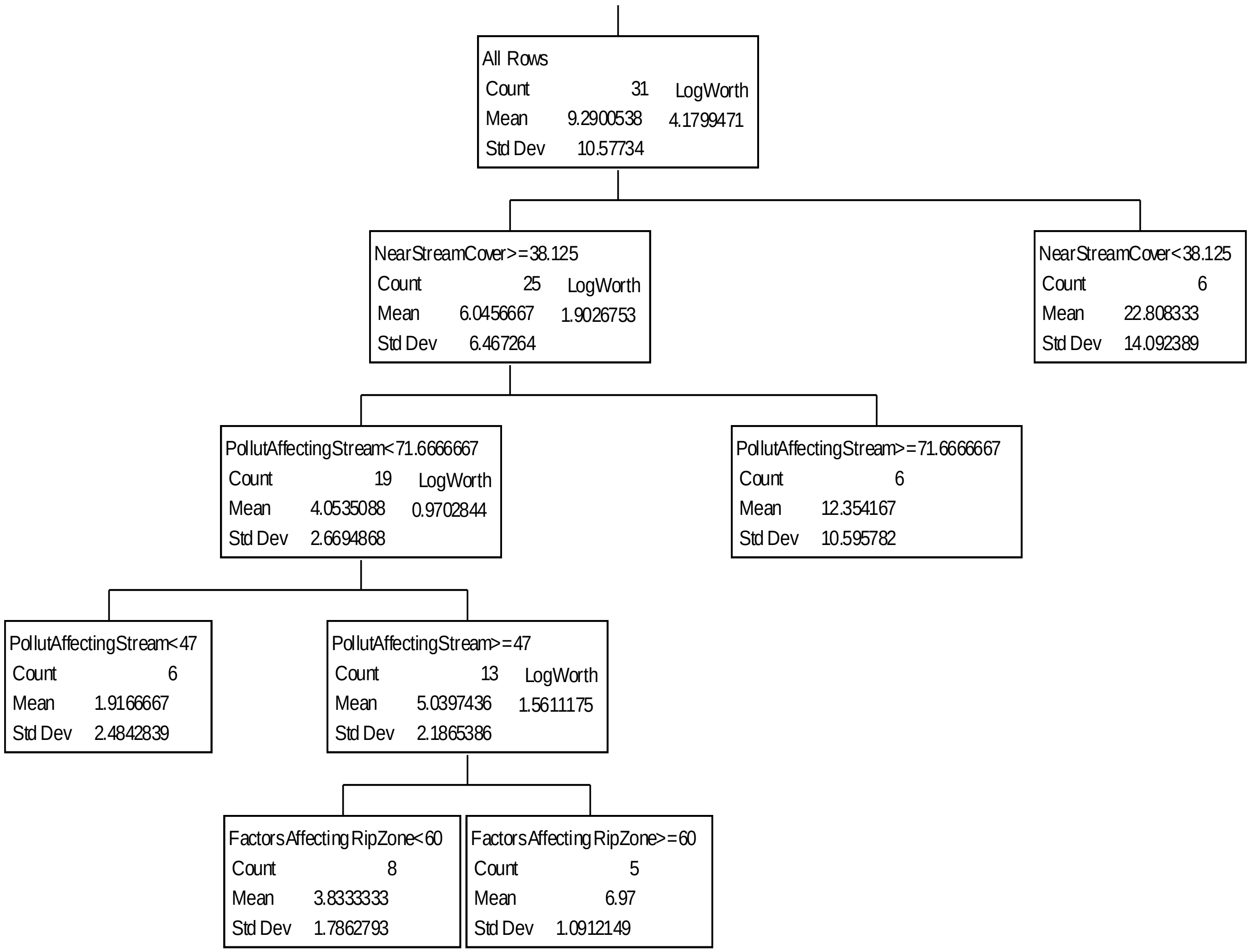
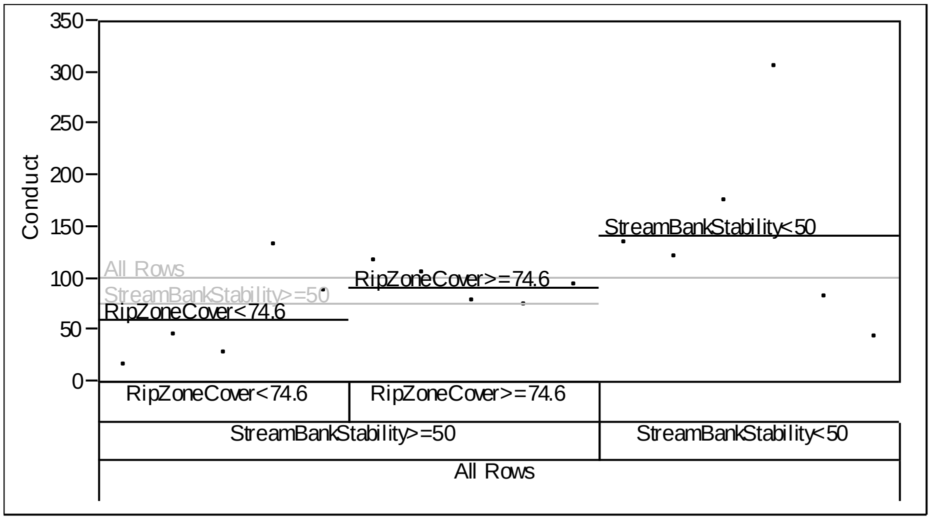


Figure 9, continued.



RSquare	N	N Splits
0.264	16	2

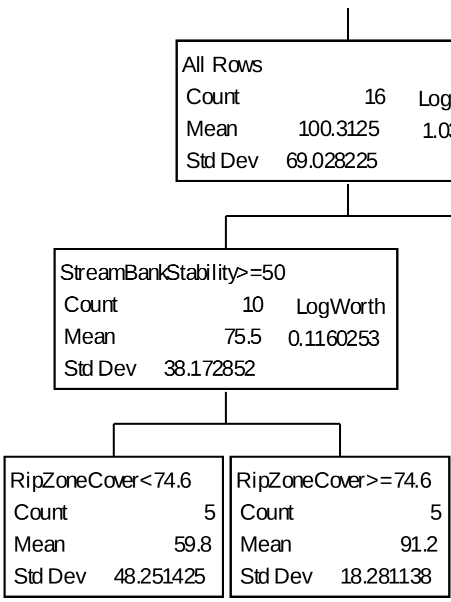
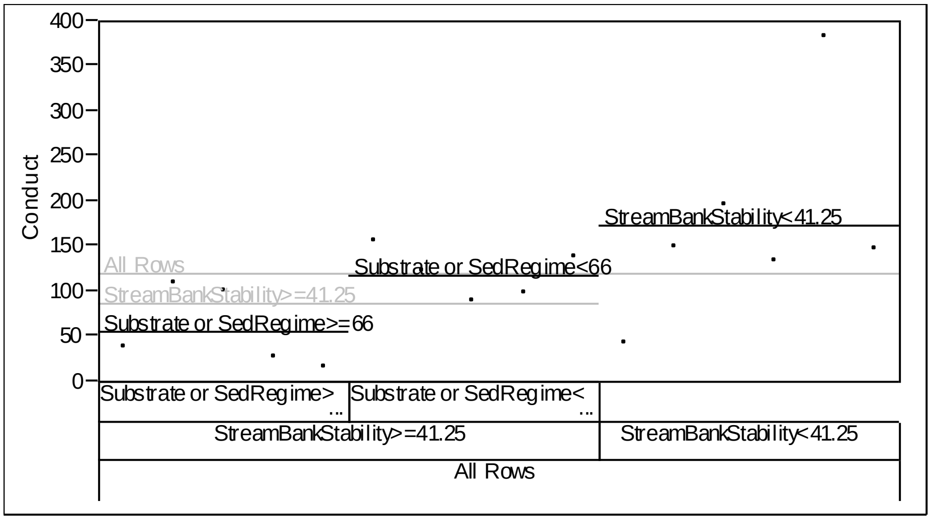


Figure 10. Recursive partitioning analysis of specific conductivity against riparian assessment metrics (modified version) at biology reaches in the piedmont and mountains.



RSquare	N	N Splits
0.333	16	2

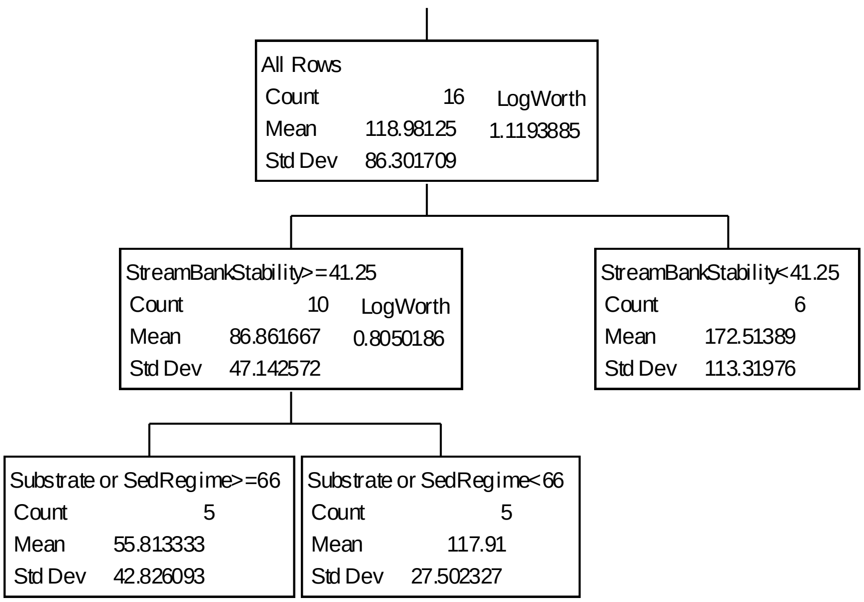
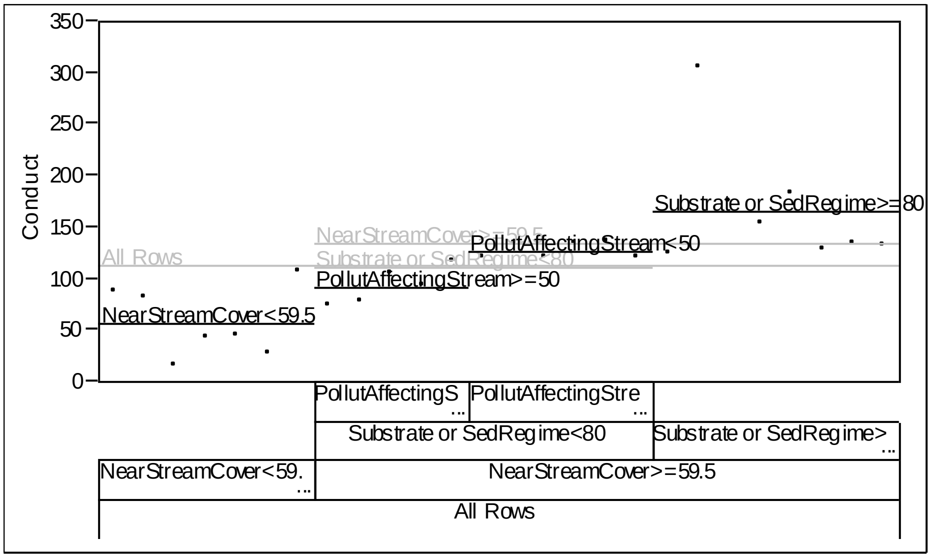


Figure 11. Recursive partitioning analysis of specific conductivity against riparian assessment metrics (modified version) over watersheds in the piedmont and mountains.



RSquare	N	N Splits
0.585	26	3

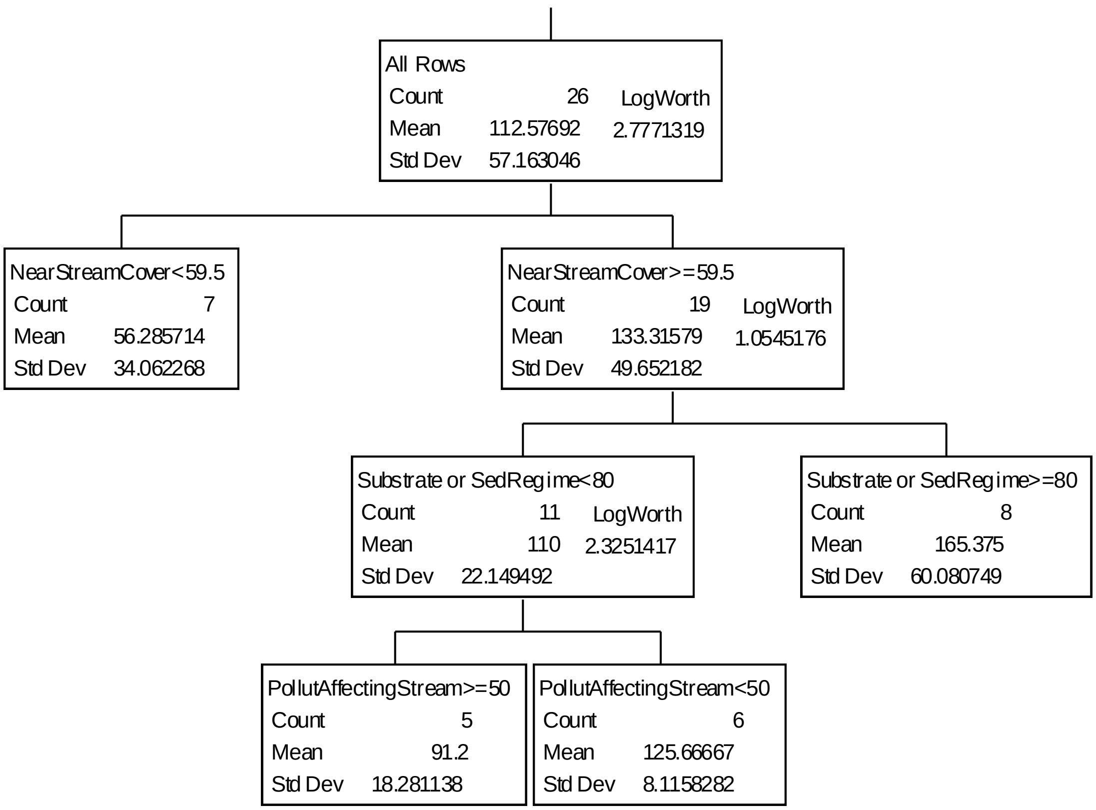
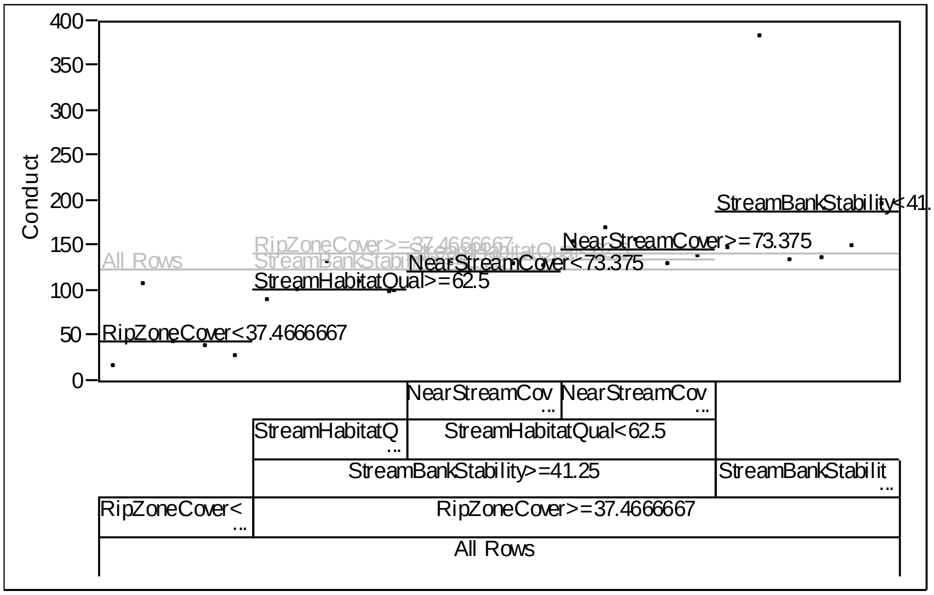


Figure 12. Recursive partitioning analysis of specific conductivity against riparian assessment metrics (modified version used for the piedmont and mountains) at biology reaches for all provinces combined.



RSquare	N	N Splits	Imputes
0.535	26	4	2

Figure 13. Recursive partitioning analysis of specific conductivity against riparian assessment metrics (modified version used for the piedmont and mountains) over watersheds for all provinces combined.

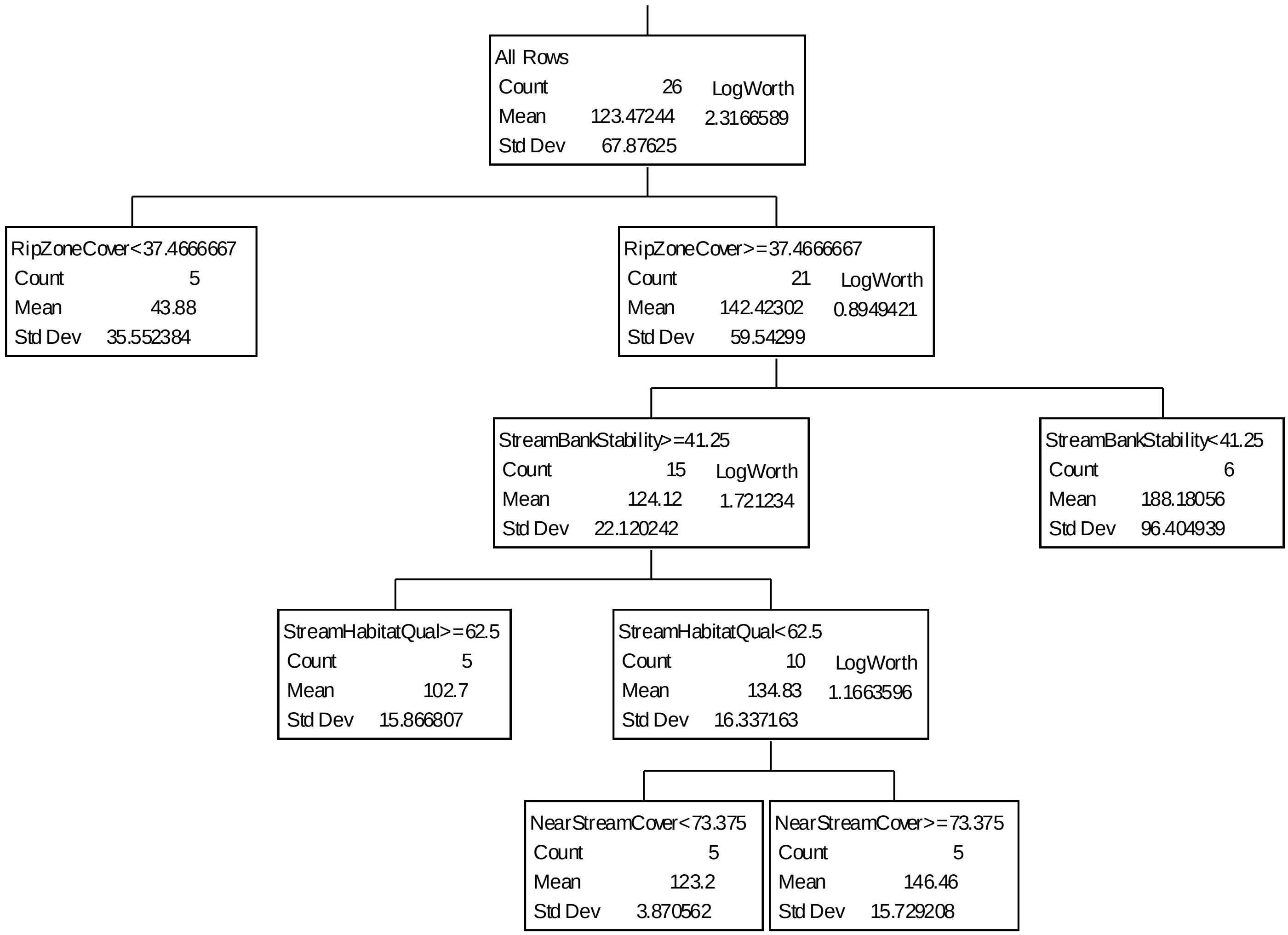


Figure 13, continued.

