NC STATE UNIVERSITY

Final Stream Restoration Assessment Report – 2009

Prepared by

NC State University
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For
NC Clean Water Management Trust Fund

Introduction: In 2006, NC State University was awarded a monitoring contract with the Clean Water Management Trust Fund (CWMTF) (2005A-900). The purpose of the contract was to establish an evaluation protocol for assessing a subset of the CWMTF's stream restoration, stormwater and agricultural best management practices (BMP) projects. The project includes a field evaluation of forty two existing stream restoration, stormwater and agricultural projects, to provide a snapshot of project effectiveness and water quality benefits. NC State University was asked to prepare a rapid, yet effective evaluation of these projects. These evaluations were planned for a single project visit and used to assess whether the project were likely to meet their proposed goals. Eighteen stream sites were selected by review of CWMTF files and discussions with project managers for the initial assessment work that was conducted during the summer of 2006. In addition, in 2008 and 2009 eleven additional sites were evaluated and five sites from the 2006 surveys were revisited and rescored. The revisited sites include Ambrose, Harris/Howard, Raccoon, Sharp and Upper Laurel. It is anticipated that the results and recommendations from this effort will provide CWMTF with a better understanding of the status and water quality benefits of stream restoration projects and will aid in the selection process for future projects. This report provides a summary of the stream restoration assessment component of this grant project.

- *Selection Criteria*. Stream restoration projects that feature natural channel design approaches including modification to dimension, pattern and profile and were longer than 1000 linear feet were the target for this assessment project. Some exceptions were made at the discretion of NC State University and Clean Water Management Trust Fund staff.
- *Site Evaluation*. An evaluation protocol for stream restoration projects was developed by NC State University, and is posted online at http://www.bae.ncsu.edu/programs/extension/wqg/sri/cwmtf/index.html. This protocol was field tested and subsequently sent to several agencies and individuals for external review. The goal of this protocol is to be a rapid and effective assessment of four major components of restoration. As part of this evaluation, numeric values are given to several parameters within four categories: channel condition including bedform, dominant substrate material and streambank stability; riparian habitat including riparian vegetation and floodplain condition; aquatic insect condition including community structure and cover/refuge; and the condition and function of instream structures. Stream size, land cover, eco-region and the number of years following construction are variable. Each evaluation was conducted by a group of five to eight trained individuals divided into teams. An engineering team scored channel condition and instream structures. Two biology teams sampled and scored vegetation and macroinvertebrate communities. In addition, photographs, a written log, and GPS locations were collected. Photographs of each site were also collected and can be provided to CWMTF upon request.

Results:

Table one and Figure one provide the individual element scores and the total score for all 29 projects assessed and the five sites that were revisited. The total score represents the sum of all four component evaluations, including channel condition; riparian habitat and floodplain condition; aquatic insect community structure including a cover/refuge component; and condition and function of instream structures. The maximum possible score is 168 points.

Table 1: Stream assessment score results for all 29 CWMTF site visits and five revisits in 2006 through 2009

	Evaluation Categories	Ambrose	Ambrose2	Avon Creek	Cartoogachaye	Darnell	East Fork	Free Nancy	Harris/ Cockerham	Harris/ Howard	Harris/ Howard 2	Hopper's Creek	Lake Wheeler Trib	Little Brasstown-Campbell	Little Brasstown-Carringer	Little Brasstown-Mason	Little Brasstown-Sheppard	Little Sugar	Mickey
Channel Condition	Bedform Condition	17.5	16	6	10.5	18	16	12	9.5	17	19	14	14	8	19.5	20	17	8	20
	Dominant Substrate Material	11	11	6	11	12	10	7	12	11	12	3	7	3	10	11	11	6	10
	Streambank Stability	22	24	23	13	18	24	24	19	21	24	19	17	19	16	21	20	13	22
Riparian Habitat	Riparian Vegetation	9	8	8	14	14	11	14	16	11	12	14	8	19	18	17	18	12	15
	Floodplain Condition	20	21	17	15	18	13	14	19	22	22	19	24	18	17	18	17	18	22
Aquatic Insects	Community Structure	13	13	8	22	15	7	11	15	14	17	8	6	16	22	22	23	9	23
	Cover and Refuge	5	7	8	12	10	8	16	8	12	10	8	7	8	16	10	16	12	16
Instream Structures	Structure Function	14.7	14.8	11.9	3.4	15.2	14.4	12.5	14.6	15.9	15.9	15.5	14.5	7.4	14.4	15.6	13.6	10.6	14.9
	Structure Condition	11.4	11.3	9.4	5.1	11.6	11.7	11	8.3	10.7	11.3	11.3	7.9	5.0	10.3	11.7	10.2	9.1	11.5
	Total Score	**124**	**126**	**97**	**106**	**132**	**115**	**122**	**121**	**135**	**143**	**112**	**105**	**103**	**143**	**146**	**146**	**98**	**154**

	Evaluation Categories	Raccoon Creek	Raccoon Creek2	Ramey	Rocky Branch Phase 1	Rocky Branch Phase 2	Salem Creek	Sharp Creek	Sharp Creek2	Snow Creek	Swannanoa	Tom's Creek	Town Branch	Upper Laurel Creek	Upper Laurel Creek2	Wood	Young's Fork	CWMTF average	Points possible
Channel Condition	Bedform Condition	11.5	14.5	17.5	17	19	14.5	20	19.5	19.5	16	20	15	8	16	19	8.5	14.6	20
	Dominant Substrate Material	11	11	12	11	11	12	12	12	9	11	11	12	12	12	11	6	9.1	12
	Streambank Stability	21	20	20	24	24	20	22	23	19	14	24	24	13	24	20	19	19.9	24
Riparian Habitat	Riparian Vegetation	13	18	8	15	12	9	11	16	15	16	15	11	11	17	12	13	13.2	20
	Floodplain Condition	17	19	14	21	23	17	20	19	21	18	23	17	21	21	17	13	18.6	24
Aquatic Insects	Community Structure	12	16	17	12	14	12	14	18	18	13	16	9	18	18	18	10	14.7	24
	Cover and Refuge	10	14	10	16	10	5	10	16	10	10	16	10	12	14	14	10	10.5	16
Instream Structures	Structure Function	14.7	14.5	10.7	15.6	15.5	16.0	15.3	14.9	15.2	16.0	15.2	14.8	9.8	11.2	14.8	7.6	13.3	16
	Structure Condition	11.1	10.7	10.8	11.8	11.4	12.0	11.4	9.6	10.9	12.0	10.6	11.0	8.5	8.5	11.0	5.5	9.9	12
	Total Score	**121**	**138**	**120**	**143**	**140**	**118**	**136**	**148**	**138**	**126**	**151**	**124**	**113**	**142**	**137**	**93**	**124**	**168**

Figure 2: Comparison of restoration effectiveness for 29 existing projects and five site revisits, with projects arrayed from lowest to highest index score. Total score equals the sum of channel condition, riparian habtiat, aquatic insects and instream structures.

