River Restoration in the Southeast

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NC STATE UNIVERSITY Bio&Ag ENGINEERING

Sea Grant North Carolina

NC STATE UNIVERSITY

Mitigation is the Primary Driver

Mitigation Program Coordinator

KY	Kentucky Department of Fish and Wildlife Resources (KDFWR) & Northern Kentucky University
TN	Tennessee Stream Mitigation Program (TSMP) established under the Tennessee Wildlife Resources Foundation, a 501(c)(3) non-profit
VA	Virginia Department of Environmental Quality; Virginia Aquatic Resource Trust Fund (ILF)
NC	NC Division of Mitigation Services (NC DEQ)
SC	South Carolina Department of Natural Resources (SCDNR)
GA	Georgia Land Trust (ILF)
MS	IRT - Mobile District Corps of Engineers Regulatory Division
AL	IRT - Mobile District Corps of Engineers Regulatory Division
FL	Florida Department of Environmental Protection

State Grant Programs for Restoration

TN	Stream and Wetland Restoration Grant (Dept. of Environment & Conservation)
VA	Stream Restoration Assistance Program
NC	NC Land & Water Fund (formerly CWMTF); NC DWR Water Resources Grants
SC	SC DNR Fish Habitat Improvement
GA	Cooperative Agreement for Stream Bank Restoration Program
FL	State Water Quality Assistance Grants

Federal Grants for Restoration

Environmental Protection Agency 319 Grant Program

RIBITS
Regulatory In-lieu Fee and Bank Information Tracking System

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TRACKING

- Mitigation
- WQT
- Both

MENU

Mitgation
- Banks & Sites
- ILF Programs
- Umbrella Instruments
- NRDA Projects
- Public Notices

Knowledge
- Related Resources
- Credit Classifications
- Bank & ILF Establishment
- Mitigation Concepts

Tools
- Reporting
- Assessment Tools
- Find Credits

Training
- Help / User Guides

FILTER

- USACE District
- State
- FWS Field Office
- NOAA Fisheries Region

ALL DISTRICTS

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OpenLayers Map

USACE Districts

RIBITS News

Stream Enhancement
Stream Establishment
Stream Re-establishment
Stream Rehabilitation

RIBITS Sponsors

US Army Corps of Engineers®

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USDA

NOAA FISHERIES

About RIBITS

RIBITS (Regulatory In lieu fee and Bank Information Tracking System) was developed by the U.S. Army Corps of Engineers to track mitigation banking and in-lieu fee (ILF) program activities across the United States. RIBITS includes information regarding banks and ILF program sites, associated documents, mitigation credit availability, service areas, and policies and procedures that affect bank and ILF program development and operation.