Table 1. Locations of benthic macroinvertebrate sampling points.*

Stream Name	Site Designation	River Basin	Physiographic Province	Type	Latitude	Longitude
Pipes Branch	Pipes Branch	Hiwassee	Mountains	RHO	35.093715	83.914541
Sudderth Branch	Sudderth Branch at SR 1537 Mission Rd	Hiwassee	Mountains	RLO	35.068703	83.936403
Fall Branch	Fall Branch at Fall Br Rd above US 64	Hiwassee	Mountains	RHO	35.083342	83.986089
Graham Branch	Graham Branch at 1531 above Hendrix Rd	Hiwassee	Mountains	RHO	35.096403	83.960603
Gibbs Creek	Gibbs Creek below Grey Rock Rd	Tar	Piedmont	RHO	36.190902	78.514875
Sand Creek	Sand Creek at SR 1623 - north site	Tar	Piedmont	RHO	36.182746	78.559081
Hatchers Run	Hatchers Run at US 15	Tar	Piedmont	RHO	36.274544	78.608054
Coon Creek	UT Coon Creek at SR 1515 - Horner Siding Rd	Tar	Piedmont	RHO	36.354811	78.568071
Toms Creek	Toms Creek at SR 2044 - Ligon Mill Rd	Neuse	Piedmont	UHO	35.909132	78.527344
Speight Branch	Speight Branch at SR 1385 - Lily Atkins Rd	Neuse	Piedmont	ULO	35.725472	78.755103
Williams Creek	UT Williams Creek at McKenan Dr	Neuse	Piedmont	UHO	35.736828	78.810161
Williams Creek	Williams Creek above US1 at Edinburgh St	Neuse	Piedmont	UHO	35.736392	78.800003
Bolin Creek	Tanbark Branch at Umstead Park	Neuse	Piedmont	UHO	35.920105	79.064856
Bolin Creek	Bolin Creek at SR 1777 - Homestead Rd	Neuse	Piedmont	RHO	35.943170	79.086084
Horsepen creek	UT Horsepen Creek (King George Branch) at Friendly Ave	Cape Fear	Piedmont	ULO	36.088892	79.908336
Horsepen creek	UT Horsepen Creek at Chance Rd	Cape Fear	Piedmont	ULO	36.126406	79.890047
Horsepen creek	Horsepen Creek at Radar Rd	Cape Fear	Piedmont	UHO	36.096114	79.922503
Hendricks Creek	above Hospital Rd. off US 64 bypass	Tar	Coastal Plain	ULO	35.917684	77.564219
Hendricks Creek	below Northern Blvd. (NC 44)	Tar	Coastal Plain	ULO	35.913764	77.560411
Hendricks Creek	below Sunset Rd.	Tar	Coastal Plain	UHO	35.905632	77.554132
Hendricks Creek	below Wilson St.	Tar	Coastal Plain	UHO	35.897488	77.540213
Hendricks Creek	below St. James St.	Tar	Coastal Plain	UHO	35.894949	77.538356
Reedy Branch	above 10th St (NC 33)	Tar	Coastal Plain	ULO	35.602189	77.348883
Green Mill Run	below Memorial Dr.(NC 11/43)	Tar	Coastal Plain	UHO	35.585456	77.395476
Green Mill Run	S of 10th St (NC 33)- N of High School	Tar	Coastal Plain	UHO	35.602846	77.361654
Phillipi Branch	NC 33	Tar	Coastal Plain	ULO	35.589591	77.262443
UT Cow Swamp	at SR 1722	Tar	Coastal Plain	RLO	35.529175	77.259373
UT Crisp Creek	above NC 42	Tar	Coastal Plain	RLO	35.891357	77.340605
Reedy Branch	below Wayne Mem. Dr. (SR 1556)	Neuse	Coastal Plain	RLO	35.425207	77.926085
UT Stoney Creek	behind Mall - N of US 13 & W of US 70	Neuse	Coastal Plain	RLO	35.379365	77.940880
Moss Neck Swamp	below Alvin Rd.	Lumber	Coastal Plain	RLO	34.683088	79.149020

*All benthic macroinvertebrate sampling points are located at or just below a riparian assessment reach.

Table 2. Modified metrics for high order (top) and low order (bottom) riparian assessments for piedmont and mountain watersheds.

SRC Indicator	Condition Category (High Order) Relatively unaltered	Somewhat altered	Altered	Severely altered
Habitat Types (Major Habitats = riffles and pools, riprap. Minor Habitats = root mats, leaf packs, sticks, woody debris ≥ 4" in diameter, and macrophytes tooted in the channel.)				
1a. Major habitats	Riffles and pools make up > 50% of stream	Riffles and pools make up 25 - 50% of stream	Riffles and pools make up 10 to 25% of stream	Riffles and pools buried, make up < 10% of stream
Score =	50 45	40 35 30	25 20 15	10 5 0
Score 0 to 50 (if riprap or impervious channel lining is present and represents > 25% of total available habitat, the score should be at the lowest end of the category best categorizing the reach)				
1b. Minor habitats	Four (4) habitat types or more common in channel	Two (2) habitat types common; two (2) rare	Three (3) habitat types rare OR 1 common and one (1) rare	One (1) or two (2) habitat types present but rare
Score =	50 45	40 35 30	25 20 15	10 5 0
Score 0 to 50				
Substrate Structure (Whenever riffles and pool sequences are entirely absent, scores below for both embededness and riffle makeup should be recorded as = 0.)				
2a. Embededness	0 to 25% embededed; little to no silt present	25 t 50% embeded; clear at baseflow, turbid at high flow; silt deposits in pools	50 to 75% embeded; silt covers everything but riffles	75 to 100% embeded; turbid at low flow; silt covers everything
Score =	50 45	40 35 30	25 20 15	10 5 0
Score 0 to 50 (if riprap or impervious channel lining is present and represents > 25% of total available habitat, the score should be at the lowest end of the category best categorizing the reach)				
2b. Riffle Makeup	Mix of boulders, cobbles, and gravel; very little to no sand	Mostly cobbles and gravel with moderate amounts of sand; boulders rare or absent	Largely gravel and sand; cobbles absent or very rare; boulders absent	Sand, clay, and bedrock only; gravel absent or rare; cobbles and boulders absent
Score =	50 45	40 35 30	25 20 15	10 5 0
Score 0 to 50 (if riprap or impervious channel lining is present and represents > 25% of total available habitat, the score should be at the lowest end of the category best categorizing the reach)				

SRC Indicator	Condition Category (Low Order) Relatively unaltered	Somewhat altered	Altered	Severely altered
Habitat Types (Major Habitats = riffles and pools, riprap. Minor Habitats = root mats, leaf packs, sticks, woody debris > 0.5" indiameter, and macrophytes tooted in the channel.)				
1a. Major habitats	Riffles and pools present, strongly defined; occurring regularly, > 30% of stream	Riffles and pools present, well defined;irregularly distributed; 20 to 30% of stream	Riffles and pools present but weakly defined; infrequent; 10 to 20% of stream	Riffles and pools poorly defined or entirely absent; < 10% of stream
Score =	50 45	40 35 30	25 20 15	10 5 0
Score 0 to 50 (if riprap or impervious channel lining is present and represents > 25% of total available habitat, the score should be at the lowest end of the category best categorizing the reach)				
1b. Minor habitats	Three (3) or more habitat types common in channel	Two (2) habitat types common OR 1 type common + 2 rare	Three (3) habitat types rare OR 1 type common and 1 rare	One (1) or two (2) habitat types present but rare
Score =	50 45	40 35 30	25 20 15	10 5 0
Score 0 to 50				
Substrate Structure (Whenever riffles and pool sequences are entirely absent, scores below for both embededness and riffle makeup should be recorded as = 0.)				
2a. Embededness	0 to 25% embededed; little to no silt present	25 to 50% embeded; clear at baseflow, turbid at high flow; silt deposits in pools	50 to 75% embeded; silt covers everything but riffles	75 to 100% embeded; turbid at low flow; silt covers everything
Score =	50 45	40 35 30	25 20 15	10 5 0
Score 0 to 50 (if riprap or impervious channel lining is present and represents > 25% of total available habitat, the score should be at the lowest end of the category best categorizing the reach)				
2b. Riffle Makeup	Mix of boulders, cobbles, and gravel; very little to no sand	Mostly cobbles and gravel with moderate amounts of sand; boulders rare or absent	Largely gravel and sand; cobbles absent or very rare; boulders absent	Sand, clay, and bedrock only; gravel absent or rare; cobbles and boulders absent
Score =	50 45	40 35 30	25 20 15	10 5 0
Score 0 to 50 (if riprap or impervious channel lining is present and represents > 25% of total available habitat, the score should be at the lowest end of the category best categorizing the reach)				

Table 3. Correlations between biology and riparian assessment metrics for the coastal plain.

Variable	by Variable	Corr	N	Signif	Corr
Site Pairwise Correlations					
NearStreamCover	EPT Taxa	-0.51	14	0.062	
PollutAffectingStream	EPT Taxa	0.57	14	0.033	
Watershed Pairwise Correlations					
Substrate or SedRegime	Total Taxa	0.44	14	0.113	
PollutAffectingStream	Total Taxa	0.44	14	0.112	

Table 4. Correlations between water quality and riparian assessment metrics for the coastal plain.

Variable	by Variable	Corr	N	Signif	Corr
Site Pairwise Correlations					
StreamBankStability	Temp	-0.81	6	0.049	
Watershed Pairwise Correlations					
HabitatQualRipZone	Temp	-0.57	10	0.084	
StreamBankStability	Conduct	-0.72	8	0.045	
NearStreamCover	Temp	0.67	10	0.032	
RipZoneCover	Temp	0.72	10	0.019	

Table 5. Correlations between DWQ Total Score (DWQ-TS) or the riparian assessment procedure Cumulative Function Score (CFS) and various biological and physical indicators of water quality for coastal plain watersheds.

Variable	DWQ-TS (biology reach)	CFS (biology reach)	CFS (over watershed)
Temperature	-0.10	-0.28	-0.28
Dissolved oxygen, mg/L	-0.50	-0.45	-0.17
Specific conductivity	0.27	0.31	0.39
Total taxa	0.22	0.05	0.11
NCBI	0.15	0.08	-0.21
EPT taxa	-0.13	-0.01	-0.10
EPT abundance	-0.12	-0.25	-0.21

Table 6. Correlations between biology and riparian assessment metrics for the piedmont and mountains.

Variable	by Variable	Corr	N	Signif	Corr
Site Pairwise Correlations					
StreamBankStability	Corrected EPT*	0.38	16	0.142	
PollutAffectingStream	Corrected EPT*	0.38	17	0.128	
<u>Watershed Pairwise Correlations</u>					
StreamBankStability	Corrected EPT*	0.48	16	0.058	
PollutAffectingStream	Corrected EPT*	0.54	17	0.025	
RipZoneCover	Corrected EPT*	-0.60	17	0.011	
NearStreamCover	Corrected EPT*	-0.71	17	0.001	

Table 7. Correlations between water quality and riparian assessment metrics for the piedmont and mountains.

Variable	by Variable	Corr	N	Signif	Corr
Site Pairwise Correlations					
NearStreamCover	DO mg/L	0.54	12	0.072	
StreamBankStability	Temp	-0.49	15	0.064	
StreamBankStability	Conduct	-0.53	15	0.044	
NearStreamCover	Temp	0.52	16	0.038	
NearStreamCover	Conduct	0.53	16	0.036	
RipZoneCover	Conduct	0.53	16	0.033	
StreamBankStability	pH	-0.56	15	0.032	
Watershed Pairwise Correlations					
Substrate or SedRegime	DO mg/L	0.59	12	0.042	
Substrate or SedRegime	Temp	-0.52	16	0.037	
RipZoneCover	pH	0.56	16	0.023	
RipZoneCover	Temp	0.57	16	0.021	
NearStreamCover	Conduct	0.58	16	0.019	
RipZoneCover	Conduct	0.58	16	0.019	
NearStreamCover	pH	0.58	16	0.018	
StreamBankStability	Temp	-0.61	15	0.016	
StreamBankStability	Conduct	-0.62	15	0.014	
NearStreamCover	Temp	0.63	16	0.009	
StreamBankStability	pH	-0.69	15	0.005	

Table 8. Correlations between DWQ Total Score (DWQ-TS) or the riparian assessment procedure Cumulative Function Score (CFS) and various biological and physical indicators of water quality for piedmont and mountain watersheds.

Variable	DWQ-TS	CFS
Temperature	-0.47	-0.08
Dissolved oxygen, mg/L	0.01	0.21
Specific conductivity	-0.12	0.20
pH	-0.21	0.14
Corrected EPT	0.17	-0.06

Table 9. Correlations between riparian assessment metrics and DWQ stream habitat assessment metrics for the coastal plain.

Variable	by Variable	Corre	N	Signif	Corr
Site Pairwise Correlations					
PollutAffectingStream	3-Bottom Substr	-0.50	14	0.071	
ChannelCondition	7-Light Penetrat	0.51	14	0.065	
CumulativeFunctionScore	7-Light Penetrat	0.52	14	0.057	
ChannelRipZoneConnection	7-Light Penetrat	0.54	13	0.055	
StreamHabitatQual	7-Light Penetrat	0.53	14	0.053	
Habitat or InStreamWoodyStructure	7-Light Penetrat	0.58	14	0.030	
HabitatQualRipZone	8-Rip Zone Width	0.58	14	0.029	
Habitat or InStreamWoodyStructure	8-Rip Zone Width	0.62	14	0.018	
RipZoneCover	8-Rip Zone Width	0.62	14	0.017	
ChannelRipZoneConnection	8-Rip Zone Width	0.71	13	0.007	
RipHabitatQual	8-Rip Zone Width	0.73	14	0.003	
ChannelCondition	8-Rip Zone Width	0.74	14	0.003	
StreamHabitatQual	8-Rip Zone Width	0.74	14	0.003	
CumulativeFunctionScore	8-Rip Zone Width	0.75	14	0.002	
RipZoneCondition	8-Rip Zone Width	0.75	14	0.002	
FactorsAffectingRipZone	8-Rip Zone Width	0.76	14	0.002	

Table 10. Correlations between DWQ stream habitat assessment metrics and water quality over all physiographic provinces.

Variable	by Variable	Corr	N	Signif	Corr
<u>Watershed Pairwise Correlations</u>					
6-Bank Stability	DO mg/L	-0.50	22	0.018	
1-Channel Mod	DO mg/L	-0.57	21	0.007	
3-Bottom Substr	Temp	-0.55	26	0.003	

Table 11. Correlations between water quality and stream biology over all provinces.

Variable	by Variable	Corr	N	Signif	Corr
Watershed Pairwise Correlations					
DO mg/L	Corrected EPT*	0.22	22	0.325	
pH	Corrected EPT*	-0.43	16	0.097	
Conduct	Corrected EPT*	-0.44	26	0.023	
Temp	Corrected EPT*	-0.45	26	0.022	

Urban High Order Riparian Assessment Protocol, V. 2.0

1.0 Background

This assessment manual is designed for assessing the condition of 3rd to 4th order riparian ecosystems that originate in the coastal plain of North Carolina, and are influenced by urban land uses. It was prepared to aid in filling out the field sheets for the Urban High Order Riparian Assessment Version 2.0. It was modified from the one developed for rural landscapes by adjusting indicators and thresholds to better represent reference sites occurring in urban environments. This assessment method was not designed for evaluating active beaver impoundments. However, it can be used to assess beaver-impounded reaches where *only* the channel has been backed up by a downstream impoundment. In this case the water does not inundate the adjacent floodplain except following heavy rainfall events. In such cases, Stream and Riparian Condition indicators Sediment Regime (#1), Channel-Riparian Zone Connection (#3), and Stream Bank Stability (#7) (pages 4 and 5) should not be assessed because channel features are underwater or channel processes have been modified.

High order streams in the coastal plain include 3rd to 4th order intermittent and perennial streams. This assessment method is not appropriate for riparian ecosystems in other physiographic provinces, low order (1st – 2nd order) riparian systems, or larger river systems such as the Tar or Neuse Rivers. Although developed in coastal plain drainage basins in North Carolina, it would probably be applicable to some other coastal plain regions in the Southeast. Further use of this method will allow evaluation to see how well it works in other urban areas of the coastal plain.

High order riparian areas in the coastal plain include those with both intermittent and perennial flow. Intermittent streams tend to cease flow in late summer and early fall when evapotranspiration during the growing season has depressed water tables throughout their drainages, thus reducing surface flows from upstream tributaries and disconnecting the source of local groundwater discharge to the surface. Precipitation from tropical depressions, hurricanes, and convective storms can interrupt periods of low discharge.

In comparison with low-order riparian ecosystems, those of unaltered 3rd and 4th order streams have larger floodplains and are wetter. In their unmodified condition, they receive proportionally more water from overbank flow during floods and receive groundwater discharge from larger aquifers than their low-order counterparts. Consequently, they support vegetation adapted to longer periods of saturation and flooding, such as bald cypress and water tupelo in the canopy and lizard’s tail and water willow in the ground layer. In urban locations where channelization has created spoil piles and drained floodplains, Chinese privet is often prevalent. Riparian ecosystems range in condition from relatively natural, un-channelized reaches buffered by forest to channelized reaches with bank and bed hardened with concrete or other artificial substrate.