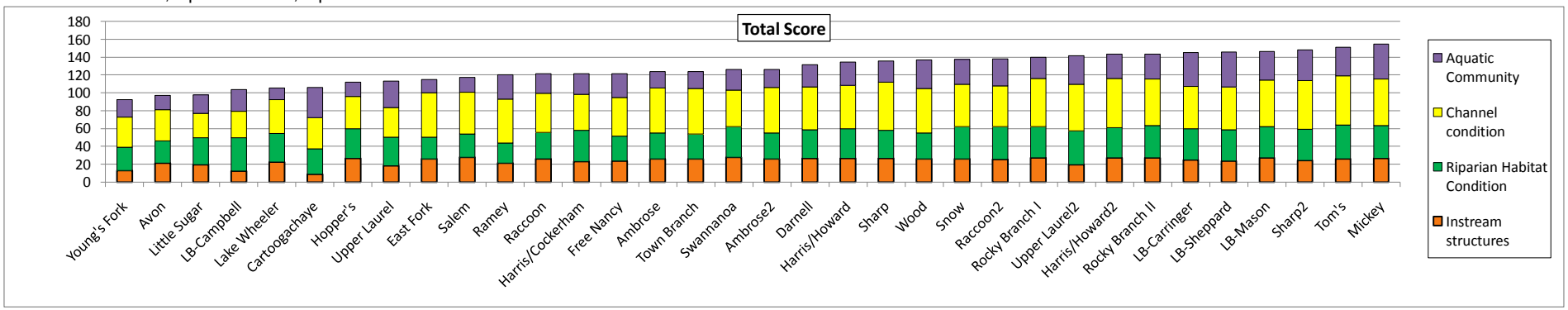


Figure one illustrates the total scores from all of the projects. Scores range from 93 to 154 with a mean score of 127 for the 34 assessments conducted.

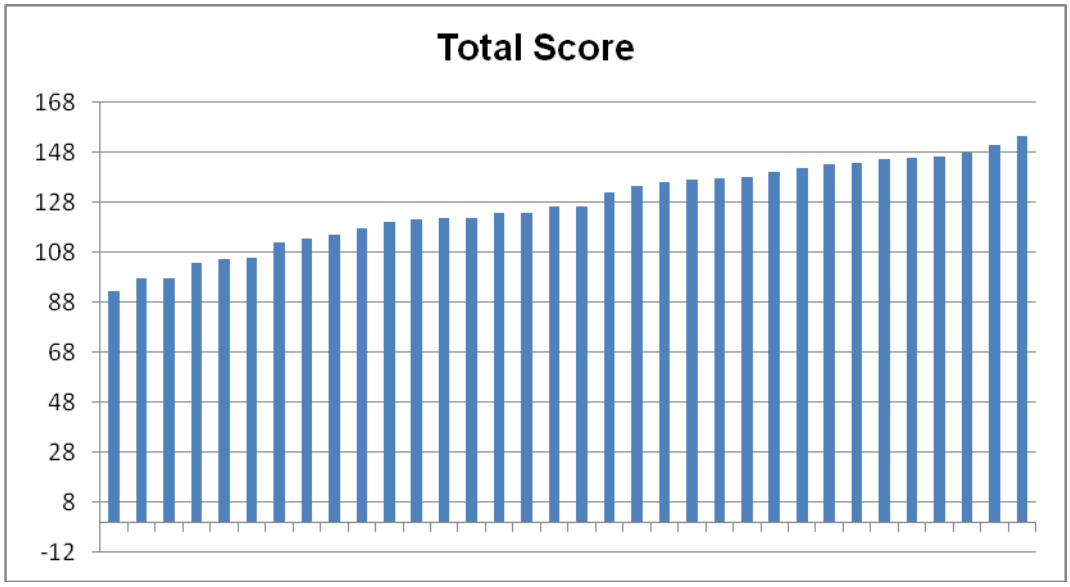


Figure 1: Overall stream restoration scores (maximum score = 168)

Comparison of projects is difficult due to high variability in environmental conditions, including stream size (0.2 to 105 square miles), time since construction completion (0 to 8 years) and ecoregion. In addition, project effectiveness can be influenced by numerous other factors, including site constraints, design parameters, construction expertise and watershed conditions, all of which were not included in this evaluation process. Individual evaluation summaries have been prepared for each project assessed, and brief summaries of these evaluations are noted in Appendix 1 of this report. Project effectiveness was assessed as it related to the initial goals stated in the proposals to CWMTF. The primary goal of many projects was to reduce sedimentation by stabilizing eroding stream banks and/or reconnect the stream to relic floodplains through natural channel design. These assessments concluded that these initial goals were accomplished at most of the projects. In addition, some projects also proposed improving biological integrity and instream habitat as an additional goal. The data are not conclusive but indicate some positive trends in the biological communities over time. Future studies are needed to validate long-term improvements.

By combining the information collected for all 29 projects and five revisits for a total of 34 data points, NC State University staff attempted to evaluate three causal factors contributing to degree of restoration effectiveness, including:

1. Watershed size
2. Watershed development density
3. Project age

Because of the high variability observed in these projects, many more project assessments are necessary to document statistically significant conclusions regarding hypothesis testing for these

factors evaluated alone or in combination. The results presented below are preliminary observations intended to inform future studies of restoration effectiveness.

- *Watershed Size.* Watershed drainage areas ranged from 0.2 to 105 square miles. This area affects the stream size and the complexity of factors influencing water quality and habitat. We divided projects into two categories: (1) small (less than 3 square mile drainage area) and, (2) large (greater than or equal to 3 square miles). Figure 3 shows the comparison of effectiveness ratings for the small and large projects. We expected projects in smaller drainage areas to have higher effectiveness, because large projects have more impacts from wastewater, stormwater, upstream sediment sources, and other external stressors of water quality. This expected trend, however, was not apparent in this sample set.

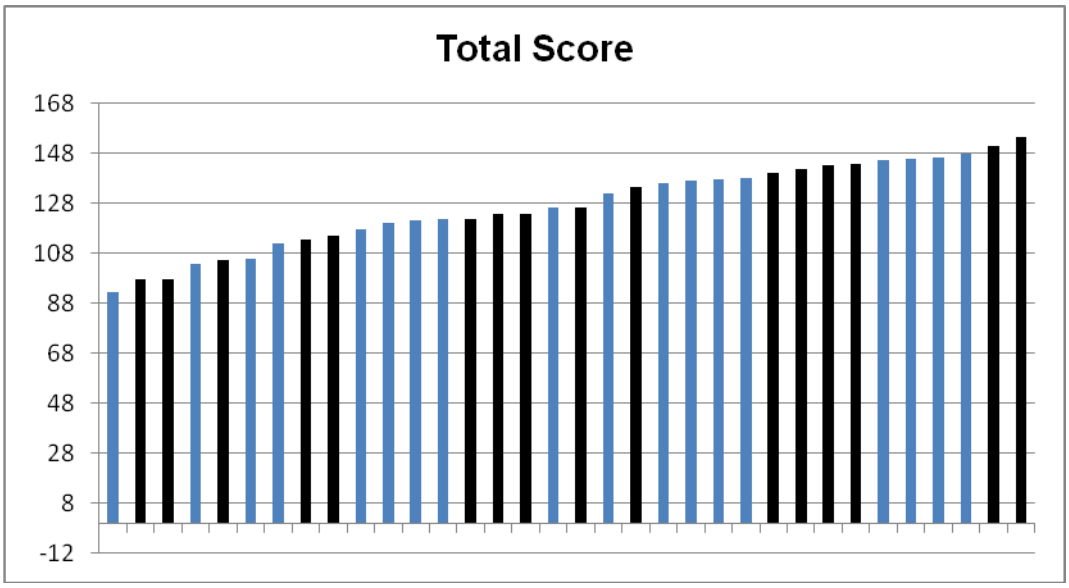


Figure 3: Comparison of restoration effectiveness for small and large watershed projects. Projects are arrayed from lowest to highest index score. Projects in small watersheds (<3 sq mi) are highlighted with dark columns.

- *Watershed Development Density.* The degree of urbanization in the watershed affects the potential impact of stormwater, channel instability, and wastewater on water quality and habitat. We divided projects into two categories: (1) rural (less than 10 percent of the watershed urbanized) and, (2) urban (greater than or equal to 10 percent urbanized). Figure 4 shows the comparison of effectiveness ratings for all projects, with urban projects shown as dark bars (8 projects). Even though the results are not statistically significant, there is a visual trend indicating that rural projects score higher than urban watershed projects. This is likely due to urban projects having more impacts from channel confinement, wastewater, stormwater, upstream sediment sources and other external stressors of water quality.