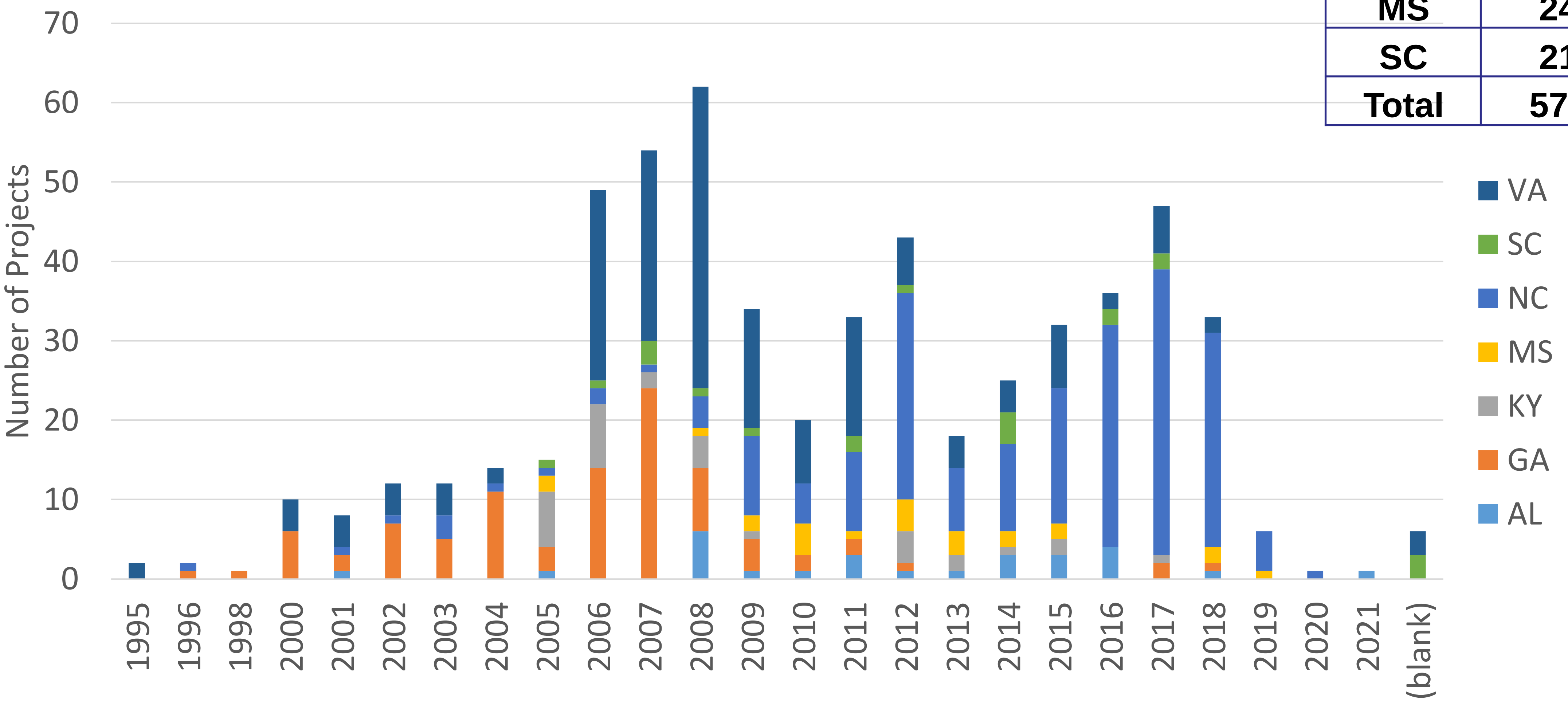
With support from the U. S. Environmental Protection Agency, U. S. Fish and Wildlife Service, NOAA-National Marine Fisheries Service (NOAA-NMFS), and Federal Highway Administration, RIBITS has grown to include conservation banking and multi-agency banking activities. Support from the U. S. Department of Agriculture allows RIBITS to track water-quality trading activities in multiple states, with pilot projects in the states of Virginia and Iowa, and additional support from NOAA-NMFS allows RIBITS to track credits for restoration banks recognized under Natural Resource Damage Assessment statutes.

Upcoming modifications include a mitigation banking module for RIBITS newest partner agency, the Bureau of Land Management.