The presence of stormwater outfalls as a water source is one of the signature properties of higher order urban streams. This is partly a consequence of the conversion of low order streams to stormwater drainages that now feed directly to high order riparian floodplains and stream channels. Stormwater drainages may shunt runoff directly from impervious surfaces or from detention ponds. In either case, there is little opportunity for infiltration in the drainage basin. This results in higher peak flows and lower base flows than occurred prior to urbanization. Where the construction of storm detention basins is required, faulty design, construction, and maintenance can render them ineffective in moderating peak flows and removing sediments, nutrients, and other pollutants. In urban areas there is a general pattern of truncated low-order drainages and channelization in the high order streams that remain. The purpose of all of these modifications is to transport water away from urban areas to reduce potential damages due to flooding. Consequently, the drainage network offers little opportunity for ameliorating water quality and reducing peak discharge. The additional hydraulic loading downstream can alter channel morphology. Therefore, riparian ecosystems in urban areas are highly degraded.

2.0 Office and Field Methods

Reasons for conducting an assessment should be clearly established. They may include the following:

- documenting baseline conditions along a given reach
- determining types and degree of alteration in a drainage basin by assessing multiple sites
- determining how a proposed project will alter riparian condition
- comparing several reaches as part of an alternatives analysis
- identifying specific actions that could be taken to minimize project impacts
- determining the effects of specific manipulations following restoration or other management practices.

Defining objectives of an assessment may reduce misunderstanding among stakeholders and other interested parties. It will also focus the interpretation of assessment results on the specific requirements of a project.

For some assessment parameters, we used field data to validate relationships between riparian condition and water quality (biogeochemical and biotic). In other cases, relationships are based on information published in scientific literature. Finally, best professional judgment was employed where there are as yet no data to validate relationships. However, all parameters are calibrated and field tested against reference sites that range between relatively unaltered to severely altered.

2.1 Office preparation.

Maps and photographs are useful in characterizing a reach for assessment. They provide such information as project boundaries, location of jurisdictional wetlands, and location of proposed alterations or restoration. Geographic features are needed in evaluating some of the indicators such as the presence of roads, ditches, buildings, tributary streams, land use, land cover, and other pertinent features. Some useful sources are (a) high-resolution aerial photographs, such as DOQQs, (b) county soil surveys, (c) topographic maps (USGS 1:24,000), and (d) drainage maps. While the field assessment may be completed without these sources during the field visit, field time can be shortened considerably by having access to remotely acquired information. For areas that may contain both rural and urban drainages, criteria for choosing the right set of field sheets is provided on the last page of this protocol (2.5).

Equipment should be assembled before the field visit. Essential items are a GPS unit, shovel or trowel, hand-held laser level, stiff tape measure or meter stick, and 300 ft tape.

2.2 Guidelines for rejecting or moving sites

A watershed can be characterized by assessing a statistically robust number of reaches and using the data from the assessed watershed to make inferences about riparian areas in the watershed as a whole. Various random and stratified random approaches could be used depending on the questions being posed. Regardless of the method applied for randomly selecting reaches for sampling, in some cases, a randomly assigned reach will occur at a place that the assessment procedure was not designed to assess(e.g., in a beaver impoundment) and so must be moved or rejected.

If a reach is rejected or moved, the reason for rejection should be noted on the data sheet in the space provided on page 1 (Part A). The following guidelines for moving or rejecting reaches should be followed in the sequence in which they appear. These criteria will probably only be applied in cases where one is assessing randomly-selected reaches. Items 1 and 2 are mapping exercises for the office. The remainder are conducted in the field.

1. If a random point marking the center of a reach is located within 300 ft of another random point, it should be rejected and another point should be substituted.

2. If a stream junction occurs less than 150 ft downstream of the randomly selected point, the reach should be moved upstream until the entire 300-ft reach is above the junction. If a junction occurs less than 150 ft upstream from the random point, then the 300-ft reach should encompass the main stem (the same stem on which the random point falls).

3. If the randomly selected 300-ft reach falls entirely with in beaver impoundment (where both channel and floodplain are impounded) or other type of impoundment, the site should be rejected. If the random center point is <150 ft from the upstream or downstream boundary of a beaver or other impoundment, the point should be moved upstream or downstream in the un-impounded reach to allow assessment of an un-impounded 300 ft reach. (If moved upstream, the channel may be backed-up, thus requiring that Stream Riparian Condition indicators Sediment Regime, Channel-Riparian Zone Connection, and Stream Bank Stability be omitted.) In many cases, beaver impoundments show a stepwise pattern in which the upper end of one impoundment is adjacent to the dam of the next impoundment upstream. In such cases, moving the reach upstream or downstream will still place it in an impoundment and so the site should be rejected. If rejected, no substitution should be made for the point.

2.3 Data collection and observations on-site

Page 1. If none of the above-described rejection criteria are met, then urban high order reaches should be assessed as outlined below. Field sheets are referred to by page number below:

Page 1, Reasons for rejecting or moving a randomly assigned reach (Part A). The top section provides boxes for recording whether a randomly assigned reach has to be rejected or moved for occurring at a place that the assessment procedure was not designed to assess. A reach that is specifically chosen for assessment would presumably not be rejected and a “0” would be recorded in each box. However, for randomly chosen reaches that that must be rejected or moved, Part A provides a format for recording the reason for rejection or distance and reason moved (if the reach should be moved).

Page 1, Upstream and Downstream Influences on Reach (Part B). This category provides information on whether the reach is hydrologically affected by an impoundment. First, record if the channel is backed up by a beaver or other impoundment. Standing, non-flowing water in the channel suggests that there is an impoundment downstream from reach. A channel can be affected by an impoundment without a dam occurring within the assessed reach or even if there is no impounded water on the floodplain. (Note: even an impounded reach may begin to flow during high rainfall events). Although this assessment method was not developed for assessing the condition of impoundments, a channel that is backed up should be assessed if its riparian zone is not impounded, but indicators Sediment Regime, Channel-Riparian Zone Connection, and Stream Bank Stability (pp. 4 and 5) should not be assessed. Instead, “Bv” should be recorded in the appropriate data boxes on page 3. Care should be taken to make sure standing, non-flowing water is not simply a result of channel bed scour that creates an elongated pool of stagnant water.

Next, record if the reach was formerly and recently impounded by beaver, but has been abandoned (or dam removed). An abandoned beaver impoundment should be assessed as un-impounded.

Page 1, General Channel Condition (Part C). Part of characterizing channel condition requires determining the general condition of the stream channel: channelization, incision, presence of large downed wood (LDW), and degree to which the near-channel zone is vegetated. Record these conditions in the boxes in Part C.

Channel incision can be recognized by a deep channel (deeper than expected for the size of the drainage basin) that lacks adjacent spoil piles. Incision is often caused by an increase in the volume of peak flows due to an increase in the area of impervious surfaces and compaction of soils in the drainage basin. In contrast, channelization can usually be identified by the presence of spoil piles or berms along one or both sides of the channel, and by the level of the adjacent historic floodplain being positioned below that of the berm.

Both incision and channelization tend to reduce or eliminate the frequency of overbank flow, thus eliminating contact between floodwater and the floodplain. In some 2nd - 4th order systems, the original stream channel can still be found on the floodplain, but it is much more narrow and shallow than the channelized section and usually has little or no flow.

Another factor in characterizing channel condition requires determining if there is large downed wood (LDW) in the stream channel. If there is none, search the stream banks for sawed-off pieces of logs in the floodplain. Sawed-off large wood indicates that LDW has been removed from the stream (“de-snagged”) to facilitate flow.

Page 2, Site Sketch. The sketch provides a grid on which to map the relative area of cover types within 90 ft of each side of the stream and for less-detailed information or notes about conditions from 90-300 ft. Sixty 30 x 30 ft grids have been pre-drawn on the page to facilitate sketching a 90-ft riparian zone on each side of the stream channel.

The sketch map is to be drawn facing downstream with the center of the reach positioned at the midpoint (+) in the center of the map. Marks are also provided for the 10 ft, 50 ft, and 90 ft riparian zones. Sixty 30 x 30 ft grids have been pre-drawn on the page to facilitate sketching a 90-ft riparian zone on each side of the stream channel. Notes on the condition of the 90 – 300 ft zone should be made to the left and right of the grids.

Cover types should be marked with abbreviations provided in Part D, page 2 (OF, MF, LDR, etc.), along with a north arrow. If a stream meanders or curves along the 300 ft reach, the sketch should be adjusted so that it is shown as straight. The meander can be drawn in the box located on the right side of the sketch map. Likewise, the channel cross-section can be drawn in the other box. Rough estimates of dimensions can be made (depth from bank top to channel bottom, width of channel, height of berm above floodplain, etc.).

Page 2, Riparian Zone Cover (Part D). This indicator provides information on the general structure of vegetation in zones adjacent to the stream channel. Information needed for recording attributes can be obtained from the Site Sketch grid on page 2. Riparian Zone Cover influences the condition of all aspects of riparian zone. For hydrology, infiltration in the riparian zone is greater under forested conditions than for other land covers. Also, evapotranspiration rates tend to be higher than some of the other cover types that have lower biomass and especially those that have impervious surfaces. Overland flow from adjacent land uses may be more effectively intercepted, dispersed, and absorbed by forest cover as long as gullying does not occur. (Gullying is not as great a problem in most areas of the coastal plain as it is in piedmont riparian zones.) Impervious surfaces disrupt groundwater flow paths by preventing infiltration and by shunting water to streams via surface flows. This also contributes to increased flashiness and potentially to channel incision.

Biogeochemistry is similarly affected by riparian zone condition because forested riparian zones are well known for their capacity to trap sediments and to intercept nutrients transported by surface and ground water through the riparian zone. In addition, microbial processes are maintained by organic matter produced above and belowground, both of which are greater under forested conditions than other cover types.

For habitat maintenance, mature riparian forests provide the structure for riparian-dependent animals. In addition to the canopy trees and other strata, snags and downed wood are essential for maintaining a suite of vertebrates and invertebrates that depend upon large detritus for food and cover. Both vertical and horizontal structural complexity is higher in forests than in other cover types.

Calibration of land-use cover types relies upon both field data and the literature. For urban riparian zones, scores for cover types were derived by adapting components of the Land Development Intensity (LDI) index developed in Florida.[1] The Florida index is based on embodied energy (also called "emergy") analysis[2] and incorporates total energy flow, corrected for quality that occurs in a unit area of land use. It represents the intensity of human use and encompasses such factors as air and water pollutants, alteration of physical structure, hydrologic changes, etc. Some of the land uses in Florida (e.g., orange groves, etc.) do not occur our study area. Others were adapted or combined based on our best judgment. For example, golf courses may include multiple cover types such intensively managed lawns and rooftops. When only portions of golf courses are present in an assessed riparian zone, alternative land uses were chosen, such as intensively managed lawns or golf courses.

As yet, there are no data to validate these adaptations of the Florida LDI index. However, we have conducted preliminary assessments in the field along a range of reference sites (relatively unaltered to severely altered) in developing the description of conditions for each of the indicators. We chose to set reference standard conditions for urban areas as high as those for rural areas (e.g., old and mature forest) because timber harvesting is unlikely in built-out suburban areas. However, the most degraded urban conditions are lower than those of rural areas. The net result expands the rural scale to include more degraded conditions commonly found in urban but not rural areas. This allows differentiation between varieties of urban land uses that are absent or rare in rural areas.

The 90 ft riparian zone outer boundary was chosen for RZC because the riparian zone would likely be influenced by surrounding forest, which in this region, can generally reach 90-100 ft in height. Therefore, if growing within the 90-ft riparian zone, a 90-ft tree would have more than a 50% chance of falling into the riparian zone. Of those that fall into the riparian zone, some would be capable of contributing wood to the stream channel. The 50-ft inner zone was chosen to correspond with the NC buffer rules and the 10-ft zone was chosen to correspond to the zone that would most likely affect channel processes (see Near-stream Cover, below).

To evaluate riparian zone cover, the site sketch should be filled out first. From this, the percent cover of the condition (rows) of each zone (columns) should be identified and entered in the adjacent blank cell for each condition identified. One or more cover types could occur in any given zone. By entering the percent cover for each type within a zone, the calculated RZC score is based on a weighted average of all cover types present.
The assessor should verify that multiple cover types add up to 100 percent for each column.

Because property boundaries often occur along streams, management activities may differ on each side of the stream. Therefore, riparian cover is assessed for each side

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[1] Brown, M.T. and M.B. Vivas. 2005. Landscape development intensity index. Environmental Monitoring and Assessment 101:289-309.
[2] Odum, H.T. and E.C. Odum 2001. A Prosperous Way Down. Univ. Press of Colorado, Boulder, CO.

separately, with a maximum score of 50 for each side and 100 for both sides. A score of 100 means that riparian zone cover is similar to relatively unaltered reference sites.

An example of scoring is as follows: Suppose that the left side of the stream bank has low density residential (LDR), but the 0-10 ft buffer is Old Forest with lawns and houses in the 10-90 ft zone (Table 1). In this case, 100% Old Forest (OF) would be entered for the 0-10 ft zone (since low density residential would not adequately characterize the zone). However, 100% LDR would be recorded for the outer two zones (10-90 ft).

In this scenario, the percent cover of each cover type is multiplied by the appropriate RZC score and summed across all cover types within a zone. Therefore, the column total for each zone must always equal 100%. In the example below, the LEFT side RZC score would be 38 (20+15+3). The sum of zone scores for LEFT and RIGHT is used to assign the total riparian zone cover score when computing functioning. In the example below, the total RZC score for the LEFT and RIGHT sides would be 61.3 (38.0+23.6). These calculation may be conducted in the office.

Table 1. Calculation of Near Stream Cover (NSC) and Riparian Zone Cover (RZC) indicators. Total reach score for each is the sum of the LEFT and RIGHT sides.

Land use by cover type	LEFT SIDE ZONE (distance from stream)						RIGHT SIDE ZONE (distance from stream)						
	0-10 ft	%	10-50 ft	%	50-90 ft	%		0-10 ft	%	10-50 ft	%	50-90 ft	%
Old Forest	20	100	25		5		OF	20		25		5	
Mature Forest	20		25		5		MF	20		25		5	
Young Forest	19		24		5		YF	19		24		5	
Successional Forest	19		23		5		SF	19		23		5	
Recently Harvested	18		22		5		RH	18		22		5	
Shrubs/Saplings	17		21		4		SS	17	100	21	30	4	
Perennial Herb	16		2		4		PH	16		2		4	
Low intensity pasture	15		20		4		LIP	15		20		4	
Annual rowcrop	14		18		3		AR	14		18		3	
Low density residential			15	100	3	100	LDR			15		3	
Intensely managed lawns	9		11		2		IML	9		11		2	
Medium density residential			7		1		MDR			7		1	
High density residential			7		1		HDR			7		1	
Medium density mobile homes			6		1		MDM			6		1	
High density mobile homes			5		1		HMD			5		1	
High density buildings			0		0		HDM			0		0	
Impervious	0		0		0		IP	0		0	70	0	100
Total %		100		100		100			100		100		100
RZC Scores		20.0		15.0		3.0			17.0		6.3		0.0

Housing unit density and number of housing units per side of stream (used in Table 1) were calculated as follows:

Land use by cover type (Brown and Vivas 2005)	Density (units/ha)	Density (units/acre)[3]	# units/side of 300 ft reach[4]
Low density residential (LDR)	<10	<4	<3
Medium density residential (MDR)	10-20	4-8	3-5
High density residential (HDR)	>20	>8	>5

Medium density mobile home (MDM) and high density mobile home (HDM) cover types have the same densities and number of units per side as medium density residential (MDR) and high density residential (HDR), respectively.

Page 2, Near-stream Cover (Part D). This indicator provides information on the structure of vegetation nearest the stream channel (within 10 ft). Both biogeochemistry and habitat of the stream channel are more greatly influenced by the proximity of the near-stream cover than the riparian zone as a whole. Vegetation nearest to the stream channel affects in-stream habitat by contributing leaves for shredder biota, a source of LDW to the channel for instream structural habitat complexity, and by providing shade that ameliorates stream water temperature for stream biota. Streamside vegetation is important in stabilizing stream banks, thus reducing erosion and preventing nutrient–laden sediment from entering streams. In addition, vegetation nearest a stream provides the best opportunity for nutrient uptake because it is often closest to the areas of groundwater discharge to the channel. In addition, tree roots extend into the stream channel, creating small pools that trap leaf litter. Therefore, both biogeochemistry and habitat of the stream channel are more greatly influenced by the proximity of the near- stream cover than the riparian zone as a whole.

Scoring for Near-stream Cover (NSC) is derived from the RZC scores for the LEFT and RIGHT 0-10 ft zones. The score for the 0-10-ft zone must be multiplied by 2.5 to covert the NSC total score to a 0 to 100 scale. Scores for each side range from 50 (Old Forest) to 0 (Impervious). Applying the RZC scenario presented above, the LEFT NSC score would be 50 (i.e., 20*2.5) and the RIGHT NSC score would be 42.5 (i.e., 17*2.5). Again, these calculations can be performed in the office.

Page 3, Summary Sheet. This page provides space for recording RZC and NSC scores and information from Part E, Stream and Riparian Condition. This allows pages 4 and 5 to be used repeatedly. All summary data, except RZC and NSC scores, should be filled in before leaving the site to make sure nothing is missed.

Pages 4 and 5, Stream and Riparian Condition (SRC) Scores (Part E). The seven indicators in this section are scored to determine the condition of the stream channel and its riparian zone. Scores should be entered on page 3, Summary Sheet.

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[3] Conversion factor 2.47 acre/ha (results rounded to nearest integer)

[4] "# units/side of 300 ft reach" means the number of units on one side of the assessed reach, within 90 ft of the stream (based on the size of the assessment area and the Brown and Vivas (2005) density criteria; results rounded to the nearest integer). Each side of the assessment area is 300 ft long x 90 ft wide = 27,000 ft^2, or 0.62 acre; 0.62 acre x 4 units/acre = 2.48 units; 0.62 acres x 8 units/acre = 4.96 units

Stream and Riparian Condition indicator scores, along with RZC and NSC scores, can be used to estimate condition. Each column describes four discrete categories from relatively unaltered to severely altered. Each category can be further assigned a condition from high to low within a category.

At the top of each indicator category from unaltered to severely altered is a general description of the indicator's condition. Below each general description are more specific descriptions of field indicators, each proceeded by a letter (a-d). On the Summary Sheet (p. 3), space is provided to record one or more of the letters (each which corresponds to specific indicator) that best describes the site's condition. Verbiage in brackets ([ ]) provide some guidance on scoring.

Each stream riparian condition indicator is related to slightly different aspects of the three categories of function: hydrology, biogeochemistry, and habitat. Some are related only to stream channel condition, some only to riparian zone condition, and some to both. A general outline of the rationale for the seven indicators is provided below. Together with the Near Stream Condition and the Riparian Zone Condition, the indicators are assembled in Table 2 into the function categories.

1. *Instream woody structure.*

This indicator is related to all three functions, but for channel condition only. Wood in the stream channel affects hydrology by creating pool and riffle sequences that dissipate energy of flowing water and stores water in pools during low flows. In small, unchannelized streams, live tree roots may play this role. Woody structure affects biogeochemistry by providing a surface for microbial activity and a potential source of dissolved organic carbon (DOC), which is released into the water slowly over long periods of time. DOC can be used as an energy source for denitrification and other microbial processes. Instream wood also provides structural habitat complexity for epifauna and epiphytes. In larger streams, fish and invertebrates may use woody structure for resting during high flows and for hiding (shelter).