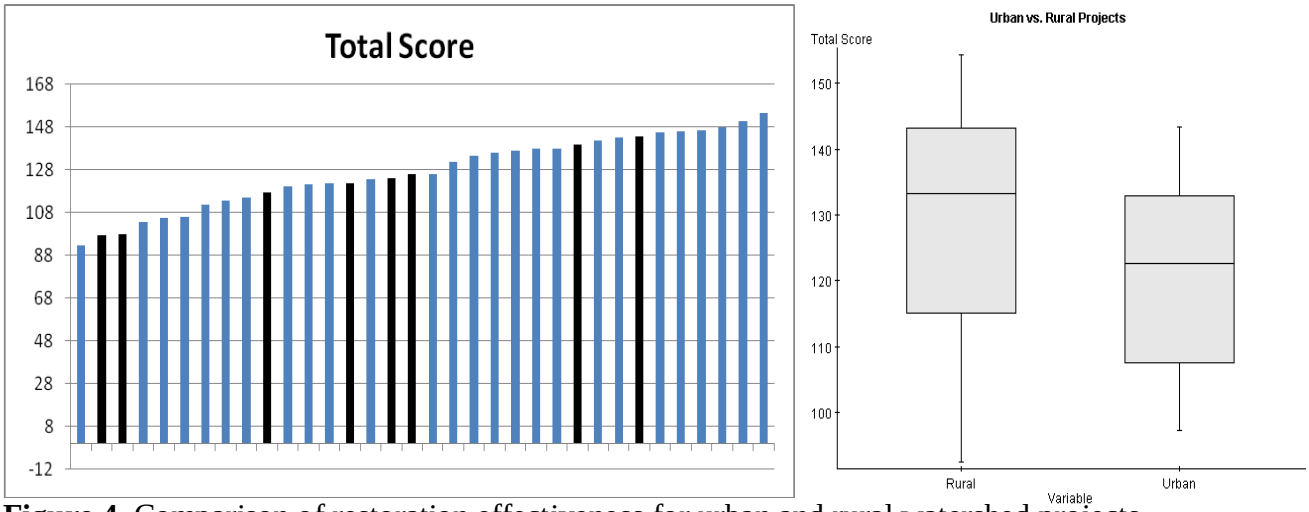


Figure 4. Comparison of restoration effectiveness for urban and rural watershed projects. Projects are arrayed from lowest to highest index score with urban projects highlighted by dark columns.

- *Project Age.* Projects ranged in age from 0 to 8 years since implementation. The age of the project affects the degree to which the ecosystem has recovered from degradation and disturbance. Age influences the growth of vegetation, establishment of microhabitats, and physical sorting of sediments following variable hydrologic events. Unlike traditional engineering projects, stream restorations are expected to improve over time as vegetation develops and bedform diversity develops naturally. Three factors confound this expected trend in this study. The first is the variability between sites, the second is that different types of projects are selected as CWMTF and grantees become more sophisticated regarding suitable projects, and the third is improvement in restoration practices. Figure 5 shows the comparison of effectiveness ratings for all projects in

Figure 5. Comparison of restoration effectiveness (i.e. total index score) to project age.

relation to project age. The results are not statistically significant and there is no visual trend indicating a causal relationship. Figure 6 illustrates the separate components of the evaluation (instream structures, vegetation, invertebrate community composition and habitat, and channel condition) as they vary with project age. In 2006, no trends were identified. However, with the 11 new sites and five revisits added to the data set there is a statistically significant trend indicating an improvement in structure function and condition with newer projects, likely due to an improvement in design and installation of structures that has resulted from training, education and more experience.

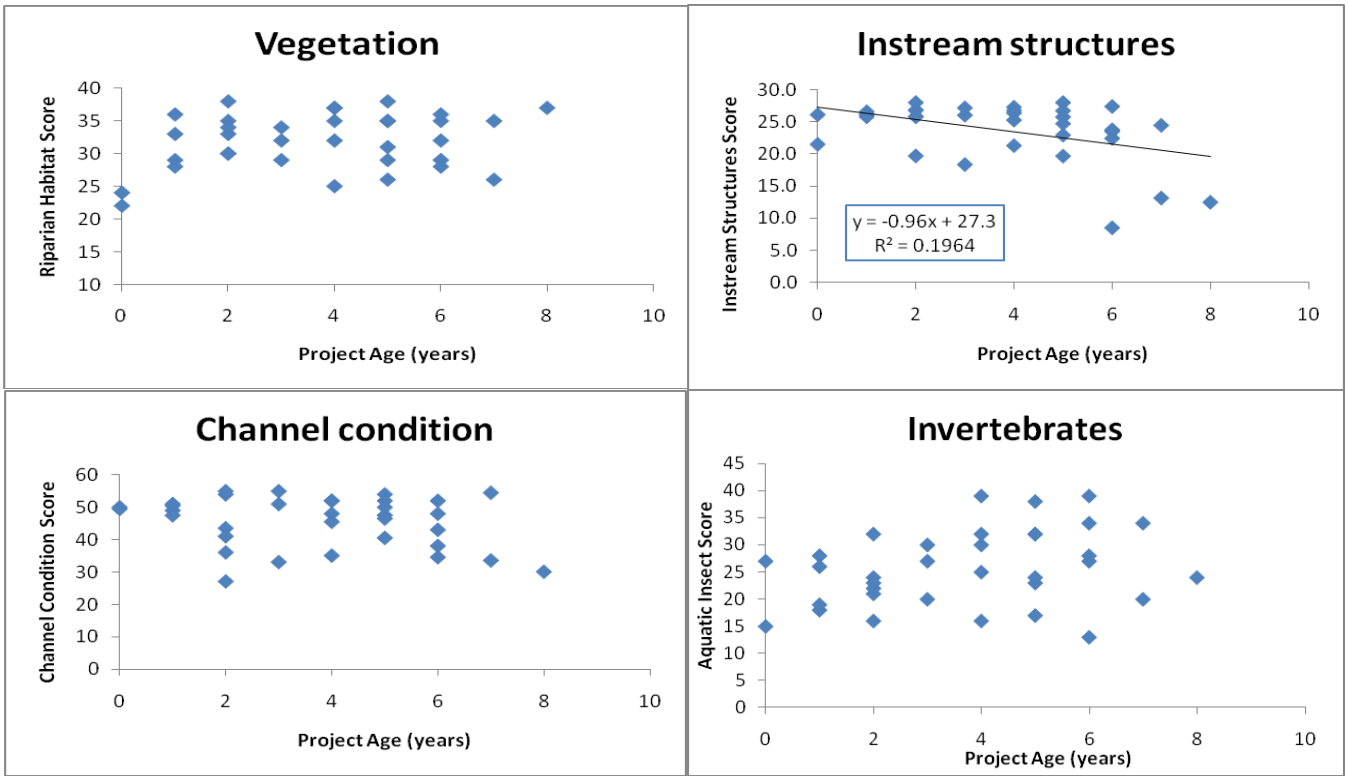


Figure 6. Comparison of separate aspects of restoration effectiveness (as measured by index scores) with age. Project ages ranged from zero to eight years.

In 2006, only one variable, "Abundant taxa in common" was identified to have a strong relationship with age. However, in 2008 with the addition of the 11 new sites and 5 revisits added to the data set, this trend was no longer visibly apparent or statistically significant to the data set as shown in Figure 7. Invertebrate community measures would be expected to increase as a project ages and insects from upstream successfully colonizes the restoration reach. A direct relationship between project age and macroinvertebrate indices would indicate that the projects are moving toward biological recovery. However, this particular data set of projects did not provide a clear indication of benthic recovery. Lake Wheeler tributary, despite maturing for six years post construction, scored poorly on benthic indices due to a lack of flow at the time of assessment. When this site was removed from the dataset, the comparison of Aquatic Insect Score relative to project age revealed a statistically significant positive trend (see Figure 8).