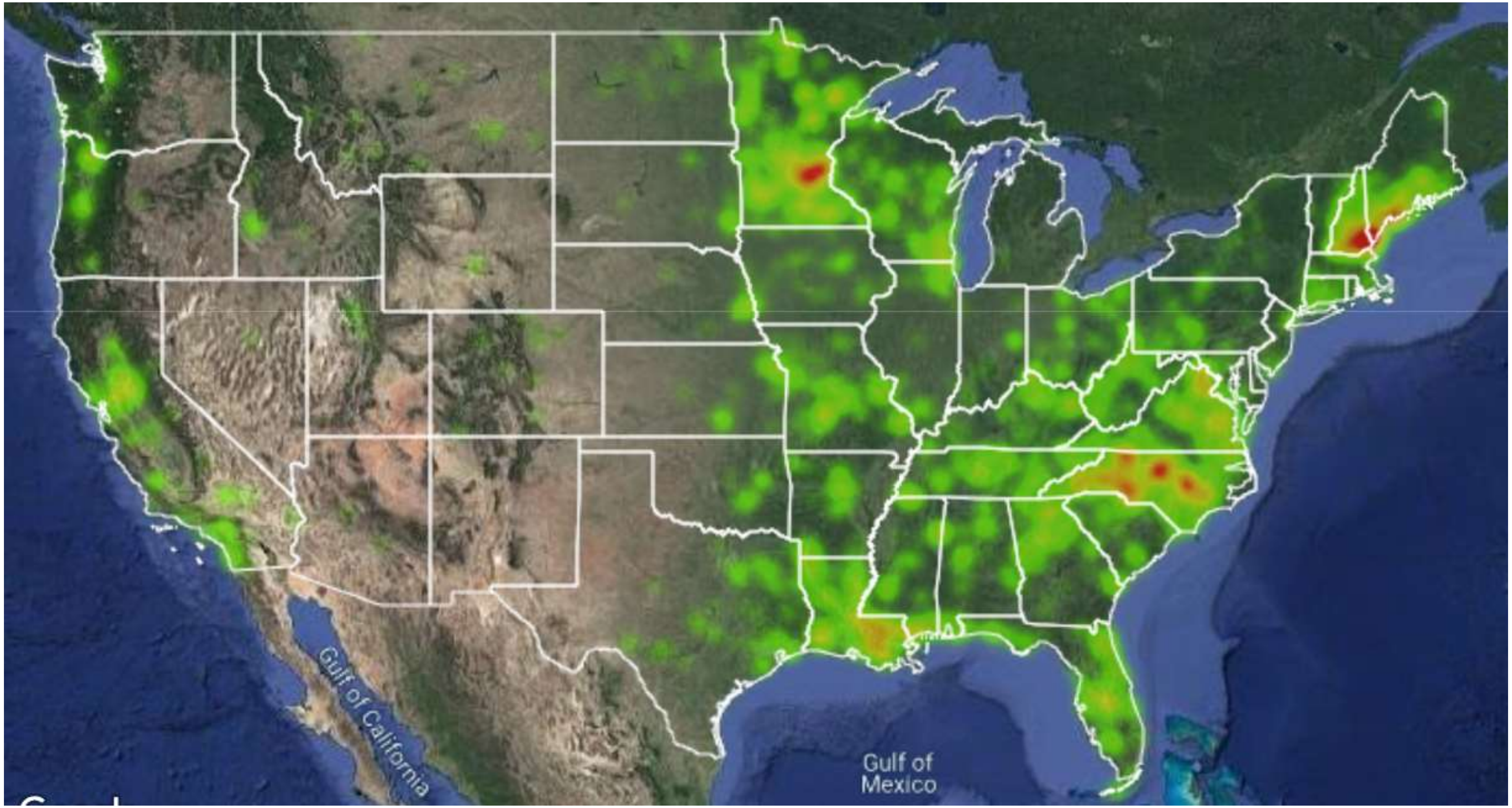
Hosted by CWBI (Civil Works Business Intelligence)