2. *Sediment regime.*

This indicator is related only to the biogeochemistry of free-flowing stream channels. It should not be used to assess channels that have been backed up by an impoundment. In such cases, indicators either fail to develop adequately or are not readily observed. Excess sediment in free-flowing headwater reaches may come from storm drainages that enter streams at road crossings, from construction sites, from excessive bank erosion upstream, and from other land disturbance activities. Thus, excess sediment indicates erosional problems within a reach and upstream from the assessed reach. Sediments influence channel biogeochemistry by acting as a carrier of sediment-bound phosphorus, the major mechanism by which phosphorus (and heavy metals) are transport by fluvial systems. Phosphorus enrichment may change the N/P ratio of the stream and enrichment with heavy metals may harm intolerant aquatic biota. Stream channel habitat is normally compromised when excess sediments lower water transparency, suppress primary production of epiphytic algae, and bury the habitat of benthic and epiphytic organisms. We have not incorporated this indicator into habitat of the stream channel function, however, because "4. Pollution affecting the stream" addresses many of the same stream habitat conditions. Further, the sediment regime indicator is not indicated for the

Table 2. Example of how indicator scores are averaged to obtain various function, channel condition, and riparian zone condition scores. Indicator scores are averaged by function (columns) to obtain Hydrologic, Biogeochemical, and Habitat mean functions.

INDICATORS	STREAM CHANNEL			RIPARIAN ZONE		
	Hydrology	**Biogeo-chemistry**	**Habitat**	**Hydrology**	**Biogeo-chemistry**	**Habitat**
Riparian zone cover				44	44	44
Near-stream cover		45	45			
Instream woody structure	10	10	10			
Sediment regime		10				
Channel-riparian zone connection	30	30	30	30	30	30
Pollution affecting stream	40	40	40			
Factors affecting riparian zone				10	10	10
Habitat quality of riparian zone						10
Stream bank stability		50	50			
Function Score: Mean of all appropriate indicator scores for each function and whether for stream or riparian zone.	27	31	35	28	28	24
	Mean Function Score for Channel = 31			Mean Function Score for Riparian Zone = 27		
	Composite Function Score = 29					

hydrology function in the stream channel. We acknowledge that excessive sediment deposits in channels reduce bankfull channel flow capacity. For channelized streams, filling contributes positively to channel-riparian zone connection indicator, described next.

Often, channels of channelized streams begin to fill over time, especially those in urbanizing areas that are subject to erosional problems upstream. The filling may seem to indicate that the channel is restoring its morphology, but excess sedimentation will still continue to cause problems for biota if not prevented.

3. Channel-riparian zone connection.

This indicator is based on the degree to which a free-flowing stream channel is incised. It is related to all functions for both stream channels and riparian zones. (The indicator should not be used to assess channels that have been backed up by an impoundment for reasons stated above.) The indicator's application to all functions reflects the fact that the connection between channel and riparian zone is fundamental to the characteristic functioning of riparian ecosystems. The degree of channel incision determines the degree to which functioning is impaired in both the stream channel and riparian zone. Channelized streams and channels incised by high flow velocities affect hydrology by transporting water more rapidly through the system during high flows and by increasing the groundwater slope toward the channel during low flows. Both types of alterations reduce the residence time of water in the system by increasing water flows and reducing storage.

Greater channel capacity of channelized and incised streams, compared to natural channels, requires greater flow volumes to reach a stage at which overbank flow is initiated. This can greatly reduce the duration and frequency of flooding or eliminate it altogether. Overbank flow is the major mechanism by which the channel and riparian zone are hydrologically connected. This in turn affects biogeochemistry in at least two ways: the lowered water table may eliminate contact of surficial groundwater with the organic rich surface horizons of the soil, thus reducing the potential for denitrification in both the channel and riparian zone. A lowered water table also exposes the soil column to greater aeration, thus suppressing anaerobic processes that are common in the floodplains of headwater streams. For biogeochemical processes as a whole, the system becomes more oxidized, which reduces the capacity to accumulate organic matter.

Hydrologic alterations caused by channelization or incision also adversely affect habitat for aquatic and wetland-dependent species. In the riparian zone, hydrophytes are less likely to occur. Within the stream, greater flow velocities, especially during storm flows, increase sediment concentrations through re-suspension and scour, thus degrading habitat.

4. Pollution affecting the stream.
This indicator is related to all three functions, but for channel condition only. Pollutant source for assessment purposes is herein defined as drains from streets and detention ponds, roadside ditches, channelized tributaries, and drainage from impervious surfaces. Pollutant sources affect hydrology by contributing excess water to stream channels. Higher and flashier flows may lead to additional channel incision and headward erosion. Pollution sources, by definition, contribute excess nutrients (primarily nitrogen and phosphorus) and/or toxic pollutants to stream channels, thus interfering with normal biogeochemical cycling. Habitat is also adversely affected by nutrient or chemical additions. Excess nutrients in the presence of sufficient sunlight can create algal accumulations that may lead to nighttime anoxia. Toxic chemicals can directly poison stream organisms.

Pollutant sources affect stream channels both by entering a reach from upstream and by entering within a reach itself. We assume that sources within the reach are generally more detrimental than sources upstream from a reach. Regardless, distance upstream and type of source should be taken into consideration. However, beaver impoundments trap sediment and increase the residence time of water, thus allowing time for nutrient processing and removal. Therefore, some pollutant sources may be disregarded if a beaver impoundment occurs between pollutant sources and the assessed reach. However, more egregious inputs such as toxic chemicals, domestic sewage, and animal waste are expected to alter stream water chemistry even if partially processed through a beaver impoundment before entering reach.

Stormwater detention ponds are meant to moderate peak flows from impervious surfaces and trap sediment and toxic chemicals. Consequently, some pollutant sources may be disregarded if a detention pond occurs between the sources of pollution and the assessed reach. However, in some cases storm detention basins are improperly planned, designed, constructed, or maintained, thus rendering them ineffective in moderating flows and/or trapping sediments and pollutants. Therefore, where detention basins occur within 1,500 ft above an assessed reach (or along a contributing tributary), the detention pond(s) should be examined to determine if they are properly designed or managed. If the detention basins are determined to be ineffective, then they should be treated as a source of pollution rather than as a sink (trap).

Storm water treatment systems are often sophisticated engineered systems. While there are criteria to determine whether they have been properly designed and constructed, and whether they are being properly operated, evaluation of their effectiveness is beyond the scope of this assessment method. The reader is referred to EPA regulatory[5] and non-regulatory[6] information, NC Division of Water Quality guidelines and regulations[7], and the Center for Watershed Protection[8] for further information.

5. Factors affecting the riparian zone.

This indicator is related to all three functions, but for riparian zone condition only. The rationale is the same as provided above for stream channels. The difference is that sources of degradation are limited to those within or directly adjacent to a reach. (It is assumed that alterations to upstream riparian zones do not directly affect the riparian zone of the assessed reach, but that such alterations are taken into account by the previous indicator).

Alterations to the riparian zone, but not to channels directly, include grading, filling, excavation, cultivation, impervious surfaces, and other activities in non-forest land uses. Variations in scoring reflect the degree to which they are believed to alter condition. For example, discharges to the riparian zone from septic or sewer systems are considered potentially more detrimental than intensively managed lawns.

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[5] for US EPA stormwater regulatory information see http://www.epa.gov/ebtpages/watestormwater.html; federal stormwater regulations and requirements are included in NPDES regulations 40 CFR Part 122; portions of other regulations are also relevant (see EPA web page for more detail); EPA publishes numerous documents related to stormwater management, including a series of Stormwater Technology Fact Sheets (eg, Wet detention ponds EPA 832-F-99-048, Vegetated swales EPA 832-F-99-027, Stormwater wetlands EPA 832-F-02-020, Bioretention EPA 832-F-99-012, etc.)

[6] US EPA Office of Research and Development's Urban Watershed Management Branch provides non-regulatory information about urban stormwater risks and management (see http://www.epa.gov/ednnrmrl); EPA ORD UWMB publishes numerous documents, journal articles and books related to urban stormwater; a CD compilation of UWMB reports is available from this web page; also available is an electronic copy of Burton, G. Allen, Jr. and Robert E. Pitt. 2001. Stormwater effects manual: A toolbox for watershed managers, scientists and engineers. Lewis Publishers (CRC Press), Boca Raton, FL, USA.

[7] see NC DWQ stormwater permitting units web page (http://h2o.enr.state.nc.us/su/stormwater.html); pertinent documents include: NC DENR. 1999. Stormwater best management practices.; state stormwater management program (SSWMP) supplement sheets; stormwater management regulations 15A NCAC 2H .0100 (especially 2H .1008 "Design of stormwater management measures"); and stormwater fact sheets prepared by the Land-of-Sky Regional Council

[8] see Center for Watershed Protection web page (http://www.cwp.org); CWP has recently released the Urban Subwatershed Restoration Manual series, an 11-part series of manuals written for a broad audience including planners, engineers and consultants (Schueler, Tom. 2004. An integrated framework to restore small urban watersheds. Urban Subwatershed Restoration Manual No. 1. Center for Watershed Protection, Ellicott City, MD.

Channelization drains adjacent floodplains and increases the capacity of the channel to convey water. This typically eliminates overbank flow onto the floodplain, thus degrading the riparian zone. However, the loss in functioning of a former floodplain of a deeply channelized stream would be ameliorated somewhat if water that would otherwise bypass the former floodplain via ditches and culverts is instead diverted to a forested riparian zone. Forested riparian zones are capable of trapping sediment and removing nutrients before they reach the channel. Especially egregious pollutant inputs, such as toxic chemicals and sewage, would likely overwhelm the capacity of a forested riparian zone to remove them and are still treated as a severe alteration.

Beaver impoundments trap sediment and increase the residence time of water, thus allowing time to remove nitrate. Therefore, if a beaver impoundment occurs between pollutant sources and the assessed riparian zone, such pollutant sources may be disregarded. However, egregious pollutant inputs described in the "extremely altered" category would not be expected to be ameliorated much by a beaver impoundment.

6. *Habitat quality of riparian zone.*
This indicator is related only to the habitat function of the riparian zone. Vegetation composition (evaluated relative to native forest) is a direct measure of plant habitat, which in turn affects animal habitat. It is assumed that mature to old forests represent the least altered condition that is conducive to supporting native communities. The footnote provides a list of canopy species characteristic of native forests. If at least four of the listed species are present in the canopy and the understory is intact with minimal cover of invasive species (Table 3), then the remaining composition and structure of the forest is assumed to be relatively unaltered.

When forest cover is less than 50%, it is assumed that habitat quality is severely degraded for forest-dependent species. Invasive and ecotone-dependent species displace those that require contiguous canopy of intact forest as cover becomes more fragmented.

7. Stream bank stability.
This indicator is related to the biogeochemistry and habitat functions of free-flowing streams. (It cannot be used to assess channels backed up by impoundments. In such cases, indicators either fail to develop adequately or are not readily observed.) As stream discharge increases, hydraulic energy is first dissipated along stream banks and on LDW and roots residing in the channel. Some of this energy results in bank erosion, exposes roots, and causes bank slumping and tree fall, when excessive. If the stream channel is not incised, even higher flows associated with overbank flow transfer total stream energy to the floodplain where it is dissipated without erosion over a large surface area, thus protecting the channel itself from excessive scouring. While some bank erosion and sediment redistribution are natural processes, they are minor in low gradient headwater streams in the coastal plain. Alteration of riparian condition is assumed if erosion, slumping, and undercutting are excessive (especially in places other than at cutbanks) and herbaceous vegetation is unable to re-establish on banks after extreme events. Alterations in bank stability lead to excessive introduction of sediment to the channel and is ultimately transported to downstream ecosystems.

Table 3. Invasive, non-native species found in riparian ecosystems.

Species	**Common name**	**Prevalence**
Trees		
none to rare		
Shrubs		
Ligustrum sinense	Chinese privet	common
Elaeagnus angustrifolia	Russian olive	uncommon[1]
Herbs		
Lonicera japonica	Japanese honeysuckle	common
Microstegium virmineum	Japanese stiltgrass	common
Rosa multiflora	multiflora rose	uncommon[1]
Murdania keisak	Asian dayflower	common
Polygonum cuspidatum	Japanese knotweed	common
Vines		
Lonicera japonica	Japanese honeysuckle	common
Pueraria lobata	kudzu	uncommon[1]

[1]Uncommon invasive in riparian ecosystems, but may be abundant elsewhere.

2.5. Office and Field Criteria for Differentiating Urban from Rural Reaches

This guidance is used to determine which protocol should be used to assess a randomly assigned reach. Presence of any one indicator below is sufficient for confirming urban status (either in the office or in the field).

Office Determinations (made using USGS 7.5 minute series topographic maps and USGS digital orthophoto quarter quads or higher resolution orthogonalized aerial photographs)

1. >10% impervious surface within a circle centered on random point (low order 600 ft radius; high order 1,500 ft radius; see template of aerial photographs, in Appendix).
2. Area denoted as urban on USGS topo (brown, purple, or pink color).
3. Housing density >2.37 units/acre[9] (for low order, >62 units in 600 ft radius circle; for high order >384 units in 1,500 ft radius circle). (Units are dwelling units: single family home = 1 unit, duplex = 2 units, each apartment with in a complex = 1 unit.)

Field Determinations

1. Stormwater treatment unit (wet or dry detention/retention, or infiltration basin, etc.) is located in assessment reach or upstream (low order within 600 ft; high order within 1,500 ft) or within watershed.
2. Stormwater input to stream or floodplain from urban stormwater sources, such as curb-and-gutter street or parking lot, is located in assessment reach or upstream (low order within 600 ft; high order within 1,500 ft). Here, "stormwater input" does not refer to road ditches or grassed swales. (Grassed swales and ditches in agricultural settings indicate that the rural riparian assessments should be used.)
3. Sewer line right-of-way is in riparian zone within 50 ft of stream channel.
4. Three or more dwelling units are located within 90 ft of the stream (either side) along 300 ft assessment reach[10].

[9] The rural-urban threshold housing density (2.37 units/acre) is the mean of the lowest density urban zoning classification for Greenville, NC (R-15S, 3 units/acre) and the rural residential zoning classification for Pitt County, NC (minimum lot size 25,000 ft^2, which equals 0.57 acre or 1.74 units/acre).

[10] Based on the rural-urban threshold housing density (2.37 units/acre) and the size of the assessment area (300 ft x 180 ft = 54,000 ft^2, or 1.24 acre; 1.24 acre x 2.37 units/acre = 2.94 units, or ~3 units within the assessment area).

Urban High Order Riparian Assessment, V. 2.0

[ ] Site #   Date ______________

[ ] Watershed   Field Crew ____________________________

[UHO] Stream type

A. Reasons for Rejecting or Moving a Randomly Assigned Reach. (Enter 1 for Yes, 0 for No)

[ ] Reach rejected (check one): ( ) both channel and riparian zone flooded by beaver impoundment; ( ) channel and riparian zone flooded by other impoundment type; ( ) inaccessible. **If rejected, do not assess.**

[ ] Reach moved upstream or downstream ( ) feet due to ( ) beaver impoundment in <50% of reach; ( ) other impoundment type, or ( ) overlap of previous reach. Enter 1 for yes, 0 for no in box, enter distance moved, and check reason.

B. Upstream and Downstream Influences on Reach. (Enter 1 for Yes, 0 for No)

[ ] Only the channel is backed up by downstream impoundment; the riparian zone is not inundated, except after a heavy rainfall event. ***If so, conduct assessment, but do not assess SRC #2, #3, and #7 (pp. 4 & 5).***

[ ] Reach formerly and recently impounded by beaver or man-made dam, but now abandoned and recovering.

C. General Channel Condition. (Enter 1 for Yes, 0 for No)

[ ] Unincised, free-flowing stream with large downed wood (LDW) and/or litter and tree roots in channel.

[ ] Unincised, free-flowing stream with little or no LDW, litter, and tree roots in channel.

[ ] Channelized or incised stream with trees growing in and along channel and LDW or leaf litter in channel.

[ ] Channelized or incised stream with trees growing in and along channel, but lacking much LDW or leaf litter in channel. (Look for evidence of desnagging as possible reason.)

[ ] Channelized or incised stream with mostly shrubs and/or herbaceous vegetation growing in and along channel; few or no trees.

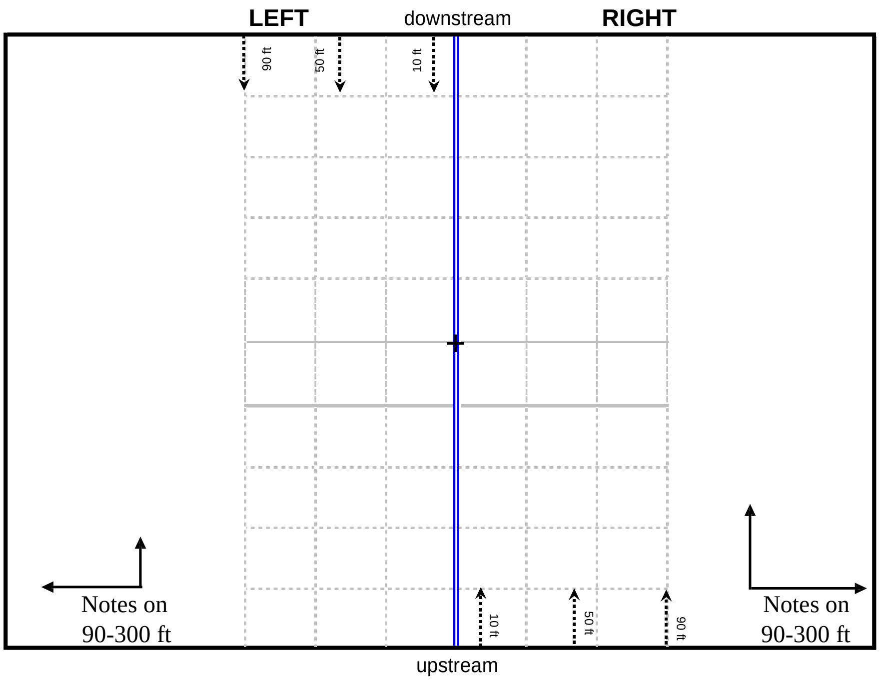
[ ] Stream channel rip-rapped, bulkheaded, or lined with concrete bottom.

[ ] Relic stream channel present on former floodplain.

Notes:

Site # _______ Watershed ________________________________ Date ________________

Site Sketch *Reach is 300 ft in upstream-downstream direction by 180 ft wide. Each square is 30 ft x 30 ft. Identify and label cover types to 90 ft using abbrevations in Part D below. Portray stream as straight. Add north arrow.*



Draw stream's meander

Draw channel x-section

D. Riparian Zone Cover

- In the blank boxes, record the % cover for each cover type by zone (0-10 ft, 10-50 ft, 50-90 ft). For example, if a zone is equally represented by two cover types, record 50 in the boxes adjacent to the cover types. Insert abbreviations (OF, MF, etc.) for cover types on sketch map above. (Age ranges in parentheses. For Mature Forest that has been selectively cut or high graded, record as Young Forest. These data should be transferred to the "RZC Calculator" file to calculate RZC and NSC scores. (Appendix C). (Make sure that total % = 100 for each column.) The NSC score is 2.5 times the total score for the 0-10-ft zone.