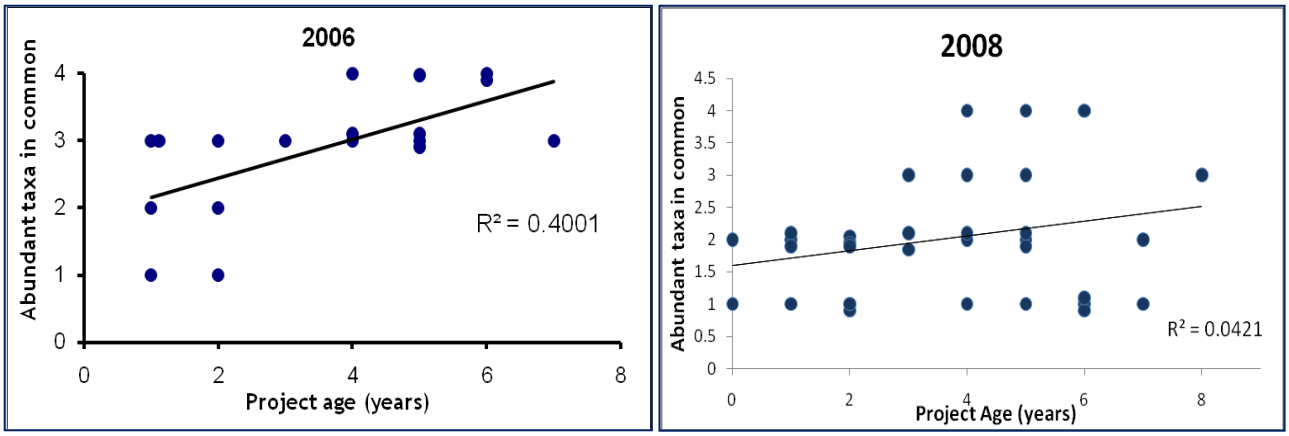
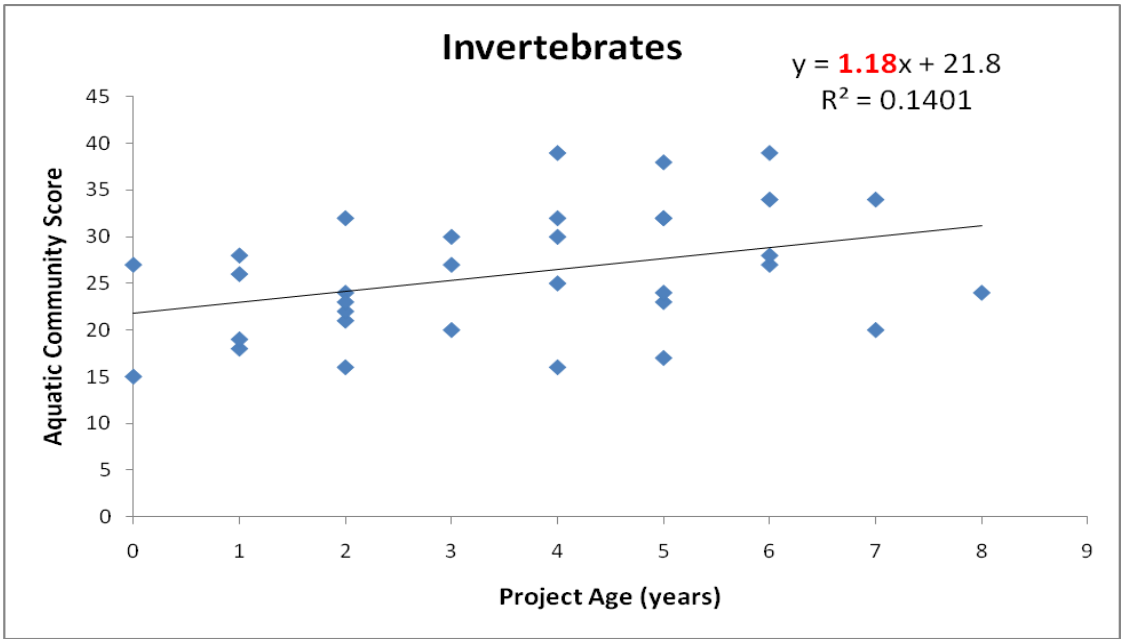


Figure 7. Comparison of project age and the index score for "Abundant taxa in common", a measure of invertebrate community similarity between sampling sites above and within the



restoration project. Eighteen sites in 2006 and 34 sites in 2008 (including 5 revisits).
Figure 8: Regression comparison of the aquatic community score to project age excluding Lake Wheeler Farms restoration project.

In addition, we hypothesized that of the four components assessed the macroinvertebrate communities are the one factor that is most likely dependent on the other elements assessed, including riparian habitat, instream structures and channel condition. Therefore, we compared the aquatic community scores to these other assessment variables to determine if a relationship exists. Of the three comparisons, it was determined that the aquatic insect score only had a statistically significant relationship with the riparian habitat score (see Figure 9). The positive slope of the trend (0.88) indicates that the observed quality of macroinvertebrates was directly correlated with the quality of riparian habitat.

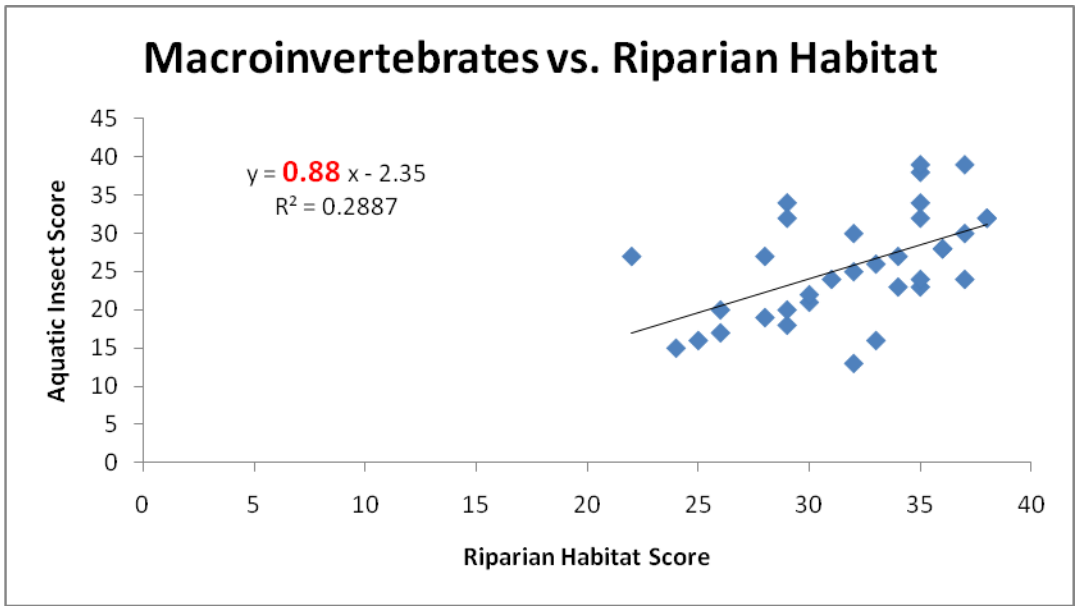


Figure 9: Regression comparison of aquatic insect score to riparian habitat score.

In addition, we evaluated the results of the five site revisits. The five sites, including Ambrose, Harris/Howard, Raccoon, Sharp and Upper Laurel, were originally scored in 2006 and revisited and rescored in 2008. These five sites were selected because they were all fairly recently constructed and showed a great potential to mature and improve in quality over time. Figure 10 indicates that all five revisit sites exhibited an improvement in restoration performance. The range of improvement was 1.9 to 24 percent with a mean improvement of 11.2%. The least improvement occurred at Ambrose Creek as a result of recent mowing of the entire creek and floodplain.