Southeast Stream Projects By Year

NC	199
VA	179
GA	94
KY	32
AL	27
MS	24
SC	21
Total	576

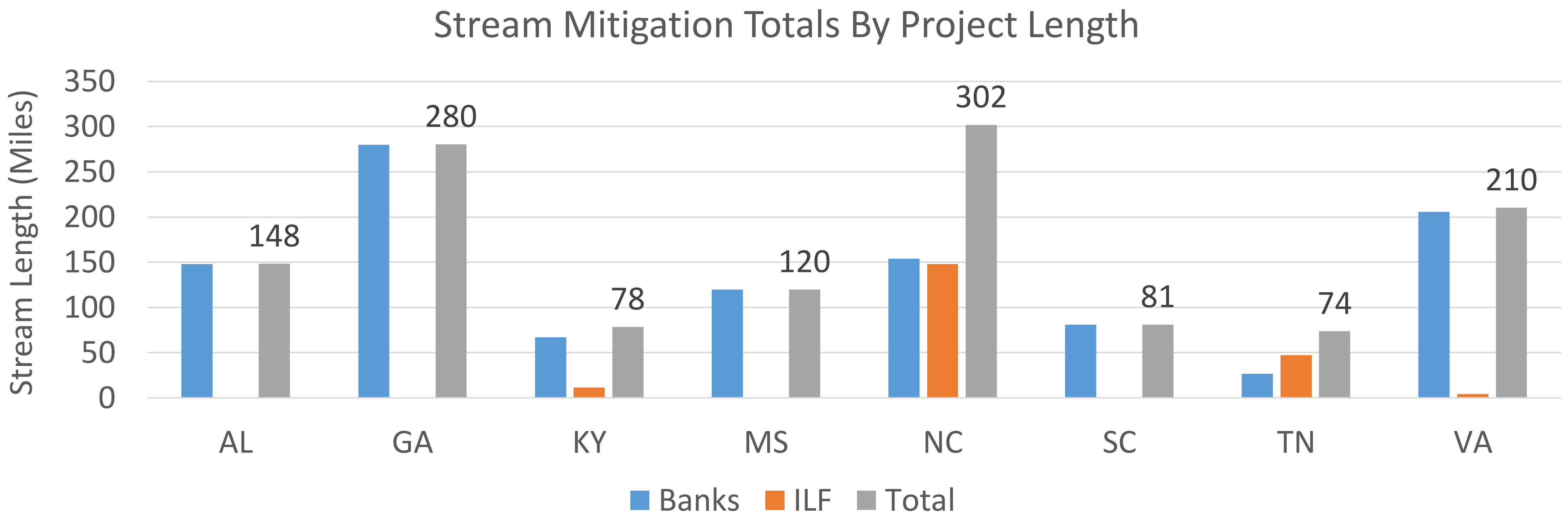


RIBITS – Total Approved Mitigation Banks



Southeast Stream Mitigation By Project Length

- Mitigation Categories: Enhancement, Establishment, Re-establishment and Rehabilitation
- Total Miles = 1,293 Miles; 86% Banks & 14% In Lieu Fee (ILF).
- National Total = 1,451 Miles
- Southeast accounts for 89% of all stream mitigation




UT Soque River, GA


Millstone Creek, NC


UT Chilogatee Branch, TN


Cahaba Stream, AL


Hunting Creek, SC


Tuscarora Creek, VA


Hatchery Creek, KY


Elm Creek, KY

Challenges

- KY - property issues (e.g. severed mineral rights for coal and oil/gas), regulatory consistency, and construction contractor performance
- MS/AL - moving stream channels without verifying water tables/hydrology, lack of construction oversight, lack of flexibility and in-the-field adjustments, unnatural stream channel substrates leading to erosion

New Restoration Approaches

- South Carolina US Army Corps Regional Guidance 18-01 (RGL 18-01)
- Restoration Credit for Removal of Perched and Undersized Culverts
- Flexibility on factors to determine credit generation

Potential Site: Tributary to Gills Creek; Replace with a Bridge per ILF

North Carolina Stream Restoration Practices & Policies Developed through Strong Partnerships

- Many Disciplines
- Universities
- Agencies
- Private Sector
- Non-Profit Organizations

NC State University Stream Restoration Program

Established: 1998

Mission: Advance the Science & Practice of Stream Restoration through

- Teaching
- Research
- Networking

www.ncsu.edu/srp

NC STATE UNIVERSITY Bio&Ag ENGINEERING Stream Restoration Program

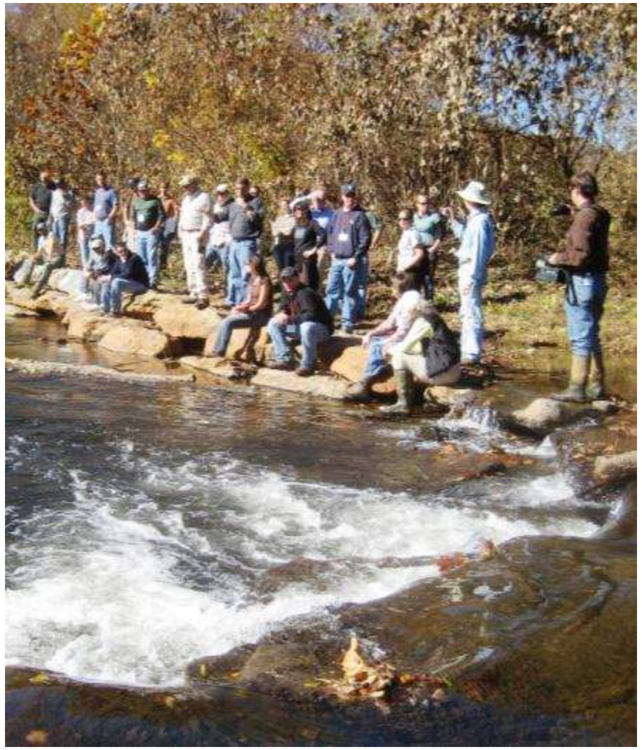
NC State University A&T State University COOPERATIVE EXTENSION Empowering People · Providing Solutions