Land use by cover type	LEFT SIDE ZONE (distance from stream)						RIGHT SIDE ZONE (distance from stream)						
	0-10 ft	%	10-50 ft	%	50-90 ft	%		0-10 ft	%	10-50 ft	%	50-90 ft	%
Old Forest (OF), >75 y old	20		25		5		OF	20		25		5	
Mature Forest (MF), 50-75 y old	20		25		5		MF	20		25		5	
Young Forest (YF), 25-50 y old	19		24		5		YF	19		24		5	
Successional Forest (SF), 5-25 y old	19		23		5		SF	19		23		5	
Recently Harvested (RH), 0-5 y old	18		22		5		RH	18		22		5	
Shrubs/Saplings (SS)	17		21		4		SS	17		21		4	
Perennial Herb (PH) (incl. residential lawns)	16		20		4		PH	16		20		4	
Low intensity pasture with livestock (grazing intensity <3 animals/acre) (LIP)	15		18		4		LIP	15		18		4	
Annual crop agriculture (AR)	14		17		3		AR	14		17		3	
Low density residential, single family (<3 houses per side, within 90 ft of channel); minimally managed lawns (LDR)			15		3		LDR			15		3	
Intensely managed lawns, golf course, recreation field, etc. (IML)	9		11		2		IML	9		11		2	
Medium density residential, single family (3-5 houses per side, 10-90 ft from channel) (MDR)			7		1		MDR			7		1	
High density residential, single family (>5 houses per side, 10-90 ft from channel) (HDR)			7		1		HDR			7		1	
Medium density mobile home (3-5 units per one side of 100 yd reach within 90 ft of channel) (MDM)			6		1		MDM			6		1	
High density mobile home (more than 5 units per one side of 100 yd reach within 90 ft of channel) (HDM)			5		1		HMD			5		1	
High density building, multi-unit: strip mall, commercial mall, condos, manufacturing, motels, institutions, etc. (HDB)			0		0		HDM			0		0	
Impervious (IP)	0		0		0		IP	0		0		0	
Total % (If <100%, correct data entry													
	NSC=				RZC=			NSC=				RZC=	

Urban High Order Riparian Assessment, V. 2.0

Site # ___________ Watershed ____________________ Date _______

C. Riparian Zone and Near Stream Cover (p. 2)

☐ RZC (total of possible 100%, both sides)

☐ NSC (total of possible 100% derived from both sides of "0-10 ft" zone, multiplied by 2.5)

D. Stream and Riparian Condition (SRC) indicator scores (pp. 4 & 5)

☐ 1. Instream woody structure

☐ Sub -condition "a, b, or c."***(If channel is backed up by beaver, enter Bv.)***

☐ 2. Sediment regime

☐ Sub-condition "a, b, c, or d." **(*If channel is backed up by beaver, enter Bv.)***

☐ 3. (LEFT) Channel-riparian zone connection***(If channel is backed up by beaver, enter Bv.)***

☐ Sub-condition "a, b, c, or d." **(If channel is backed up by beaver, enter Bv.)**

☐ 3. (RIGHT) Channel-riparian zone connection***(If channel is backed up by beaver, enter Bv.)***

☐ Sub-condition "a, b, c, or d." **(If channel is backed up by beaver, enter Bv.)**

☐ If relic channel of former floodplain is observed, record '1"; otherwise record "0" here.

☐ 4. Pollution affecting the stream

☐ Sub-condition "a, b, c, or d."

☐ 5. (LEFT) Factors affecting the riparian zone

☐ Sub-condition "a, b, c, or d."

☐ 5. (RIGHT) Factors affecting the riparian zone

☐ Sub-condition "a, b, c, or d."

☐ 6. (LEFT) Habitat quality of riparian zone

☐ Sub-condition "a, b, or c."

☐ 6. (RIGHT) Habitat quality of riparian zone

☐ Sub-condition "a, b, or c."

☐ 7. (LEFT) Stream bank stability***(If channel is backed up by beaver, enter "Bv")***

☐ Sub-condition "a, b, c, or d." ***(If channel is backed up by beaver, enter Bv.)***

☐ 7. (RIGHT) Stream bank stability***(If channel is backed up by beaver, enter "Bv")***

☐ Sub-condition "a, b, c, or d." ***(If channel is backed up by beaver, enter Bv.)***

Notes:

E. Stream and Riparian Condition (SRC). *For each SRC indicator, record on page 3 the SRC indicator score and one or more letters (a-d) that apply. (If a condition is encountered that is not provided, choose a score, and explain the alteration and rationale for scoring in notes on p. 3.) Verbiage in brackets ([ ]) provides guidance on scoring.*

	Condition Category			
SRC Indicator	**Relatively Unaltered**	**Somewhat Altered**	**Altered**	**Severely Altered**
1. Instream woody structure	Much large down wood (LDW) in channel and along banks. (Recent treefalls from extreme weather events or erosion not applicable.) **(a)** LDW represents a variety of decay classes[1]. **(b)** LDW in channel and along banks represents a mix of sizes >4 inch dia. Some LDW >8 inch dia.	Some LDW in channel and along banks. Some may be partially buried in bottom. **(a)** LDW in channel and along banks represents a variety of decay classes[1]. **(b)** Few or no LDW >8 inch dia. [If large >4 inch dbh trees grow along both banks, score 80, if only along one side, score 70, if streamside trees are <4-inch dbh, score 60.]	Few or no LDW in channel and on banks[2] but potential supply is present. **(a)** LDW represents only one decay class[1]. [If large >4 inch dbh trees grow along both banks, score 50, if only along one side, score 40, if streamside trees are <4-inch dbh, score 30.]	No LDW in channel **(a)** Stream is channelized and periodically cleared of debris to maintain drainage **(b)** No large trees (>4 inch dbh) grow along channel banks. **(c)** Stream is lined with rocks, rip-rap, or concrete. [Assign lowest score to channels partially in culvert or lined with rocks, etc.]
Score =	100 90	80 70 60	50 40 30	20 10 0
2. Sediment regime[3, 4]	Little or no silt or sand carried by stream. Water runs fairly clear even during periods of high flow. **(a)** Stream is not channelized. **(b)** Channel bottom is mostly sandy with little or no silt on channel bottom or on floodplain. [If sand deposition in channel bottom is due to upstream activities, then see "severely altered" category.]	Some silt carried by stream. **(a)** At high flows, suspended sediment evident in water. **(b)** When water runs clear during base flow, sediment can be re-suspended by shuffling feet in channel. **(c)** Thin layer (<1 inch thick) of silt deposited on channel bars or on floodplain surface. [Thickest deposits score lower.] **(d)** Sediment >1 inch thick due to recent abandonment of impoundment[4].	Silt and sand carried by stream. **(a)** Water is silt laden, esp. after heavy rains. **(b)** Thick (1-2 inches) silt or sand deposited on channel bars, bank edge, or on floodplain (if present).	Heavy sediment load carried by stream. **(a)** Sediment suspended in water even during low flow. **(b)** Thick (>2 inches) sand or silt layers recently deposited on channel bars, bank edge, or on floodplain (if present). **(c)** Evidence that sand or silt deposits in reach are being generated by upstream activities.
Score =	100 90	80 70 60	50 40 30	20 10 0
3. Channel-riparian zone connection[3, 4]	Strong evidence of overbank flow on floodplain. **(a)** No apparent channelization or incision. **(b)** Wrack, sediment, and/or trash on floodplain. [Sparse wrack scores 45.] **(c)** High water marks on trees apparent. **(d)** No spoil berm alongside channel, but perhaps a natural levee.	Evidence of occasional overbank flow on floodplain. **(a)** Some wrack, sediment, trash on floodplain, but sparse and/or old. **(b)** Stream channelized within historic channel with low spoil berms or breaks in them along channel. (Channel may have been channelized in past, but filled sufficiently with sediments that overbank flow now is common.) **(c)** Channel slightly channelized or incised.	Evidence of overbank flow only after extreme (rare) flood events. **(a)** No or little wrack on floodplain. **(b)** Channelization (i.e., spoil berms present and high). **(c)** Channel deeply incised (not channelized).	Overbank flow eliminated. **(a)** Deep channelization with spoil berms present. **(b)** Deeply incised (not channelized). **(c)** Filling and/or leveling of floodplain, some or all of fill may have been derived from spoil from channelization. **(d)** Presence of high artificial levee or other channel-containment structure.
Score (L) =	Left Bank: 50 45	40 35 30	25 20 15	10 5 0
Score (R) =	Right Bank: 50 45	40 35 30	25 20 15	10 5 0
4. Pollution affecting the stream[5]	No on-site or off-site pollution affecting stream. **(a)** There is no pollution entering directly into the stream within the reach or within 1,500 ft (500 yd) located upstream from reach. **(b)** All stormwater detention basins and ponds within 1,500 ft (500 yd), if present, are adequately designed and maintained to reduce peak flows and trap sediment and nutrients. [Condition scores 90.] **(c)** Stream is not channelized. [If stream is channelized, score 90.]	Only off-site pollution affecting stream. **(a)** Pollution feeds directly into stream channel within 1,500 ft (500 yd) upstream from reach (not within reach). **(b)** Water from inadequately designed or maintained detention basin enters stream within 1,500 ft (500 yd) above reach. [More sources or more proximate pollution sources should be scored lower.]	On-site pollution affects stream. **(a)** Pollution from stormwater directly enters stream reach. **(b)** Water from inadequately designed or maintained detention basin directly empties into reach. **(c)** Overland-flow from impervious surfaces, gardens, and lawns directly enters reach. **(d)** Stream culverted for 5-20% of length. [Presence of several pollution sources should be scored lower than fewer sources.]	Especially egregious pollution affects stream. **(a)** Sediment input from construction activities entering channel directly. **(b)** >20% of reach passes through culvert. **(c)** Evidence of sewer line or septic source leaking into stream (note evidence). **(d)** Hydrocarbons or other toxic chemicals leaking directly into stream (note evidence).
Score =	100 90	80 70 60	50 40 30	20 10 0

[1] Decay classes: (1) bark intact, leaves attached, no evidence of decay, (2) loose bark, no leaves, (3) peeling bark, fungi present, (4) advanced stages of decay, no bark or soft enough for a prod to be easily poked through, and (5) bole decayed into ground.

[2] If few or no LDW occurs within channel, check banks for sawed-off pieces in floodplain, which indicates de-snagging. LDW from severe bank erosion not applicable. If impossible to determine presence of LDW due to high flow, score 55.

[3] Do not assess SRC #2, #3, & #7 if stream is backed up by downstream beaver impoundment. Do assess relic beaver impoundments.

[4] Sediment layer of relic beaver impoundment may be deep at upstream end of former impoundment and reduced in depth closer to former dam site.

[5] Pollutant sources include runoff from roadside ditches, stormwater drainage, leakage from septic drainfields, runoff from intensely managed lawns or kennels, direct drainage from impervious surfaces including roof tops, and discharge from inadequate detention facilities. Note, beaver impoundments and *adequately designed and maintained* detention basins largely negate the effects of most pollution, except those described in the "severely altered" category. Therefore, other upstream pollutant sources may be disregarded if an impoundment or properly operating detention basin occurs between the pollutant source(s) and the assessed reach.

E. Stream and Riparian Condition (cont.)

SRC Indicator	Condition: Relatively Unaltered	Somewhat Altered	Altered	Severely Altered
5. Factors affecting riparian zone[1]	No pollution[2] or other factors affecting riparian zone condition within reach. **(a)** Stream is not channelized and no pollution empties into riparian zone. **(b)** All stormwater detention basins and ponds, if present, are adequately designed and maintained to reduce peak flows and trap sediment and nutrients. [Presence of clippings or organic waste in floodplain scores 45.]	Pollution[2] or other factors somewhat affecting riparian zone. **(a)** Stream is not channelized and water from properly designed and maintained detention facilities empties into riparian zone. **(b)** Stream is channelized and drainage or stormwater is discharged (or diverted) to riparian zone where it is detained and processed before entering stream. [Forested riparian zone scores higher than other cover types.]	Pollution[2] or other factors affecting riparian zone. **(a)** Stream not channelized and pollution empties directly into riparian zone. [More than one pollutant source should be scored lower than only one source within reach.] **(b)** Water from tributary streams and roadside ditches is diverted directly to channel, thus bypassing riparian zone. **(c)** 5-25% of riparian zone (0-50 ft) of reach filled, graded, cultivated, or covered with impervious surface. **(d)** Sewer and storm drain system or power line right of way are within riparian zone. [Forested riparian zone scores higher than other cover types.]	Especially egregious pollution or factors affecting riparian zone. **(a)** More than 25% of riparian zone of reach filled, graded, excavated, cultivated, or converted to other non-forested land covers. **(b)** Stream so incised or deeply channelized (with high spoil berms) that overbank flow to floodplain is extremely unlikely even during major storm events AND no stormwater is diverted to former floodplain. **(c)** Evidence of sewage or toxic chemicals entering riparian zone (note evidence). [Lack of forest on former
Score (L) =	Left Bank: 50 45	40 35 30	25 20 15	10 5
Score (R) =	Right Bank: 50 45	40 35 30	25 20 15	10 5
6. Habitat quality[3] **of riparian zone (0-90 ft)**	Habitat quality intact. (a) Riparian zone dominated by old or mature intact[4] forest (>95% of area). No or low cover of exotic or invasive species. No grazing, mowing, or selective harvesting within riparian zone. [Old or Mature forest (>50 yr. old) scores 50; slightly younger forest scores 45. Exotics in 5-25% in any stratum scores 45.]	Habitat quality somewhat degraded. **(a)** Intact[4] forest covers 75-95% of riparian zone with remainder of area representing other cover types. **(b)** Intact forest covers >95% of riparian zone with exotic or aggressive species covering >25% in at least one stratum. **(c)** Forest canopy covers >95% of riparian zone with at least one understory stratum of native vegetation asent or not well represented (due to understory removal or timber harvesting, etc.). [Old or Mature forest (>50 yr. old) should be scored higher than younger forests.]	Habitat quality degraded. **(a)** Intact[4] forest covers 50-75% of riparian zone with remainder of area representing other cover types. **(b)** Intact forest covers 75-95% of riparian zone with exotic or aggressive species covering >25% in at least one stratum. **(c)** Forest canopy covers 75-95% of riparian zone with at least one understory stratum of native vegetation absent or not well represented (due to understory removal, timber harvesting, etc.). [Old or Mature forest (>50 yr. old) should be scored higher than younger forests in all cases.]	Habitat quality extremely degraded. **(a)** Forest covers <50% of riparian zone with remainder of area representing other cover types. **(b)** Intact[4] forest covers 50-75% of riparian zone with exotic or aggressive species covering >25% in at least one stratum. **(c)** Forest canopy covers 50-75% of riparian zone with at least one understory stratum of native vegetation absent or not well represented (due to understory removal, timber harvesting, etc.). [Old or Mature forest (>50 yr.
Score (L) =	Left Bank: 50 45	40 35 30	25 20 15	10 5
Score (R) =	Right Bank: 50 45	40 35 30	25 20 15	10 5
7. Stream bank stability[5]	Stream bank relatively stable. **(a)** Evidence of erosion or bank failure absent or minimal (<10%) of length. **(b)** Streamside vegetation tightly binds soil along banks, although exposed roots may occur at cut banks of stream channel. [Slight erosion or bank undercutting scores 45.]	Stream bank moderately stable. **(a)** 10-25% of bank eroded or slumping. **(b)** If trees present along bank, a few large (>1 inch dia.) roots exposed. **(c)** Most eroded areas recovering.	Stream banks unstable. **(a)** 25-50% of bank eroded. **(b)** Erosion, slumping, and undercutting prevalent, especially at places other than cutbanks. **(c)** If trees present along bank, many large (>1 inch in dia.) roots exposed with some trees toppled into stream due to undercutting.	Stream bank extremely unstable. **(a)** >50% of bank eroded **(b)** Erosion, slumping, and undercutting prevalent, esp. at places other than cut banks. **(c)** If trees present along bank, many toppled into stream due to undercutting. **(d)** Banks hardened with rocks, gabions, concrete, or bulkheading.
Score (L) =	Left Bank: 50 45	40 35 30	25 20 15	10 5
Score (R) =	Right Bank: 50 45	40 35 30	25 20 15	10 5

[1] Riparian zone is from the stream bank to the floodplain or former floodplain edge if >90 ft. If former floodplain is not discernible, use 90-ft RZC boundary.

[2] See page 4, footnote 5, for definition of pollution.

[3] Habitat quality encompasses both plant and animal habitat and includes both quality and area. Quality assumes that mature or old forest with appropriate quality and quantity of LDW, snags, and characteristic 3-D structure.

[4] Intact forest is one with all strata present, including canopy, midstory, understory, and herb layers. Canopy must be comprised of trees >6 inch (>15 cm) dbh, including at least 4 of the following species: red maple, bald cypress, sycamore, sweetgum, water tupelo, swamp blackgum, elm, and wetland oaks. Forest cover could be linearly arranged along channel or in blocks scattered within the riparian zone.

[5] Do not assess SRC #2, #3, & #7 if stream is backed up by downstream beaver impoundment. Assess relic beaver impounments. For relic impoundments, sediment layer may be deep at upstream end of unmaintained impoundment and reduced in depth closer to former dam site.