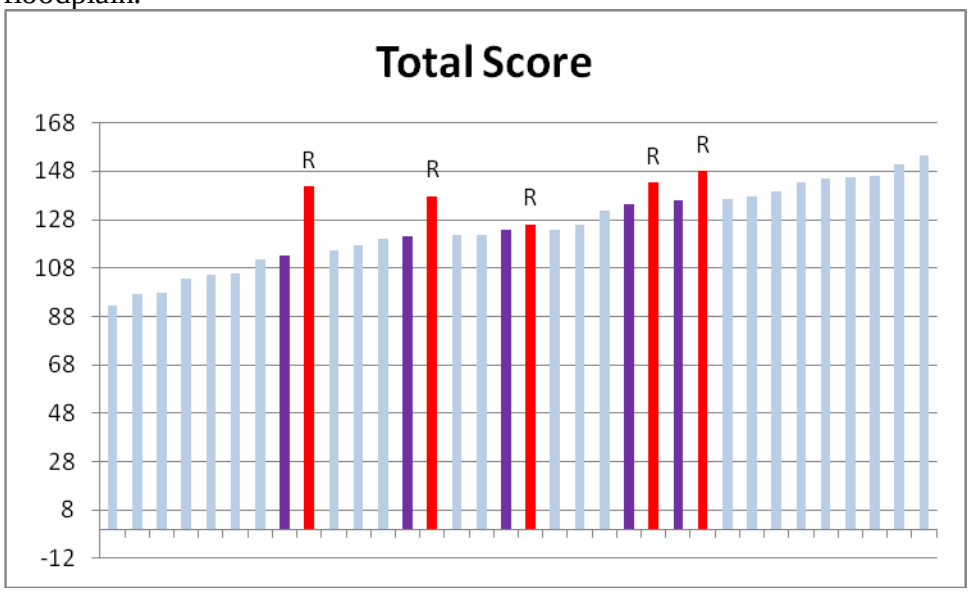


Figure 10*:* Comparison of restoration effectiveness for five project revisits. Projects are arrayed from lowest to highest index score. Revisited sites are indicated in purple for their initial assessment in 2006 and in red for their revisit score in 2008.

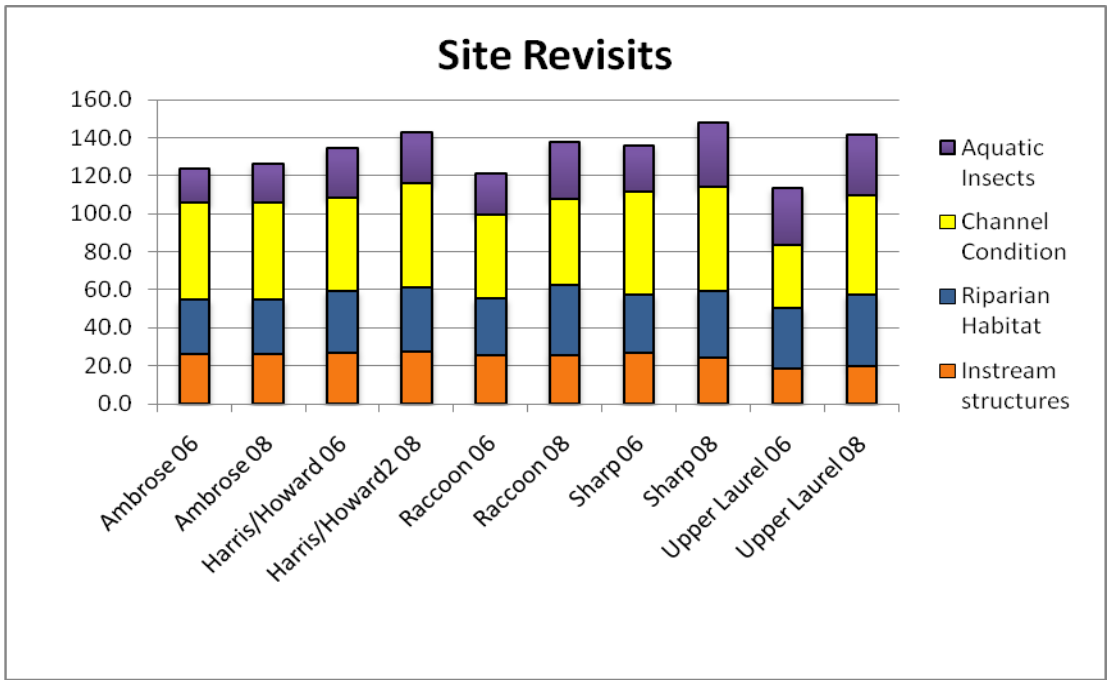


Figure 11: Comparison of restoration effectiveness for five project revisits.

Figure 11 indicates the relative area of score for the four components assessed, including instream structures, channel condition, riparian habitat and aquatic insects. The graph indicates that very little if any change occurred in instream structures as could be expected. Rather improvements were realized in channel condition, riparian habitat and aquatic insects.

***Site Selection Suitability Assessment*:**

Following discussions with CWMTF staff, NC State University conducted two stream restoration site selection training days with CWMTF field staff. Working with CWTMF staff, we identified two proposed stream projects in the mountains and two in the Piedmont to visit and assess the restoration need and potential for these sites. NCSU developed a draft qualitative assessment form to use for the field visits. The field form was reviewed by CWMTF and changes were made accordingly. The assessment form is provided in Appendix 2. NCSU conducted two stream restoration site selection training days in 2009 with CWMTF field staff on March 19 in the mountains and March 23 in the Piedmont. The NCSU restoration need assessment form was used to assess proposed stream restoration projects in both regions. In addition, several existing projects were visited to review their performance. A quantitative protocol for stream restoration selection and evaluation, which incorporates clearly stated goals, may still be worthy of future consideration.

Summary and Evaluation:

- *Project Effectiveness.* Field evaluations were conducted at 29 existing stream restoration projects. Many projects were initially selected by applicants because of severe bank erosion rates and incision resulting in sedimentation of streams. Therefore, in most

instances, the primary goals noted for these projects were to stabilize eroding stream banks and to reconnect the stream to a floodplain. Natural channel design was frequently used as a procedure for correcting these perturbations. At a subset of these projects improvement of biological habitat or integrity were included as additional goals. In general the 29 projects that were evaluated by the NCSU teams noted that bank erosion has been reduced or eliminated and that the use of natural channel design methodologies has been an effective method for reconnecting streams to relic floodplains or for creating new accessible floodplains for streams. Therefore initial projects goals at most projects were achieved and implementation of CWMTF protocols was effective. In addition, the data indicates a statistically significant positive trend in aquatic insect indices, including cover and refuge, when compared to project age. In addition, five relatively young projects were revisited two years after their initial assessment. Revisit scores indicate that the quality of these projects continued to improve over time as channel condition and riparian habitat continued to develop and improve as well as the aquatic macroinvertebrate community that depends on these elements for food, cover and other habitat aspects.

Pre-construction evaluations (habitat, stability, and benthic macroinvertebrate communities) were not conducted; therefore improvements in these conditions cannot be determined. It does appear, however, that many projects are moving toward biological recovery as project age increases and as riparian vegetation develops and matures, as noted in figures 8 and 9, respectively. In addition, it is anticipated that complete ecological recovery which mimics reference conditions will take much longer than most of these projects have been completed. As a result, longer monitoring programs following construction are needed to realize ecological recovery as a result of stream restoration.

Conclusions and Recommendations:

- *Project Selection*
  - Institute a standard glossary of terms with regards to natural channel design, restoration and enhancement for the application submittal and review process. "Natural channel design" stream projects were targeted for this assessment project. However it was determined that this term in addition to "stream restoration" can mean different things to different designers, and can range from simple enhancement and cattle exclusion to priority one stream restoration, in which the channel dimension, pattern and profile are all modified.
  - Train restoration design review personnel in proper design procedures. Many of the design issues that became apparent during the field evaluations may have been avoided during the project review phase.
- *Pre-Project Assessment*
  - Require project goals to be clearly stated and well documented, with a basis for assessing whether these goals have been met.
  - Institute a combined qualitative and quantitative assessment method for establishing project goals and measureable objectives and for determining if

projects are meeting the goals and objectives established. Identify specific indicators that are appropriate for measuring the objectives for each project.

- *Design and Construction Issues.* During the evaluations the field teams noted construction and design issues that were fairly consistent between projects. Recommendations to address these issues are as follows:

1. Stream channel and floodplain morphology
   - Adequate floodplain width (entrenchment ratio) and consistent floodplain grading. Floodplain irregularities (both elevation and width) are detrimental to project stability
   - Appropriate width/depth ratio to maintain stability and sediment transport
   - Low streambank slope and bank height ratio to minimize bank erosion and promote floodplain access
   - Appropriate stream channel pattern to dissipate energy and promote bedform diversity
   - Appropriate channel sizing to ensure channel cross-sections are not over-sized, in order to allow adequate frequency for floodplain access during larger rain storms
   - Consistent grading of stream channel cross sections to avoid irregularities
2. In-stream structures
   - Appropriate location, size, and installation of structures for bank protection, grade control, habitat enhancement, and sediment transport. For example, boulder structures (cross-vanes and sills) should not be placed at the head of a riffle or just slightly upstream of the riffle as they frequently result in scour that erodes the streambed and pushes the constructed riffle downstream, resulting in short or non-existent riffle sections.
   - Enhancement of riffles, pools, and steps to promote bedform diversity while avoiding unnatural scour and channel blocking. Use of native bed material below the depth of potential scour in constructed riffles is encouraged. Bedform variability is necessary to establish diverse aquatic habitat.
   - Proper construction including anchoring the logs and/or boulders into the bed and banks, appropriate use of geotextiles and chinking rocks, and prevention of piping and undermining.
3. Streambank stabilization
   - Appropriate use of temporary biodegradable matting, grasses, live stakes, and bioengineering to minimize bank erosion and promote permanent native forest establishment along stream channels.
4. Riparian floodplain forest:
   - Appropriate planting and maintenance to ensure long-term success of native forest buffer
5. Stormwater management in the riparian corridor
   - Appropriate collection and treatment of offsite stormwater delivered to the stream through pipes or ditches, including the installation of step-pools,

plunge pools, wetlands, level spreaders, and other BMPs on or adjacent to the floodplain

6. Road crossings
    - Appropriate use of culverts and bridges in conjunction with in-stream structures to cross streams while maintaining geomorphic stability, sediment transport, and floodwater passage. Structure construction is critical, as poor structure placement or construction affects sediment and water movement downstream, reshaping the channel.

- *Evaluation*
    - Metric modification and testing. During the field evaluations, NCSU staff noted several issues with the metrics themselves that should be re-tested and modified for any future evaluations.
    - Project construction disturbs the ecological community. There is a recovery period, and the length of this recovery period is unknown. Long-term monitoring is needed to define the length and trajectory of this recovery period. Impacts to the ecological community such as stormwater, acute disturbances, drought, sediment input from upstream, wastewater, and agriculture. This monitoring could not separate external, off-site factors from design and implementation of the restoration itself. Seasonal variability also has an unknown effect.
    - The evaluation protocol developed by NC State University proved to be an effective tool for rapid assessment of stream restoration effectiveness. However, this protocol needs to be further tested and refined.

Appendix 1. Existing Stream Restoration Project Evaluations.

Project	Project Score	Primary goal	Effectiveness	CWMTF_ Num	County	constr	DA	Length
Ambrose Creek	123.6 Revisit -126	Establish stable channel	Excessive sedimentation is entering the project from upstream and is impacting pool quality and benthic habitat within the restored reach. Project effectiveness would be much improved if the sources of this sediment were controlled. ***Revisit-*** The anticipated improvement in riparian vegetation and invertebrate cover and refuge scores was not realized due to floodplain and streambank mowing. In addition, bedform habitat continues to be poor due to upstream sedimentation and reduced riffle habitat.	2002A-405	Surry	2005	2.30	1250
Avon Creek	97.4	Stabilize Avon Creek	Data from this urban restoration project suggested that catchment-wide perturbations were impacting the functionality of the stream and its riparian zone, but that the intended goals of the project were obtained. Sediment from upstream sources is filling in pools within the restored reach and it's also evident from the benthic macroinvertebrate information that water quality conditions in the catchment are impacted.	2000B-401	Gaston	2002	0.75	985
Cartoogachaye	110.7	Stabilize eroding banks	Data from this evaluation noted that the placement of the log revetment structures to stabilize eroding stream banks has been compromised by stream energy following extremely high flow events. In addition, the field team noted the occurrence of transverse bars and sections of active bank erosion within this reach of stream.	1997A-006	Macon	2000	22.0	1060
Darnell Reach	129.1	Reduce sedimentation	Surface protection and root density estimates from this project were very high and in general bank stability is good. These conditions successfully address the first goal of this project. However the project maintains a fairly flat gradient and have several long runs dominated by fine mucky sediment which provide little or no functional habitat.	1999B-408B	Surry	2002	5.50	1250
East Fork	115.1	Reduce sediment load; restore habitat; restore floodplain function	Streambank stability scores were excellent overall, thus indicating this goal has been met. The restoration resulted in reconnecting much of the channel to an existing floodplain. This was achieved for most of the reach, however, some sections of the channel appeared to still be incised or have only a moderate floodplain available (near the culvert) restricting access of some floodwaters.	2007-406	Watauga	2008	0.2	1440
Free Nancy Branch	121.1	Establish stable channel and create an accessible floodplain	Data from this urban restoration project suggested that catchment-wide perturbations were impacting the functionality of the stream and its riparian zone, but that the intended goals of the project were obtained. Sediment from upstream sources is filling in pools within the restored reach and it's also evident from the benthic macroinvertebrate information that water quality conditions in the catchment are impacted.	1998B-410	Iredell	2000	0.79	2280
Harris/Cockerham	121.4	Reduce sedimentation	Bank stability within this reach is generally good with no areas of bank erosion or sloughing, and herbaceous plant cover is vibrant with woody stems thriving. However the field team noted that the project maintains a fairly flat gradient with riffles located only at the beginning and end of the reach. The rest of the project is notably void of riffles. It is unlike that these conditions improved aquatic habitat above background conditions.	1999B-408B	Surry	2001	17.50	1200