APPENDIX B

Coordinates of All Riparian Assessment Reaches*

Stream Name	Site Designation**	River Basin	Physiographic Province	Type	Latitude	Longitude
Pipes Branch	Pipes Branch	Hiwassee	Mountains	RHO	35.093715	83.914541
Sudderth Branch	Sudderth Branch at Timpson Rd	Hiwassee	Mountains	RLO	35.071561	83.940629
Sudderth Branch	UT Sudderth Branch at Timpson Rd	Hiwassee	Mountains	RLO	35.070012	83.940295
Sudderth Branch	Sudderth Branch at SR 1537 Mission Rd	Hiwassee	Mountains	RLO	35.068703	83.936403
Fall Branch	Fall Branch above Adam Sutton Rd	Hiwassee	Mountains	RLO	35.087594	83.982511
Fall Branch	UT Fall Branch at Adam Sutton Rd	Hiwassee	Mountains	RHO	35.087422	83.982134
Fall Branch	UT1 Fall Branch at Fall Branch Rd	Hiwassee	Mountains	RLO	35.086613	83.983348
Fall Branch	Siebold Branch above Fall Br Rd	Hiwassee	Mountains	RLO	35.088474	83.987323
Fall Branch	Fall Branch at Fall Br Rd above US 64	Hiwassee	Mountains	RHO	35.083342	83.986089
Graham Branch	Graham Branch at NE end of Barnett Cir	Hiwassee	Mountains	RLO	35.108601	83.966857
Graham Branch	UT Graham Branch at NW end of Barnett Cir	Hiwassee	Mountains	RLO	35.107740	83.971169
Graham Branch	Graham Branch at Winding Hill Trail	Hiwassee	Mountains	RLO	35.099459	83.963425
Graham Branch	UT1 Graham Branch at Barnett Rd	Hiwassee	Mountains	RLO	35.098546	83.960766
Graham Branch	Graham Branch at 1531 above Hendrix Rd	Hiwassee	Mountains	RHO	35.096403	83.960603
Gibbs Creek	UT Gibbs Creek at Fairport Rd	Tar	Piedmont	RLO	36.241974	78.534927
Gibbs Creek	Gibbs Creek above Grey Rock Rd	Tar	Piedmont	RHO	36.192504	78.516126
Gibbs Creek	UT Gibbs Creek above Grey Rock Rd	Tar	Piedmont	RLO	36.193589	78.514960
Gibbs Creek	Gibbs Creek below Grey Rock Rd	Tar	Piedmont	RHO	36.190902	78.514875
Sand Creek	Sand Creek at NC 56	Tar	Piedmont	RLO	36.140853	78.572825
Sand Creek	Sand Creek at SR 1623 - south site	Tar	Piedmont	RLO	36.154703	78.567803
Sand Creek	Sand Creek at SR 1623 - north site	Tar	Piedmont	RHO	36.182746	78.559081
Hatchers Run	Hatchers Run below Lake Devin Rd	Tar	Piedmont	RLO	36.298629	78.624550
Hatchers Run	Hatchers Run below Providence Rd	Tar	Piedmont	RLO	36.293274	78.619156
Hatchers Run	Hatchers Run at US 15	Tar	Piedmont	RHO	36.274544	78.608054
Coon Creek	UT Coon Creek off US 15	Tar	Piedmont	RLO	36.367015	78.591933
Coon Creek	UT Coon Creek at SR 1518 - Winding Oak Rd	Tar	Piedmont	RLO	36.365402	78.572787
Coon Creek	UT Coon Creek at SR 1617 - Sidney Cottrell Rd	Tar	Piedmont	RLO	36.374695	78.563202
Coon Creek	East UT Coon Creek SR 1518 - Winding Oak Rd	Tar	Piedmont	RLO	36.366606	78.562928

Stream Name	Site Designation**	River Basin	Physiographic Province	Type	Latitude	Longitude
Coon Creek	UT Coon Creek off US 15 at Winfield	Tar	Piedmont	RLO	36.357600	78.585154
Coon Creek	UT Coon Creek at SR 1515 - Horner Siding Rd	Tar	Piedmont	RHO	36.354811	78.568071
Toms Creek	UT Toms Creek at Capital Heights Rd	Neuse	Piedmont	ULO	35.907006	78.495324
Toms Creek	UT Toms Creek at Ten Point Trail	Neuse	Piedmont	ULO	35.919373	78.512653
Toms Creek	Toms Creek at Coach Lantern Dr	Neuse	Piedmont	UHO	35.913183	78.515453
Toms Creek	UT Toms Creek at Falconhurst Dr	Neuse	Piedmont	ULO	35.911223	78.524233
Toms Creek	Toms Creek at SR 2044 - Ligon Mill Rd	Neuse	Piedmont	UHO	35.909132	78.527344
Speight Branch	Speight Branch at SR 1000 - Tryon Rd	Neuse	Piedmont	ULO	35.745940	78.750630
Speight Branch	Speight Branch at SR 1385 - Lily Atkins Rd	Neuse	Piedmont	ULO	35.725472	78.755103
Williams Creek	UT Williams Creek at SR 1308 - Laura Duncan Rd	Neuse	Piedmont	ULO	35.735689	78.843961
Williams Creek	UT Williams Creek at SR 1435 - Old Raleigh Rd	Neuse	Piedmont	ULO	35.740797	78.824998
Williams Creek	UT Williams Creek at McKenan Dr	Neuse	Piedmont	UHO	35.736828	78.810161
Williams Creek	Williams Creek at SR 1308 - Laura Duncan Rd	Neuse	Piedmont	UHO	35.753256	78.829562
Williams Creek	Williams Creek at SR 1435 - Old Raleigh Rd	Neuse	Piedmont	UHO	35.739244	78.808685
Williams Creek	Williams Creek above US1 at Edinburgh St	Neuse	Piedmont	UHO	35.736392	78.800003
Bolin Creek	Tanbark Branch at Broad St	Neuse	Piedmont	ULO	35.915251	79.068653
Bolin Creek	UT Tanbark Branch at Caldwell St	Neuse	Piedmont	ULO	35.916500	79.064265
Bolin Creek	Tanbark Branch at Umstead Park	Neuse	Piedmont	UHO	35.920105	79.064856
Bolin Creek	Bolin Creek at SR 1009 - Old NC 86	Neuse	Piedmont	RLO	35.948965	79.109399
Bolin Creek	Bolin Creek just above Jones Creek	Neuse	Piedmont	ULO	35.952740	79.094617
Bolin Creek	Jones Creek at SR 1009 - Old NC 86	Neuse	Piedmont	RLO	35.964451	79.107964
Bolin Creek	Jones Creek at Turtleback Crossing	Neuse	Piedmont	ULO	35.953965	79.094541
Bolin Creek	UT Bolin Creek at SR 1727 site a - Eubanks Rd	Neuse	Piedmont	RLO	35.966281	79.093440
Bolin Creek	UT Bolin Creek at Camden Dr	Neuse	Piedmont	ULO	35.948889	79.085391
Bolin Creek	Bolin Creek at SR 1777 - Homestead Rd	Neuse	Piedmont	RHO	35.943170	79.086084
Horsepen creek	UT Horsepen Creek (King George Branch) at Friendly Ave	Cape Fear	Piedmont	ULO	36.088892	79.908336
Horsepen creek	UT1 Horsepen Creek above Chance Rd	Cape Fear	Piedmont	ULO	36.126406	79.890047
Horsepen creek	UT2 Horsepen Creek above Chance Rd	Cape Fear	Piedmont	ULO	36.126768	79.890915
Horsepen creek	UT Horsepen Creek at Chance Rd	Cape Fear	Piedmont	ULO	36.126406	79.890047
Horsepen creek	Horsepen Creek at Distribution Dr	Cape Fear	Piedmont	ULO	36.090293	79.930887
Horsepen creek	Sherwin Branch at Chimney Rock Rd	Cape Fear	Piedmont	ULO	36.080303	79.921175
Horsepen creek	Sherwin Branch at Friendly Ave	Cape Fear	Piedmont	ULO	36.088847	79.922360
Horsepen creek	Horsepen Creek at Radar Rd	Cape Fear	Piedmont	UHO	36.096114	79.922503

Stream Name	Site Designation**	River Basin	Physiographic Province	Type	Latitude	Longitude
Hendricks Creek	Pt 7A - Hospital Rd. off US 64 Byp	Tar	Coastal Plain	ULO	35.918944	77.564491
Hendricks Creek	Pt 19A - be. Northern Blvd.	Tar	Coastal Plain	ULO	35.913402	77.559736
Hendricks Creek	2	Tar	Coastal Plain	RLO	35.894521	77.580772
Hendricks Creek	14	Tar	Coastal Plain	RLO	35.899268	77.582054
Hendricks Creek	15	Tar	Coastal Plain	RLO	35.900752	77.581436
Hendricks Creek	A13	Tar	Coastal Plain	RLO	35.903172	77.580663
Hendricks Creek	10	Tar	Coastal Plain	RLO	35.906509	77.576740
Hendricks Creek	17	Tar	Coastal Plain	RLO	35.907539	77.576077
Hendricks Creek	A6	Tar	Coastal Plain	ULO	35.909672	77.569279
Hendricks Creek	A1	Tar	Coastal Plain	UHO	35.910379	77.557696
Hendricks Creek	7	Tar	Coastal Plain	UHO	35.909179	77.555779
Hendricks Creek	Pt 23 - be. Sunset Rd.	Tar	Coastal Plain	UHO	35.907921	77.553199
Hendricks Creek	A20	Tar	Coastal Plain	UHO	35.904572	77.553594
Hendricks Creek	Pt A8 - be. Wilson St.	Tar	Coastal Plain	UHO	35.897971	77.540060
Hendricks Creek	Pt 22 - above St. James St.	Tar	Coastal Plain	UHO	35.897142	77.539561
Reedy Branch	23	Tar	Coastal Plain	ULO	35.599783	77.345785
Reedy Branch	Pt 16 - NC 33	Tar	Coastal Plain	ULO	35.601755	77.347712
Green Mill Run	A8	Tar	Coastal Plain	ULO	35.603539	77.422367
Green Mill Run	A3	Tar	Coastal Plain	ULO	35.601554	77.418121
Green Mill Run	7	Tar	Coastal Plain	RLO	35.590299	77.435262
Green Mill Run	24	Tar	Coastal Plain	ULO	35.588951	77.433166
Green Mill Run	A6	Tar	Coastal Plain	ULO	35.588605	77.433940
Green Mill Run	A2	Tar	Coastal Plain	RLO	35.587062	77.424212
Green Mill Run	A12	Tar	Coastal Plain	RLO	35.587653	77.423747
Green Mill Run	15	Tar	Coastal Plain	ULO	35.587363	77.422486
Green Mill Run	4	Tar	Coastal Plain	RLO	35.590848	77.418795
Green Mill Run	3	Tar	Coastal Plain	ULO	35.578015	77.419310
Green Mill Run	33	Tar	Coastal Plain	ULO	35.577816	77.415963
Green Mill Run	13	Tar	Coastal Plain	ULO	35.578426	77.414271
Green Mill Run	20	Tar	Coastal Plain	ULO	35.576508	77.414475
Green Mill Run	2	Tar	Coastal Plain	ULO	35.578072	77.411374
Green Mill Run	A7	Tar	Coastal Plain	ULO	35.577473	77.411575
Green Mill Run	A9	Tar	Coastal Plain	ULO	35.576067	77.405832

Stream Name	**Site Designation****	**River Basin**	**Physiographic Province**	**Type**	**Latitude**	**Longitude**
Green Mill Run	22	Tar	Coastal Plain	ULO	35.582263	77.402526
Green Mill Run	10	Tar	Coastal Plain	ULO	35.583070	77.401791
Green Mill Run	1	Tar	Coastal Plain	UHO	35.583241	77.401077
Green Mill Run	Pt A11 - Memorial Dr.	Tar	Coastal Plain	UHO	35.585176	77.395966
Green Mill Run	30	Tar	Coastal Plain	UHO	35.585972	77.393734
Green Mill Run	17	Tar	Coastal Plain	UHO	35.588866	77.380189
Green Mill Run	A12	Tar	Coastal Plain	UHO	35.587650	77.423745
Green Mill Run	26	Tar	Coastal Plain	UHO	35.599306	77.369801
Green Mill Run	A4	Tar	Coastal Plain	UHO	35.600299	77.368024
Green Mill Run	25	Tar	Coastal Plain	UHO	35.603155	77.367760
Green Mill Run	Pt 28 - N of High School	Tar	Coastal Plain	UHO	35.603532	77.365939
Phillipi Branch	NC 33	Tar	Coastal Plain	ULO	35.589591	77.262443
UT Cow Swamp	7	Tar	Coastal Plain	RLO	35.536754	77.259996
UT Cow Swamp	Pt A10 - SR 1722	Tar	Coastal Plain	RLO	35.531224	77.258793
UT Crisp Creek	6	Tar	Coastal Plain	RLO	35.893779	77.343854
UT Crisp Creek	Pt A8 - NC 42	Tar	Coastal Plain	RLO	35.891735	77.340416
Reedy Branch	21	Neuse	Coastal Plain	RLO	35.431559	77.928819
Reedy Branch	65	Neuse	Coastal Plain	RLO	35.429360	77.923336
Reedy Branch	Pt 59 - Wayne Mem. Dr. (SR 1556)	Neuse	Coastal Plain	RLO	35.425055	77.925816
UT Stoney Creek	52	Neuse	Coastal Plain	RLO	35.367759	77.930307
UT Stoney Creek	Pt 56 behind Mall - N of US 13 & W of US 70	Neuse	Coastal Plain	RLO	35.379739	77.940713
Moss Neck Swamp	69	Lumber	Coastal Plain	RLO	34.736778	79.192062
Moss Neck Swamp	32	Lumber	Coastal Plain	RLO	34.733740	79.189442
Moss Neck Swamp	51	Lumber	Coastal Plain	RLO	34.726950	79.183326
Moss Neck Swamp	61	Lumber	Coastal Plain	RLO	34.724172	79.177526
Moss Neck Swamp	31	Lumber	Coastal Plain	RLO	34.723653	79.175789
Moss Neck Swamp	42	Lumber	Coastal Plain	RHO	34.703791	79.157993
Moss Neck Swamp	55	Lumber	Coastal Plain	RHO	34.702918	79.157510
Moss Neck Swamp	45	Lumber	Coastal Plain	RHO	34.700388	79.156983
Moss Neck Swamp	11	Lumber	Coastal Plain	RLO	34.697052	79.155129
Moss Neck Swamp	34	Lumber	Coastal Plain	RHO	34.691504	79.151516
Moss Neck Swamp	18	Lumber	Coastal Plain	RHO	34.690275	79.151170
Moss Neck Swamp	12	Lumber	Coastal Plain	RLO	34.687445	79.150326

Stream Name	Site Designation**	River Basin	Physiographic Province	Type	Latitude	Longitude
Moss Neck Swamp	Pt 6 - Alvin Rd.	Lumber	Coastal Plain	RLO	34.684337	79.149217
*Reaches that are shaded are points that are at or just above benthic macroinvertebrate sampling points.						
**All site designations in the coastal plain are reaches used by Brinson in the development of the riparian assessment method.						

Appendix C. Raw Data (Part 1).

Ref Number	Stream Name	Site Designation	River Basin	Physiographic Province	Stream Type	Temperature, C	DO % Sat	DO mg/L	Conductivity	pH	1-Channel Modification	2-Instream Habitat	3-Bottom Substrate	4-Pool Variety	5-Riffle Habitat	6-Bank Stability	7-Light Penetration	8-Rip Zone Width	DWQ Total Score
1	Pipes Br.	Pipes Br.	Hiwassee	M	RHO	20.1	.	.	14	5.33	4	20	15	10	16	13	10	5	93
2	Sudderth Br.	Sudderth Br. at Timpson Rd	Hiwassee	M	RLO	20.3	40	3.6	37	6.05	5	16	8	6	13	12	8	7	75
3	Sudderth Br.	UT Sudderth Br. at Timpson Rd	Hiwassee	M	RLO	.	.	.	.	.	1	6	3	0	0	6	10	5	31
4	Sudderth Br.	Sudderth Br. at SR 1537 Mission Rd	Hiwassee	M	RLO	21.1	63	5.6	41	6.30	4	16	12	4	16	12	10	4	78
5	Fall Br.	Fall Br. above Adam Sutton Rd	Hiwassee	M	RLO	19.8	.	.	25	5.95	2	15	8	4	4	14	8	10	65
6	Fall Br.	UT Fall Br. at Adam Sutton Rd	Hiwassee	M	RHO	19.3	.	.	38	5.63	3	14	8	0	14	4	8	9	60
7	Fall Br.	UT1 Fall Br. at Fall Br. Rd	Hiwassee	M	RLO	20.6	.	.	20	5.76	2	11	8	10	7	4	7	5	54
8	Fall Br.	Siebold Br. above Fall Br Rd	Hiwassee	M	RLO	20.5	.	.	18	5.42	5	15	12	4	16	9	10	4	75
9	Fall Br.	Fall Br. at Fall Br Rd above US 64	Hiwassee	M	RHO	20.2	.	.	26	5.74	4	15	12	6	14	14	10	7	82
10	Graham Br.	Graham Br. at NE end of Barnett Cir	Hiwassee	M	RLO	19.1	.	.	27	5.06	4	13	11	8	14	10	8	6	74
11	Graham Br.	UT Graham Br. at NW end of Barnett Cir	Hiwassee	M	RLO	21.5	.	.	38	5.48	4	15	14	8	14	10	8	8	81
12	Graham Br.	Graham Br. at Winding Hill Trail	Hiwassee	M	RLO	20.7	.	.	41	6.06	4	20	12	6	16	12	10	7	87
13	Graham Br.	UT1 Graham Br. at Barnett Rd	Hiwassee	M	RLO	19.7	.	.	32	6.30	4	15	11	4	14	12	7	8	75
14	Graham Br.	Graham Br. at 1531 above Hendrix Rd	Hiwassee	M	RHO	20.6	.	.	42	6.47	4	20	14	8	14	6	8	9	83
15	Gibbs Cr.	UT Gibbs Cr. at Fairport Rd	Tar	P	RLO	.	.	.	.	.	4	5	2	6	3	12	10	9	51
16	Gibbs Cr.	Gibbs Cr. above Grey Rock Rd	Tar	P	RHO	.	.	.	.	.	4	11	3	6	0	10	10	10	54
17	Gibbs Cr.	UT Gibbs Cr. above Grey Rock Rd	Tar	P	RLO	.	.	.	.	.	4	15	3	6	0	10	10	8	56
18	Gibbs Cr.	Gibbs Cr. below Grey Rock Rd	Tar	P	RHO	.	.	.	.	.	4	11	3	6	3	6	10	10	53
19	Sand Cr.	Sand Cr. at NC 56	Tar	P	RLO	22.0	85	7.4	118	6.56	5	16	1.5	10	14	12	9	10	78
20	Sand Cr.	Sand Cr. at SR 1623 - south site	Tar	P	RLO	24.6	81	6.1	100	6.21	4	20	12	10	16	12	10	10	94
21	Sand Cr.	Sand Cr. at SR 1623 - north site	Tar	P	RHO	25.3	94	7.7	75	6.67	4	16	12	8	16	12	10	10	88
22	Hatchers Run	Hatchers Run below Lake Devin Rd	Tar	P	RLO	29.9	74	5.6	89	9.06	1	6	9	3	8	10	9	3	49
23	Hatchers Run	Hatchers Run below Providence Rd	Tar	P	RLO	24.8	53	4.4	272	6.18	5	11	2	4	0	14	2	10	48
24	Hatchers Run	Hatchers Run at US 15	Tar	P	RHO	24.1	75	6.3	80	6.47	4	16	12	9	12	6	10	9	78
25	Coon Cr.	UT Coon Cr. off US 15	Tar	P	RLO	.	.	.	.	.	3	7	1	0	0	4	10	10	35
26	Coon Cr.	UT Coon Cr. at SR 1518 - Winding Oak Rd	Tar	P	RLO	24.3	88	7.3	91	6.43	4	15	3.5	0	2	6	7	8	46
27	Coon Cr.	UT Coon Cr. at SR 1617 - Sidney Cottrell Rd	Tar	P	RLO	21.0	84	7.5	114	6.32	5	12	5.5	4	3	8	10	10	58