Project	Project Score	Primary goal	Effectiveness	CWMTF_ Num	County	constr	DA	Length
Harris/Howard	130.6 Revisit-143.2	Reduce sedimentation	Bank stability is generally good within this relatively new project and newly planted vegetation is developing. Some problems may exist with low soil moisture, impact from Japanese beetle and deer, and that dense patches of *Microstegium vimineum* are scattered through the project. Overall refuge scores were high due to the number of structures in the restored reach; however, many habitat types were reduced in quality due to project age and will likely improve as well. To our knowledge fish community structure assessments haven't been done to date. However, high refuge and pool habitat scores suggest that this reach is capable of holding fish. ***Revisit-*** Substantial development in the floodplain and streambank vegetation occurred at the Harris/Howard project since our 2006 visit, resulting in a notable increase in streambank rootmass and associated stability. However, presence of invasive plants, particularly Microstegium continues to be a concern. Repairs to structures and a coarsening of bed material improved streambed habitats as well. Slight improvements in the invertebrate community likely reflect improvements in food resource and bedform habitat.	2002A-405	Surry	2005	2.60	5200
Hopper's Creek	107.7	Decrease streambank erosion and create an accessible floodplain	Floodplain access in the restored reach is good; however, the surface soil is inadequate for growth in many places with much bare ground. In addition many live stakes were planted high on the bank and terrace, and have not survived. This project received extremely low scores for dominate substrate material suggesting that sediment produced in the catchment is settling in this reach. The low gradient and the lack of sediment transport through the restored reach also have impacted the aquatic insect population which also received low scores.	2000B-408	McDowell	2004	9.10	1000
Lake Wheeler Tributary	105.4	reconnect stream to historic floodplain, establish stable channel, improve water quality and aquatic habitat	There is evidence of floodplain flow at the site, so this goal appears to be met. However, it appears that the channel may be a little oversized in sections. This may be the result of bed scour that caused incision and subsequent channel enlargement. The channel scored good on the stability measures so it also appears that the stability goals have been met. Minimal sediment monitoring indicates a reduction in TSS leaving the site as well. However, the rapid assessment work does not indicate any improvement in aquatic habitat as of yet. Poor aquatic habitat is most likely the result of very low to non-existent	2002A-405	Wake	2002	0.3	3000
Little Brasstown-Campbell	103.5	Reduce sediment load; restore riparian vegetation	Streambank stability scores were good to excellent, thus indicating this goal has been met. The project also indicated that they intended to restore riparian buffers. The vegetation scores at this site, which has had eight years to mature, were good to excellent; thereby it appears that this project goal has also been met.	1998B-404	Cherokee	2001	9.5	3900
Little Brasstown – Carringer/Mitchell	143.2	Reduce sediment load; restore riparian vegetation	Streambank stability scores were fair to good, thus indicating this goal may not have completely been met. The proposal also indicated that they intended to restore riparian buffers. The vegetation scores at this site, which has had five years to mature, were excellent with the exception of streambank rootmass. Thereby it appears that this project goal has been met with the exception of a few areas with poor vegetative cover and rootmass on the streambanks.	1998B-404	Cherokee	2005	8.5	2040

Project	Project Score	Primary goal	Effectiveness	CWMTF_ Num	County	constr	DA	Length
Little Brasstown – Mason/Stalcup	146.3	Reduce sediment load; restore riparian vegetation	Streambank stability scores were good to excellent. It appears that this goal is being met with the exception of a few areas where the bank height ratio is slightly higher than desired. The proposal also indicated that they intended to restore riparian buffers. The vegetation scores at this site, which has had four years to mature, were excellent with the exception of invasive species. Thereby it appears that this project goal has been met with the exception of extensive mowing along the left.	1998B-404B	Cherokee	2005	3.8	1900
Little Brasstown - Sheppard	145.7	Reduce sediment load; restore riparian vegetation	Streambank stability scores were fair to excellent. It appears that this goal is being met with the exception of the areas where some channel incision has resulted in some tall banks that are bare. In addition, mowing of a powerline corridor that intercepts the creek in several locations is hampering the quality of the vegetation and the associated streambank stability in these areas. The vegetation scores at this site, which has had six years to mature, were excellent with the exception of invasive species and the powerline corridor.	1998B-404B	Cherokee	2003	5.6	4300
Little Sugar	97.7	Reduce flooding, recapture floodplain function	The stream restoration project at the Hidden Valley Ecological Garden provides Charlotte residents with an opportunity to enjoy this stream feature. It is very likely that flooding has been reduced because of the reattachment to the floodplain within this feature; however, it does not appear to improve water quality at this point. The fairly flat gradient within the restored reach and inputs of pollutants from upstream urban areas are resulting in a reduction of potential project effectiveness.	2001B-704	Mecklenburg	2003	2.00	2420
Mickey Reach	152.4	Reduce sedimentation	Bedform condition, streambank stability and structure condition were all given average or higher scores, suggesting that the channel itself is stable and that the project is moving toward accomplishing the primary goal of stabilizing the channel and in doing so decreasing the sediment delivery to the stream. Streambank root mass and associated stability can improve as woody vegetation increases on the banks. Benthic macroinvertebrates, instream cover and refuge, floodplain habitat, and structure-related biological habitat scores were all high. These scores indicate quality aquatic habitat, and habitat should continue to improve as the project matures.	1998B-408B	Surry	2002	0.45	3500
Raccoon Creek	121.2 Revisit – 137.8	Reduce erosion and sedimentation	Streambank stability and streambank root mass received higher than average scores, indicating that the project supports stable banks with low erosion loss, and is moving toward accomplishing its primary objective. Vegetative cover along the banks is thick in most places, with only a few bare areas. ***Revisit***- Raccoon Creek remains very stable with relatively no bank erosion. It is therefore continuing to meet the desired project goal. Some channel incision has resulted in taller streambanks and some erosion at the toe of the streambank as well as a decline in the ability of the stream to access the floodplain as frequently as needed. Vegetation at the site continues to grow and flourish with very few bare areas remaining. Mowing at the site has been greatly reduced. This project showed notable increases in the morphologic channel bedform, riparian vegetation, aquatic community structure and cover and refuge scores. These improvements resulted in a 14 percent increase in the total assessment score over the two year period between visits.	2000B-402	Haywood	2004	4.35	2700

Project	Project Score	Primary goal	Effectiveness	CWMTF_ Num	County	constr	DA	Length
Ramey Creek	120.0	Reduce sediment load; restore floodplain function	Streambank stability scores were excellent overall, thus indicating this goal has been met. The project also indicated that they intended to restore floodplain function. The restoration resulted in the excavation of several new floodplain areas that were accessed during the recent large rain event, indicating that this goal was also met.	2005B-412	Surry	2008	4	5000
Rocky Branch Phase 1	143.4	establish a stable channel, improve water quality and aquatic habitat	The project scored above average in all categories with the exception of aquatic insect community. This is likely the result of confounding water quality factors due to the very high impervious cover within this urban watershed. The above average scores suggest that the channel itself is stable and that the project is accomplishing the primary goals of stabilizing the channel and in doing so decreasing the sediment delivery to the stream.	1998A-411	Wake	2002	0.6	3000
Rocky Branch Phase 2	140.9	establish a stable channel, improve water quality and aquatic habitat	The project scored above average in all categories with the exception of riparian vegetation and the aquatic insect community. Vegetation is becoming established at the site and will likely continue to diversify over the next few years. The poor aquatic insect scores are likely the result of confounding water quality factors due to the very high impervious cover within this urban watershed. It also appears that some enrichment is occurring due to either fertilizer runoff or potential sewer leaks. However, the stream scored above average on all channel condition and structure functions and condition elements as well as on floodplain condition. The above average scores suggest that the project is accomplishing the primary goals of stabilizing the channel and in doing so decreasing the sediment delivery to the stream.	n/a	Wake	2006	1.1	1580
Salem Creek	118.4	Maintain a stable E4 channel	The project scored well for streambank stability, bedform condition, instream structure condition and bank protection. These scores indicate progress in stabilizing streambanks. However, cover/refuge and streambank organic matter are low. Riffle presence and length are also low. Aquatic macroinvertebrate scores were low at the sampling site above the project as well as within the project, reflecting the difficult conditions for biota in stormwater-influenced urban streams.	1999B-407	Forsyth	2001	42.80	2800
Sharp Creek	133.5 Revisit – 147.9	Improve water quality by reducing sediment load	Bank erosion within the restored reach has improved because the banks are now well vegetated with little to no apparent bank erosion, sloughing or failures. Herbaceous cover and woody stems are extremely lush and dense and associated rootmass along the banks is also extensive. Bedform condition and floodplain connection also received very high scores suggesting that the channel is stable. These data indicate that this project has addressed the initial goals noted in the proposal. The field team also noted that there has been some bush-hogging of the floodplain and mowing has approached the top of the streambank in some locations. ***Revisit*** -Vegetation continues to grow and establish on the streambanks continuing to ensure good streambank rootmass and associated bank stability. This stability is witnessed with clean washed coarse riffles and low sediment loads. The project improved in significantly in vegetation and aquatic insect scores since 2006 resulting in an 11 percent increase in the total assessment score over the two year period.	1999B-402	Watauga	2001	3.40	1040