Ref Number	Stream Name	Site Designation	River Basin	Physiographic Province	Stream Type	Temperature, C	DO % Sat	DO mg/L	Conductivity	pH	1-Channel Modification	2-Instream Habitat	3-Bottom Substrate	4-Pool Variety	5-Riffle Habitat	6-Bank Stability	7-Light Penetration	8-Rip Zone Width	DWQ Total Score
28	Coon Cr.	East UT Coon Cr. SR 1518 - Winding Oak Rd	Tar	P	RLO	22.7	108	9.3	145	6.83	5	16	7	6	7	12	10	10	73
29	Coon Cr.	UT Coon Cr. at Winfield	Tar	P	RLO	.	.	.	.	.	5	7	6	9	14	8	10	10	69
30	Coon Cr.	UT Coon Cr. at SR 1515 - Horner Siding Rd	Tar	P	RHO	25.0	100	8.2	131	6.64	5	20	14	10	16	12	10	10	97
31	Toms Cr.	UT Toms Cr. at Capital Heights Rd	Neuse	P	ULO	22.0	84	7.4	60	5.29	5	14	3	10	10	12	10	4.5	69
32	Toms Cr.	UT Toms Cr. at Ten Point Trail	Neuse	P	ULO	23.6	51	4.4	78	5.92	0	14	2.5	2	0	14	5	3	41
33	Toms Cr.	Toms Cr. at Coach Lantern Dr	Neuse	P	UHO	28.7	61	4.7	106	6.06	4	16	4	8	10	10	10	4	66
34	Toms Cr.	UT Toms Cr. at Falconhurst Dr	Neuse	P	ULO	23.7	85	7.2	76	6.13	5	6	3	8	10	10	10	0	52
35	Toms Cr.	Toms Cr. at SR 2044 - Ligon Mill Rd	Neuse	P	UHO	23.7	81	6.8	115	6.26	4.5	10	3	4	0	12	10	6	50
36	Speight Br.	Speight Br. at SR 1000 - Tryon Rd	Neuse	P	ULO	29.8	88	6.7	109	9.02	4	12	6	8	16	12	10	9	77
37	Speight Br.	Speight Br. at SR 1385 - Lily Atkins Rd	Neuse	P	ULO	25.5	96	7.8	103	6.38	5	14	11	8	14	12	10	6	80
38	Williams Cr.	UT Williams Cr. at SR 1308 - Laura Duncan Rd	Neuse	P	ULO	.	.	.	.	.	5	11	1	0	0	14	10	9	50
39	Williams Cr.	UT Williams Cr. at SR 1435 - Old Raleigh Rd	Neuse	P	ULO	25.8	16	1.4	234	6.53	2	12	3.5	4	3	4	7	4	40
40	Williams Cr.	UT Williams Cr. at McKenan Dr	Neuse	P	UHO	26.8	82	6.5	72	6.53	5	16	4	8	14	8	10	4	69
41	Williams Cr.	Williams Cr. at SR 1308 - Laura Duncan Rd	Neuse	P	UHO	24.0	88	7.4	144	6.74	2	14	3	4	3	6	10	10	52
42	Williams Cr.	Williams Cr. at SR 1435 - Old Raleigh Rd	Neuse	P	UHO	27.0	72	5.8	105	6.21	4	20	12	10	14	12	10	7	89
43	Williams Cr.	Williams Cr. above US1 at Edinburgh St	Neuse	P	UHO	29.8	109	8.3	119	6.39	3	20	12	6	7	4	2	4	58
44	Bolin Cr.	Tanbark Br. at Broad St	Neuse	P	ULO	21.5	.	.	374	6.81	5	16	10	6	16	13	10	10	86
45	Bolin Cr.	UT Tanbark Br. at Caldwell St	Neuse	P	ULO	22.2	.	.	460	6.98	3	16	4	8	12	6	7	7	63
46	Bolin Cr.	Tanbark Br. at Umstead Park	Neuse	P	UHO	22.2	.	.	304	7.02	4	15	10	6	16	12	10	8	81
47	Bolin Cr.	Bolin Cr. at SR 1009 - Old NC 86	Neuse	P	RLO	26.8	85	6.8	103	6.64	5	16	3	8	14	8	10	6	70
48	Bolin Cr.	Bolin Cr. just above Jones Cr.	Neuse	P	ULO	27.0	74	5.8	201	6.56	5	12	6	8	10	6	7	9	63
49	Bolin Cr.	Jones Cr. at SR 1009 - Old NC 86	Neuse	P	RLO	.	.	.	.	.	5	15	2	0	0	14	1	5	42
50	Bolin Cr.	Jones Cr. at Turtleback Crossing	Neuse	P	ULO	26.2	83	6.6	184	6.58	4	16	14	10	15	6	10	8	83
51	Bolin Cr.	UT Bolin Cr. at SR 1727 site a - Eubanks Rd	Neuse	P	RLO	.	.	.	.	.	5	19	3	10	10	14	10	10	81
52	Bolin Cr.	UT Bolin Cr. at Camden Dr	Neuse	P	ULO	.	.	.	.	.	5	14	12	10	12	10	10	5	78

Ref Number	Stream Name	Site Designation	River Basin	Physiographic Province	Stream Type	Temperature, C	DO % Sat	DO mg/L	Conductivity	pH	1-Channel Modification	2-Instream Habitat	3-Bottom Substrate	4-Pool Variety	5-Riffle Habitat	6-Bank Stability	7-Light Penetration	8-Rip Zone Width	DWQ Total Score
53	Bolin Cr.	Bolin Cr. at SR 1777 - Homestead Rd	Neuse	P	RHO	24.7	80	6.7	86	6.42	4	20	15	10	16	8	7	7	87
54	Horsepen Cr.	UT Horsepen Cr. at Friendly Ave	Cape Fear	P	ULO	27.1	97	7.7	132	6.69	0	6	3	5	3	4	2	0	23
55	Horsepen Cr.	UT1 Horsepen Cr. above Chance Rd	Cape Fear	P	ULO	22.9	99	8.4	78	6.11	4	19	4	10	10	12	10	6	75
56	Horsepen Cr.	UT2 Horsepen Cr. above Chance Rd	Cape Fear	P	ULO	24.5	92	7.6	77	6.34	5	15	3	7	10	10	10	10	70
57	Horsepen Cr.	UT Horsepen Cr. at Chance Rd	Cape Fear	P	ULO	21.6	93	8.2	91	6.08	4	13	3	8	7	8	10	5	58
58	Horsepen Cr.	Horsepen Cr. at Distribution Dr	Cape Fear	P	ULO	22.8	91	7.8	254	7.37	2	16	14	6	7	8	10	8	71
59	Horsepen Cr.	Sherwin Br. at Chimney Rock Rd	Cape Fear	P	ULO	22.8	77	6.6	219	6.52	2	12	2.5	5	3	0	10	7	42
60	Horsepen Cr.	Sherwin Br. at Friendly Ave	Cape Fear	P	ULO	25.0	94	7.8	130	7.37	2	12	13	6	8	6	10	6	63
61	Horsepen Cr.	Horsepen Cr. at Radar Rd	Cape Fear	P	UHO	24.5	104	8.6	174	7.44	1	17	6	6	14	4	10	7	65
62	Hendricks Cr.	Pt 7A - Hospital Rd. off US 64 Byp	Tar	C	ULO	25.0	82	6.8	118	ND	5	6	7	6	.	7	7	5	43
63	Hendricks Cr.	Pt 19A - be. Northern Blvd.	Tar	C	ULO	25.2	82.1	6.7	135	ND	5	8	7	10	.	14	8	1	53
64	Hendricks Cr.	2	Tar	C	RLO	.	.	.	.	.	.	.	.	.	.	.	.	.	.
65	Hendricks Cr.	14	Tar	C	RLO	.	.	.	.	.	.	.	.	.	.	.	.	.	.
66	Hendricks Cr.	15	Tar	C	RLO	.	.	.	.	.	.	.	.	.	.	.	.	.	.
67	Hendricks Cr.	13A	Tar	C	RLO	.	.	.	.	.	.	.	.	.	.	.	.	.	.
68	Hendricks Cr.	10	Tar	C	RLO	.	.	.	.	.	.	.	.	.	.	.	.	.	.
69	Hendricks Cr.	17	Tar	C	RLO	.	.	.	.	.	.	.	.	.	.	.	.	.	.
70	Hendricks Cr.	6A	Tar	C	ULO	.	.	.	.	.	.	.	.	.	.	.	.	.	.
71	Hendricks Cr.	1A	Tar	C	UHO	.	.	.	.	.	.	.	.	.	.	.	.	.	.
72	Hendricks Cr.	7	Tar	C	UHO	.	.	.	.	.	.	.	.	.	.	.	.	.	.
73	Hendricks Cr.	Pt 23 - be. Sunset Rd.	Tar	C	UHO	22.9	82.5	7.1	132	ND	8	10	10	6	.	16	10	6	66
74	Hendricks Cr.	20A	Tar	C	UHO	.	.	.	.	.	.	.	.	.	.	.	.	.	.
75	Hendricks Cr.	Pt 8A - be. Wilson St.	Tar	C	UHO	24.5	80.1	6.6	118	ND	7	15	13	6	.	20	5	3	69
76	Hendricks Cr.	Pt 22 - be. St. James St.	Tar	C	UHO	26.5	91	7.3	122	ND	10	10	7	4	.	18	7	6	62
77	Reedy Br.	23	Tar	C	ULO	.	.	.	.	.	.	.	.	.	.	.	.	.	.
78	Reedy Br.	Pt 16 - NC 33	Tar	C	ULO	ND	ND	ND	ND	ND	10	5	7	4	.	8	10	7	51
79	Green Mill Run	8A	Tar	C	ULO	.	.	.	.	.	.	.	.	.	.	.	.	.	.
80	Green Mill Run	3A	Tar	C	ULO	.	.	.	.	.	.	.	.	.	.	.	.	.	.
81	Green Mill Run	7	Tar	C	RLO	.	.	.	.	.	.	.	.	.	.	.	.	.	.

Ref Number	Stream Name	Site Designation	River Basin	Physiographic Province	Stream Type	Temperature, C	DO % Sat	DO mg/L	Conductivity	pH	1-Channel Modification	2-Instream Habitat	3-Bottom Substrate	4-Pool Variety	5-Riffle Habitat	6-Bank Stability	7-Light Penetration	8-Rip Zone Width	DWQ Total Score
82	Green Mill Run	24	Tar	C	ULO	.	.	.	.	.	.	.	.	.	.	.	.	.	.
83	Green Mill Run	6A	Tar	C	ULO	.	.	.	.	.	.	.	.	.	.	.	.	.	.
84	Green Mill Run	2A	Tar	C	RLO	.	.	.	.	.	.	.	.	.	.	.	.	.	.
85	Green Mill Run	12A	Tar	C	RLO	.	.	.	.	.	.	.	.	.	.	.	.	.	.
86	Green Mill Run	15	Tar	C	ULO	.	.	.	.	.	.	.	.	.	.	.	.	.	.
87	Green Mill Run	4	Tar	C	RLO	.	.	.	.	.	.	.	.	.	.	.	.	.	.
88	Green Mill Run	3	Tar	C	ULO	.	.	.	.	.	.	.	.	.	.	.	.	.	.
89	Green Mill Run	33	Tar	C	ULO	.	.	.	.	.	.	.	.	.	.	.	.	.	.
90	Green Mill Run	13	Tar	C	ULO	.	.	.	.	.	.	.	.	.	.	.	.	.	.
91	Green Mill Run	20	Tar	C	ULO	.	.	.	.	.	.	.	.	.	.	.	.	.	.
92	Green Mill Run	2	Tar	C	ULO	.	.	.	.	.	.	.	.	.	.	.	.	.	.
93	Green Mill Run	7A	Tar	C	ULO	.	.	.	.	.	.	.	.	.	.	.	.	.	.
94	Green Mill Run	9A	Tar	C	ULO	.	.	.	.	.	.	.	.	.	.	.	.	.	.
95	Green Mill Run	22	Tar	C	ULO	.	.	.	.	.	.	.	.	.	.	.	.	.	.
96	Green Mill Run	10	Tar	C	ULO	.	.	.	.	.	.	.	.	.	.	.	.	.	.
97	Green Mill Run	1	Tar	C	UHO	.	.	.	.	.	.	.	.	.	.	.	.	.	.
98	Green Mill Run	Pt 11A - Memorial Dr.	Tar	C	UHO	24.1	67	5.5	152	ND	7	10	7	10	.	14	10	7	65
99	Green Mill Run	30	Tar	C	UHO	.	.	.	.	.	.	.	.	.	.	.	.	.	.
100	Green Mill Run	17	Tar	C	UHO	.	.	.	.	.	.	.	.	.	.	.	.	.	.
101	Green Mill Run	1A	Tar	C	UHO	.	.	.	.	.	.	.	.	.	.	.	.	.	.
102	Green Mill Run	26	Tar	C	UHO	.	.	.	.	.	.	.	.	.	.	.	.	.	.
103	Green Mill Run	4A	Tar	C	UHO	.	.	.	.	.	.	.	.	.	.	.	.	.	.
104	Green Mill Run	25	Tar	C	UHO	.	.	.	.	.	.	.	.	.	.	.	.	.	.
105	Green Mill Run	Pt 28 - N of High School	Tar	C	UHO	25.8	90.7	7.4	180	ND	10	8	13	10	.	13	10	2	66
106	Phillipi Br.	NC 33	Tar	C	ULO	ND	ND	ND	ND	ND	15	8	7	8	.	18	8	10	74
107	UT Cow Swamp	7	Tar	C	RLO	.	.	.	.	.	.	.	.	.	.	.	.	.	.
108	UT Cow Swamp	Pt 10A - SR 1722	Tar	C	RLO	ND	ND	ND	ND	ND	5	3	7	4	.	8	0	2	29
109	UT Crisp Cr.	6	Tar	C	RLO	.	.	.	.	.	.	.	.	.	.	.	.	.	.
110	UT Crisp Cr.	Pt 8A - NC 44	Tar	C	RLO	ND	ND	ND	ND	ND	10	5	7	4	.	20	10	6	62

Ref Number	Stream Name	Site Designation	River Basin	Physiographic Province	Stream Type	Temperature, C	DO % Sat	DO mg/L	Conductivity	pH	1-Channel Modification	2-Instream Habitat	3-Bottom Substrate	4-Pool Variety	5-Riffle Habitat	6-Bank Stability	7-Light Penetration	8-Rip Zone Width	DWQ Total Score
111	Reedy Br.	21	Neuse	C	RLO	.	.	.	.	.	.	.	.	.	.	.	.	.	.
112	Reedy Br.	65	Neuse	C	RLO	.	.	.	.	.	.	.	.	.	.	.	.	.	.
113	Reedy Br.	Pt 59 - Wayne Mem. Dr. = Tommy Rd.	Neuse	C	RLO	24.1	15.8	1.3	127	ND	12	12	10	10	.	20	10	9	83
114	UT Stoney Cr.	52	Neuse	C	RLO	.	.	.	.	.	.	.	.	.	.	.	.	.	.
115	UT Stoney Cr.	Pt 56 - at Mall	Neuse	C	RLO	24.3	82.1	6.9	133	ND	5	2	7	4	.	4	10	9	41
116	Moss Neck Swamp	69	Lumber	C	RLO	.	.	.	.	.	.	.	.	.	.	.	.	.	.
117	Moss Neck Swamp	32	Lumber	C	RLO	.	.	.	.	.	.	.	.	.	.	.	.	.	.
118	Moss Neck Swamp	51	Lumber	C	RLO	.	.	.	.	.	.	.	.	.	.	.	.	.	.
119	Moss Neck Swamp	61	Lumber	C	RLO	.	.	.	.	.	.	.	.	.	.	.	.	.	.
120	Moss Neck Swamp	31	Lumber	C	RLO	.	.	.	.	.	.	.	.	.	.	.	.	.	.
121	Moss Neck Swamp	42	Lumber	C	RHO	.	.	.	.	.	.	.	.	.	.	.	.	.	.
122	Moss Neck Swamp	55	Lumber	C	RHO	.	.	.	.	.	.	.	.	.	.	.	.	.	.
123	Moss Neck Swamp	45	Lumber	C	RHO	.	.	.	.	.	.	.	.	.	.	.	.	.	.
124	Moss Neck Swamp	11	Lumber	C	RLO	.	.	.	.	.	.	.	.	.	.	.	.	.	.
125	Moss Neck Swamp	34	Lumber	C	RHO	.	.	.	.	.	.	.	.	.	.	.	.	.	.
126	Moss Neck Swamp	18	Lumber	C	RHO	.	.	.	.	.	.	.	.	.	.	.	.	.	.
127	Moss Neck Swamp	12	Lumber	C	RLO	.	.	.	.	.	.	.	.	.	.	.	.	.	.
128	Moss Neck Swamp	Pt 6 - Alvin Rd.	Lumber	C	RLO	24.1	58.9	4.9	105	ND	10	11	7	6	.	8	2	3	47

Appendix C (Part2).

Ref Number	Stream Name	Site Designation	Sample Type	Total Taxa	NCBI	EPT Taxa	Corrected EPT*	EPT Abundance	Riparian Zone Cover	Near Stream Cover	Habitat or In Stream Woody Structure	Substrate or Sediment Regime	Channel Ripiparian Zone Connection	Pollution Affecting Stream	Factors Affecting Riparian Zone	Habitat Quality of Riparian Zone	Stream Bank Stability	Stream Habitat Quality	Riparian Habitat Quality	Channel Condition	Riparian Zone Condition	Cumulative Function Score
1	Pipes Br.	Pipes Br.	EPT	.	.	21	24.2	89	37	30	85	100	95	75	95	50	100	77	69	81	74	78
2	Sudderth Br.	Sudderth Br. at Timpson Rd	.	.	.	.	.	.	58	69	85	65	90	85	70	60	na	82	70	83	72	78
3	Sudderth Br.	UT Sudderth Br. at Timpson Rd	.	.	.	.	.	.	43	38	15	25	30	30	45	35	na	28	38	26	39	33
4	Sudderth Br.	Sudderth Br. at SR 1537 Mission Rd	EPT	.	.	5	5.8	16	9	15	80	90	40	50	50	10	na	46	27	53	31	42
5	Fall Br.	Fall Br. above Adam Sutton Rd	.	.	.	.	.	.	8	10	45	60	55	80	90	10	na	48	41	53	48	51
6	Fall Br.	UT Fall Br. at Adam Sutton Rd	.	.	.	.	.	.	8	11	15	60	55	80	95	10	100	52	42	52	49	51
7	Fall Br.	UT1 Fall Br. at Fall Br. Rd	.	.	.	.	.	.	7	9	30	45	30	55	15	10	na	31	15	34	16	25
8	Fall Br.	Siebold Br. above Fall Br Rd	.	.	.	.	.	.	33	57	65	90	50	15	35	40	na	62	39	53	39	46
9	Fall Br.	Fall Br. at Fall Br Rd above US 64	EPT	.	.	20	23.0	68	37	42	40	75	75	30	70	55	90	55	59	54	60	57
10	Graham Br.	Graham Br. at NE end of Barnett Cir	.	.	.	.	.	.	10	14	50	77.5	65	90	45	15	na	55	34	61	38	50
11	Graham Br.	UT Graham Br. at NW end of Barnett Cir	.	.	.	.	.	.	32	10	50	77.5	45	90	55	45	na	49	44	55	44	50
12	Graham Br.	Graham Br. at Winding Hill Trail	.	.	.	.	.	.	40	35	90	100	75	90	85	60	na	73	65	79	66	73
13	Graham Br.	UT1 Graham Br. at Barnett Rd	.	.	.	.	.	.	10	15	40	70	70	30	10	10	na	39	25	44	28	36
14	Graham Br.	Graham Br. at 1531 above Hendrix Rd	EPT	.	.	26	29.9	120	22	44	75	85	70	90	10	10	70	70	28	73	32	53
15	Gibbs Cr.	UT Gibbs Cr. at Fairport Rd	.	.	.	.	.	.	46	49	20	25	60	60	90	55	na	47	63	46	64	55
16	Gibbs Cr.	Gibbs Cr. above Grey Rock Rd	.	.	.	.	.	.	63	62	20	5	40	90	90	40	40	50	58	48	62	55
17	Gibbs Cr.	UT Gibbs Cr. above Grey Rock Rd	.	.	.	.	.	.	66	50	48	10	60	100	90	40	na	64	64	62	69	66
18	Gibbs Cr.	Gibbs Cr. below Grey Rock Rd	Full	.	.	31	.	144	86	85	45	30	50	100	86	70	26	61	73	61	74	68
19	Sand Cr.	Sand Cr. at NC 56	.	.	.	.	.	.	64	65	50	70	50	75	100	50	na	60	66	60	69	65
20	Sand Cr.	Sand Cr. at SR 1623 - south site	.	.	.	.	.	.	80	81	73	83	70	70	70	80	na	74	75	73	74	74
21	Sand Cr.	Sand Cr. at SR 1623 - north site	Q4	.	.	11	12.7	64	75	82	90	75	70	95	86	100	80	83	83	83	80	82

Ref Number	Stream Name	Site Designation	Sample Type	Total Taxa	NCBI	EPT Taxa	Corrected EPT*	EPT Abundance	Riparian Zone Cover	Near Stream Cover	Habitat or In Stream Woody Structure	Substrate or Sediment Regime	Channel Ripiparian Zone Connection	Pollution Affecting Stream	Factors Affecting Riparian Zone	Habitat Quality of Riparian Zone	Stream Bank Stability	Stream Habitat Quality	Riparian Habitat Quality	Channel Condition	Riparian Zone Condition	Cumulative Function Score
22	Hatchers Run	Hatchers Run below Lake Devin Rd	.	.	.	.	.	.	35	65	33	50	25	70	20	10	na	48	22	47	25	36
23	Hatchers Run	Hatchers Run below Providence Rd	.	.	.	.	.	.	30	11	15	5	90	60	100	10	na	44	57	45	68	57
24	Hatchers Run	Hatchers Run at US 15	Q4	.	.	13	15.0	50	48	55	75	70	30	85	85	70	10	51	58	56	55	56
25	Coon Cr.	UT Coon Cr. off US 15	.	.	.	.	.	.	40	22	35	5	60	40	70	80	na	39	62	39	59	49
26	Coon Cr.	UT Coon Cr. at SR 1518 - Winding Oak Rd	.	.	.	.	.	.	20	14	40	20	30	90	50	10	na	44	27	45	31	38
27	Coon Cr.	UT Coon Cr. at SR 1617 - Sidney Cottrell Rd	.	.	.	.	.	.	57	53	50	45	40	90	80	30	na	58	52	58	57	58
28	Coon Cr.	East UT Coon Cr. SR 1518 - Winding Oak Rd	.	.	.	.	.	.	33	27	70	65	90	100	75	60	na	72	65	76	66	71
29	Coon Cr.	UT Coon Cr. at Winfield	.	.	.	.	.	.	41	36	80	60	70	90	90	70	na	69	68	72	67	70
30	Coon Cr.	UT Coon Cr. at SR 1515 - Horner Siding Rd	EPT	.	.	37	42.6	108	55	60	85	88	70	95	100	80	80	78	76	80	75	78
31	Toms Cr.	UT Toms Cr. at Capital Heights Rd	.	.	.	.	.	.	84	88	50	40	80	40	45	70	85	69	70	63	70	67
32	Toms Cr.	UT Toms Cr. at Ten Point Trail	.	.	.	.	.	.	62	70	40	50	56	40	35	5	60	53	39	50	47	49
33	Toms Cr.	Toms Cr. at Coach Lantern Dr	.	.	.	.	.	.	90	91	75	40	55	55	70	20	50	65	59	63	68	66
34	Toms Cr.	UT Toms Cr. at Falconhurst Dr	.	.	.	.	.	.	58	85	30	25	70	30	20	10	70	57	39	51	46	49
35	Toms Cr.	Toms Cr. at SR 2044 - Ligon Mill Rd	EPT	.	.	6	6.9	37	94	99	45	20	70	70	80	45	70	71	72	65	78	72
36	Speight Br.	Speight Br. at SR 1000 - Tryon Rd	.	.	.	.	.	.	99	100	80	75	80	60	75	90	40	72	86	73	85	79
37	Speight Br.	Speight Br. at SR 1385 - Lily Atkins Rd	Full	.	.	6	.	26	97	97	70	62.5	90	70	90	60	70	77	87	76	90	83
38	Williams Cr.	UT Williams Cr. at SR 1308 - Laura Duncan Rd	.	.	.	.	.	.	89	90	25	0	30	55	95	40	100	60	64	49	69	59
39	Williams Cr.	UT Williams Cr. at SR 1435 - Old Raleigh Rd	.	.	.	.	.	.	67	58	25	30	45	45	40	25	10	37	44	37	49	43
40	Williams Cr.	UT Williams Cr. at McKenan Dr	Q4	.	.	7	8.1	56	88	99	75	45	35	50	45	45	55	63	53	59	55	57

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41	Williams Cr.	Williams Cr. at SR 1308 - Laura Duncan Rd	.	.	.	.	.	.	94	90	40	35	70	90	75	70	50	68	77	66	79	73
42	Williams Cr.	Williams Cr. at SR 1435 - Old Raleigh Rd	.	.	.	.	.	.	90	90	85	70	80	60	70	45	80	79	71	77	77	77
43	Williams Cr.	Williams Cr. above US1 at Edinburgh St	Q4	.	.	7	8.1	38	55	80	67.5	75	55	40	35	5	30	55	37	56	44	50
44	Bolin Cr.	Tanbark Br. at Broad St	.	.	.	1	.	10	100	100	95	70	70	80	100	80	50	79	88	80	89	85
45	Bolin Cr.	UT Tanbark Br. at Caldwell St	.	.	.	.	.	.	81	90	90	57.5	65	55	45	10	10	62	50	64	59	62
46	Bolin Cr.	Tanbark Br. at Umstead Park	Q5	.	.	1	1.2	10	88	87	87.5	80	70	90	90	70	30	73	79	77	82	80
47	Bolin Cr.	Bolin Cr. at SR 1009 - Old NC 86	.	.	.	.	.	.	42	34	75	45	70	50	60	50	na	57	55	59	56	58
48	Bolin Cr.	Bolin Cr. just above Jones Cr.	.	.	.	.	.	.	89	82	70	60	30	60	90	20	30	54	57	54	66	60
49	Bolin Cr.	Jones Cr. at SR 1009 - Old NC 86	.	.	.	.	.	.	28	30	45	20	60	40	20	10	na	44	29	44	34	39
50	Bolin Cr.	Jones Cr. at Turtleback Crossing	.	.	.	.	.	.	89	85	90	80	40	60	90	50	30	61	67	63	71	67
51	Bolin Cr.	UT Bolin Cr. at SR 1727 site a - Eubanks Rd	.	.	.	.	.	.	69	67	75	70	80	100	100	70	na	80	80	81	82	82
52	Bolin Cr.	UT Bolin Cr. at Camden Dr	.	.	.	.	.	.	83	88	95	90	65	40	15	20	30	64	46	66	51	59
53	Bolin Cr.	Bolin Cr. at SR 1777 - Homestead Rd	Full	.	.	7	.	38	33	36	90	90	70	80	85	50	55	66	59	72	62	67
54	Horsepen Cr.	UT Horsepen Cr. at Friendly Ave	Q5	.	.	6	6.9	33	48	73	15	65	30	30	15	5	10	32	24	31	29	30
55	Horsepen Cr.	UT1 Horsepen Cr. above Chance Rd	.	.	.	.	.	.	83	87	95	70	55	85	95	50	55	75	71	76	76	76
56	Horsepen Cr.	UT2 Horsepen Cr. above Chance Rd	.	.	.	.	.	.	100	100	70	55	60	100	90	70	50	76	80	75	82	79
57	Horsepen Cr.	UT Horsepen Cr. at Chance Rd	Q5	.	.	13	15.0	66	89	91	77.5	45	30	85	60	45	50	67	56	65	59	62
58	Horsepen Cr.	Horsepen Cr. at Distribution Dr	.	.	.	.	.	.	88	90	80	85	70	70	40	50	40	70	62	72	65	69
59	Horsepen Cr.	Sherwin Br. at Chimney Rock Rd	.	.	.	.	.	.	88	88	25	30	60	75	60	50	10	52	65	51	68	60
60	Horsepen Cr.	Sherwin Br. at Friendly Ave	.	.	.	.	.	.	69	93	65	70	20	55	55	50	10	49	49	49	48	49

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61	Horsepen Cr.	Horsepen Cr. at Radar Rd	Q5	.	.	3	3.5	7	86	86	70	80	70	70	60	40	40	67	64	69	69	69
62	Hendricks Cr.	Pt 7A - Hospital Rd. off US 64 Byp	Q4	27	7.33	1	1.2	3	73	70	20	10	10	40	5	5	70	42	23	34	27	31
63	Hendricks Cr.	Pt 19A - be. Northern Blvd.	Q4	31	7.33	1	1.2	10	75	100	60	10	20	40	20	20	40	52	34	46	37	41
64	Hendricks Cr.	2	.	.	.	.	.	.	15	10	30	80	90	30	35	5	.	40	36	46	43	45
65	Hendricks Cr.	14	.	.	.	.	.	.	61	60	100	70	70	80	100	60	NA	78	73	79	76	77
66	Hendricks Cr.	15	.	.	.	.	.	.	86	85	100	100	100	90	100	80	NA	94	92	95	94	95
67	Hendricks Cr.	13A	.	.	.	.	.	.	61	60	100	90	100	100	90	80	NA	90	83	93	83	88
68	Hendricks Cr.	10	.	.	.	.	.	.	36	35	90	80	100	100	100	70	NA	81	77	86	78	82
69	Hendricks Cr.	17	.	.	.	.	.	.	48	65	100	80	100	90	100	40	NA	89	72	91	79	85
70	Hendricks Cr.	6A	.	.	.	.	.	.	66	80	10	90	40	30	40	0	90	50	37	44	45	45
71	Hendricks Cr.	1A	.	.	.	.	.	.	62	95	60	10	50	30	20	10	30	53	36	49	41	45
72	Hendricks Cr.	7	.	.	.	.	.	.	64	100	50	20	50	50	30	20	40	58	41	53	46	49
73	Hendricks Cr.	Pt 23 - be. Sunset Rd.	Q4	35	7.18	3	3.5	12	72	83	30	40	55	30	35	10	70	54	43	48	50	49
74	Hendricks Cr.	20A	.	.	.	.	.	.	89	98	70	10	40	60	75	10	20	58	53	55	63	59
75	Hendricks Cr.	Pt 8A - be. Wilson St.	Q4	49	7.17	3	3.5	20	62	61	40	20	0	10	15	15	55	33	23	27	25	26
76	Hendricks Cr.	Pt 22 - be. St. James St.	Q4	30	7.15	2	2.3	11	62	93	40	100	0	50	20	15	30	43	24	42	26	34
77	Reedy Br.	23	.	.	.	.	.	.	95	95	80	10	50	30	60	65	5	52	68	50	68	59
78	Reedy Br.	Pt 16 - NC 33	Q4	19	6.64	1	1.2	3	91	100	80	20	80	50	50	45	10	64	67	64	71	67
79	Green Mill Run	8A	.	.	.	.	.	.	94	95	80	20	35	90	20	50	40	68	50	65	50	57
80	Green Mill Run	3A	.	.	.	.	.	.	100	100	90	20	50	90	20	80	45	75	63	73	59	66
81	Green Mill Run	7	.	.	.	.	.	.	86	85	90	30	70	90	35	70	NA	84	65	80	64	72
82	Green Mill Run	24	.	.	.	.	.	.	79	83	10	70	0	40	0	10	80	43	22	35	25	30
83	Green Mill Run	6A	.	.	.	.	.	.	77	83	10	70	0	40	0	10	80	43	22	35	24	30
84	Green Mill Run	2A	.	.	.	.	.	.	11	13	90	Bv	Bv	90	50	10	NA	64	24	73	28	51
85	Green Mill Run	12A	.	.	.	.	.	.	64	65	70	50	40	70	40	40	NA	61	46	60	47	54

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86	Green Mill Run	15	.	.	.	.	.	.	11	13	100	70	50	90	50	10	NA	63	30	69	35	52
87	Green Mill Run	4	.	.	.	.	.	.	49	54	60	40	20	40	30	45	NA	43	36	42	34	38
88	Green Mill Run	3	.	.	.	.	.	.	90	93	80	20	20	50	35	10	10	51	39	49	45	47
89	Green Mill Run	33	.	.	.	.	.	.	93	95	80	10	50	40	45	30	30	59	55	56	60	58
90	Green Mill Run	13	.	.	.	.	.	.	94	95	80	20	20	70	45	25	30	59	46	56	51	53
91	Green Mill Run	20	.	.	.	.	.	.	57	91	70	40	15	70	25	5	70	63	25	58	30	44
92	Green Mill Run	2	.	.	.	.	.	.	66	100	70	50	20	80	50	10	70	68	37	63	42	53
93	Green Mill Run	7A	.	.	.	.	.	.	74	95	80	10	0	40	15	10	40	51	25	45	28	36
94	Green Mill Run	9A	.	.	.	.	.	.	98	100	80	10	50	40	50	35	40	62	58	57	63	60
95	Green Mill Run	22	.	.	.	.	.	.	44	45	30	10	40	50	10	0	50	43	24	40	29	34
96	Green Mill Run	10	.	.	.	.	.	.	44	45	10	70	70	40	10	0	80	49	31	47	38	43
97	Green Mill Run	1	.	.	.	.	.	.	44	45	10	10	30	40	10	0	30	31	21	28	26	27
98	Green Mill Run	Pt 11A - Memorial Dr.	Q4	36	7.33	4	4.6	15	73	75	80	Bv	Bv	20	45	20	Bv	58	46	56	54	55
99	Green Mill Run	30	.	.	.	.	.	.	96	95	90	20	90	70	100	30	40	77	79	76	90	83
100	Green Mill Run	17	.	.	.	.	.	.	98	100	100	20	90	80	50	50	20	78	72	79	77	78
101	Green Mill Run	1A	.	.	.	.	.	.	85	85	60	20	100	90	65	10	90	85	65	81	77	79
102	Green Mill Run	26	.	.	.	.	.	.	65	66	60	40	50	30	30	10	40	49	39	48	45	46
103	Green Mill Run	4A	.	.	.	.	.	.	49	70	60	40	50	30	40	20	30	48	40	47	44	46
104	Green Mill Run	25	.	.	.	.	.	.	81	90	80	10	50	40	55	40	40	60	56	56	60	58
105	Green Mill Run	Pt 28 - N of High School	Q4	38	8.06	2	2.3	4	60	74	70	80	55	30	45	40	40	54	50	55	52	53
106	Phillipi Br.	NC 33	Q4	36	6.69	3	3.5	5	100	100	100	65	100	80	100	100	90	93	100	92	100	96
107	UT Cow Swamp	7	.	.	.	.	.	.	8	15	50	0	0	60	0	10	NA	31	5	25	5	17
108	UT Cow Swamp	Pt 10A - SR 1722	Q4	30	7.94	0	0.0	0	48	61	10	20	20	30	10	0	NA	30	19	28	19	25
109	UT Crisp Cr.	6	.	.	.	.	.	.	6	9	50	30	0	40	20	10	NA	25	9	27	9	18
110	UT Crisp Cr.	Pt 8A - NC 44	Q4	29	7.5	0	0.0	0	38	38	30	20	0	40	10	10	NA	27	14	25	15	20

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111	Reedy Br.	21	.	.	.	.	.	.	55	60	80	40	20	30	100	70	NA	48	61	50	66	58
112	Reedy Br.	65	.	.	.	.	.	.	18	15	100	10	10	60	100	10	NA	46	35	47	40	44
113	Reedy Br.	Pt 59 - Wayne Mem. Dr. = Tommy Rd.	Q4	36	8.63	1	1.2	1	84	85	90	80	100	50	100	70	NA	81	89	81	93	87
114	UT Stoney Cr.	52	.	.	.	.	.	.	8	13	30	20	10	30	30	0	NA	21	12	21	15	18
115	UT Stoney Cr.	Pt 56 - at Mall	Q4	42	7.52	5	5.8	7	86	85	100	80	100	80	100	100	NA	91	97	91	96	93
116	Moss Neck Swamp	69	.	.	.	.	.	.	35	30	20	10	0	40	5	15	NA	23	14	21	14	17
117	Moss Neck Swamp	32	.	.	.	.	.	.	50	38	10	10	0	40	15	50	NA	22	29	19	24	22
118	Moss Neck Swamp	51	.	.	.	.	.	.	17	10	20	10	0	30	15	5	NA	15	9	15	10	13
119	Moss Neck Swamp	61	.	.	.	.	.	.	27	20	20	10	10	50	25	5	NA	25	17	25	19	22
120	Moss Neck Swamp	31	.	.	.	.	.	.	25	39	20	10	10	50	25	15	NA	30	19	27	20	23
121	Moss Neck Swamp	42	.	.	.	.	.	.	27	38	40	10	0	40	10	0	65	37	9	32	11	22
122	Moss Neck Swamp	55	.	.	.	.	.	.	40	38	40	10	0	60	10	0	65	41	13	36	15	26
123	Moss Neck Swamp	45	.	.	.	.	.	.	40	38	70	50	20	60	20	5	85	55	21	53	25	39
124	Moss Neck Swamp	11	.	.	.	.	.	.	65	63	100	90	40	60	25	55	NA	66	46	68	44	56
125	Moss Neck Swamp	34	.	.	.	.	.	.	40	38	40	10	0	40	10	5	50	34	14	30	16	23
126	Moss Neck Swamp	18	.	.	.	.	.	.	31	38	20	10	0	40	10	0	55	31	10	26	12	19
127	Moss Neck Swamp	12	.	.	.	.	.	.	14	29	40	10	60	40	35	10	NA	42	30	42	34	38
128	Moss Neck Swamp	Pt 6 - Alvin Rd.	Q4	47	6.73	15	17.3	73	31	23	40	20	0	90	25	70	NA	38	32	39	23	31