Project	Project Score	Primary goal	Effectiveness	CWMTF_ Num	County	constr	DA	Length
Snow Creek	137.5	Enhance water quality; enhance habitat	Good scores for streambank stability and aquatic macroinvertebrates indicate that the project is moving toward accomplishing its goal of improving water quality through reduced sedimentation. Pools have been established below many structures, but some riffles have been lost. Vegetation is developing well in the first year of project recovery. Mature trees provide a diverse onsite seed source. While the restoration reach contains bedrock, cobble, and gravel, some sedimentation from upstream influences average particle size and is affecting pools quality.	2004A-413	Surry	2005	8.10	4080
Swannanoa	126.0	improve water quality and restore riparian buffers	Pre and post assessment of water quality were not conducted so conclusions cannot be made as to whether the first goal is being met. The restoration covers only 1700 feet of the river, which has a 105 square mile drainage area. It is not likely that a localized project affecting such a small portion of the river and that does not address any watershed or upstream issues would have any significant impact on water quality. In addition, the streambank and buffer plantings are just beginning to become established. Drought and soil compaction appear to be hampering the vegetation. However, it is anticipated that over time, the buffer will mature and the project will achieve this goal.	2001B-405	Buncombe	2006	105	1700
Tom's Creek	150.8	Reduce sediment load; restore floodplain	Streambank stability scores were excellent overall, thus indicating this goal has been met. The project also indicated that they intended to restore floodplain function. The restoration resulted in the excavation of an extensive new accessible floodplain area that was accessed during a recent large rain event, indicating that this goal was also met. However, at the channel appeared to still be somewhat incised at the downstream end of the project restricting access of some floodwaters.	2006A-409	Surry	2006	1.8	2930
Town Branch	122.9	Improve water quality and aquatic habitat by reducing sediment	Streambank stability, bedform condition, and instream structures scored well, indicating this project is moving toward accomplishing its goals for stability and reduced erosion. The project is new; so many features of aquatic habitat have not had time to develop. Macroinvertebrate monitoring indicated that upstream communities were poor, and sampling within the reach produced macroinvertebrate taxa associated with poor water quality. Algae and emergent vegetation within the reach indicate nutrient enrichment. The growth of trees should improve riparian functionality, but mowing and poor soil quality limit the developing biomass. Lower banks have helped floodplain functionality.	2004B-401	Cherokee	2005	0.57	1129
Upper Laurel Creek	112.4 – Revisit 141.7	Correct severe channel erosion	The project suffered extensive damage during the heavy flooding associated with Hurricanes Ivan and Frances in 2004. These storms deposited a torrent of cobble debris in the stream and on the floodplain, blowing out and burying nearly all of the constructed bedform and boulder structures. Some repair work has been implemented. Streambank stability scores were only moderate, with root density and surface protection observations fairly low. The banks are well vegetated in some locations with no bank erosion, sloughing or failure in these areas. However, there are many areas of barren cobble debris torrents on the streambanks and floodplain with little herbaceous cover and few woody stems present. Despite the lack of vegetation, many of the banks are stable due to the resistance of the cobble material. The stream is	1999B-402	Watauga	2003	2.20	1420

Upper Laurel continued			efficiently connected to its floodplain which addresses one of the primary goals of the project. This reach of Upper Laurel Creek is a very steep gradient step-pool system with gravel/cobble and some boulder bed material which provides functional habitat and refuge for many of the benthic insect species. Cover and refuge scores were within the good category, suggesting that instream habitat is productive within this reach. ***Revisit*** **-** Upper Laurel Creek shows much progress in self-healing from the previous debris torrents and associated scour and deposition from the past hurricanes. There was substantial improvement in the vegetation cover and community as well as improvements in bank stability and significant improvements in the macroinvertebrate community likely the result of the improvements in plant growth. Pool habitats are still lacking and could benefit from some structure repairs throughout the reach. However, improvement in riffle habitat and a diversity of channel flow conditions have occurred. The stream exhibited a 25% increase in total assessment score over the two year period.					
Project	Project Score	Primary goal	Effectiveness	CWMTF_ Num	County	constr	DA	Length
Wood Reach	132.7	Reduce sedimentation	The project scored well for streambank stability, based on observations of geomorphology and vegetation. Aquatic insects and habitat conditions were not evaluated prior to the construction of this stream, so that an evaluation of improvement from background conditions isn't possible. Aquatic habitat created by rock structures is rated above average for CWMTF projects. Overall project cover and refuge are rated at average for CWMTF projects. As vegetation on the streambank increases, the project should continue moving toward accomplishing the goals of stabilizing the reach and also improving aquatic habitat. It appears that excessive sedimentation is entering the project from upstream and that this sediment is impacting pool quality and vegetative regeneration within the restored reach. Project effectiveness would be much improved if the sources of this sediment were controlled. The sharp bend at the downstream end appears unstable and may need further work.	1999B-408B	Surry	2001	17.00	650
Young's Fork	91.7	Reduce stress on streambanks	Structure effectiveness scores, bedform condition, and some streambank stability parameters were below average on this project. Vegetative growth is generally good on the banks, adding some stability. It appears that excessive sediment is entering the project from upstream and that this is impacting pool quality and benthic habitat within the restored reach. Project effectiveness would be much improved if the sources of this sediment were controlled. The wastewater treatment plant directly upstream contributes to odor and keeps aquatic productivity low. While much of the bank is well vegetated, mowing in the adjacent park creates a narrow buffer in places.	1997B-408	McDowell	1999	9.15	1440

Appendix 2. Stream Assessment for Evaluating Restoration Potential

Project name & location	
Assessed by	Site visit date
Watershed area (acres or sq miles)	Available buffer width (ft)
Watershed % forest	Stream length (ft)
Watershed % agriculture	Stream width in riffle/run (ft)
Watershed % urban	Depth from top of bank (ft)
Streambed substrate (sand, gravel, cobble, bedrock)	Stream slope (< 2%, 2-4%, > 4%)

Existing Conditions: Score from 0 to 4 indicating natural stream integrity and health (circle contributing factors): 0 = extremely poor; 1 = poor; 2 = fair; 3 = good; 4 = excellent

Dimension (incised, over-wide, highly variable)	
Pattern (straightened, sharp bends, cutting into hillslope)	
Profile (lacking bedform diversity, over-steep riffles, head-cutting)	
Bank stability (eroding bends, high banks, steep banks, lack of roots, high stress)	
Bed sediment (embedded with fines, excessive scour, excessive bars)	
Floodplain functions (filled, drained, levees, aggrading)	
Vegetation (natives removed, invasive plants, poor shade and food sources)	
Habitat (poor bedform, poor cover, uniform flow, lack of food and refuge)	
Macroinvertebrates (missing populations, tolerant organisms)	
Livestock access (trampled banks, missing vegetation, fecal deposition)	
Discharges (stormwater, wastewater, agricultural runoff, dumping)	
Interventions (armoring, piping, filling, dredging, crossings)	
Total Score	

Restoration Potential: Score from 0 to 4 indicating constraints for achieving restoration goals (circle contributing factors): 0 = no limitation; 1 = low; 2 = moderate; 3 = high; 4 = severe

Floodplain connection limitations (lateral or vertical confinement)	
Vegetated buffer limitations (narrow buffer, land use restrictions, invasives, beaver, deer)	
Constraints (roads, bridges, culverts, sewer lines, utilities, landowner issues)	
Uncontrolled on-site pollution (stormwater, sediment, wastewater, agriculture, roads)	
Upstream pollution sources (stormwater, sediment, wastewater, agriculture, roads)	
Total Score	

Comments: _____

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