Sea Grant North Carolina

NC STATE UNIVERSITY

Objectives:

1. Educate professionals (designers, contractors, landowners, and resource managers) about effective restoration
2. Educate students who will serve society in government, academia, and business
3. Develop and test effective technologies for restoration design, construction, and evaluation



Team of Professionals

- Faculty, staff, and students working to improve water quality and aquatic ecology through research, demonstration projects, and education.







Program Components

- Academic courses (campus and on-line)
- Professional development workshops & tours
- Technical Resources
- Southeast Regional Conference (biennial)
- Networking (e-mail list, web site)
- Demonstration Projects
- Research (Graduate and Undergraduate)

Academic Courses

- BAE 584 – Introduction to Fluvial Geomorphology (on-line)
- AES 443 – Environmental Restoration Implementation
- BAE 580 – Introduction to Land and Water Engineering (on-line)
- BAE 582 – Risk and Failure Assessment of Stream Restoration Structures (on-line)
- BAE 579 – Stream Restoration (Not currently offered)

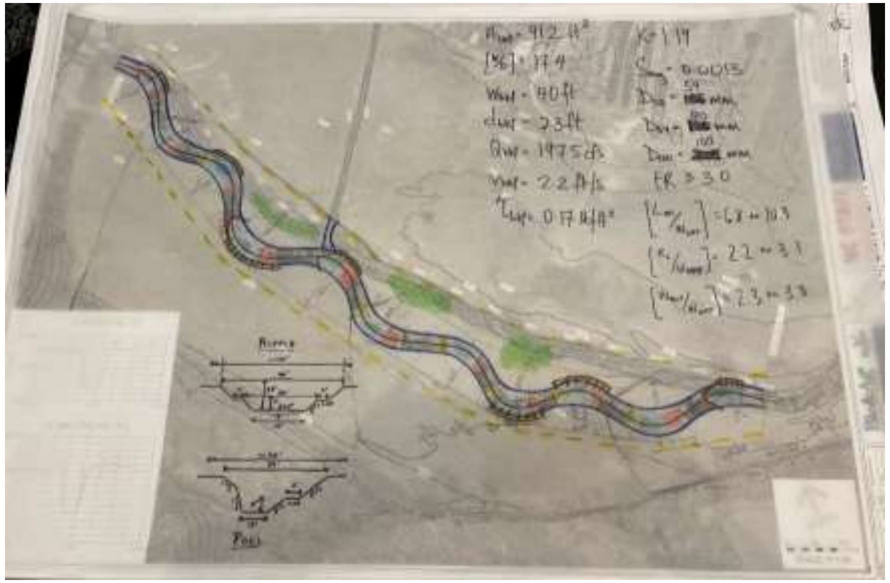
Training Courses

- Stream Assessment
- Stream Restoration
- Advanced Restoration Design
- AutoCAD for Stream Restoration
- Restoration Implementation & Evaluation
- Construction Certification for Contractors
- Vegetation Establishment & Monitoring
- Aquatic Macroinvertebrate Taxonomy
- Streambank Repair
- Hydraulic Design for Stream Restoration

River Course Workshops

- 3-day modules on Assessment, Restoration, Advanced Design, & Implementation/Evaluation
- “Hands-on” training for 30-35 professionals per session
- More than 5600 participants since 2000



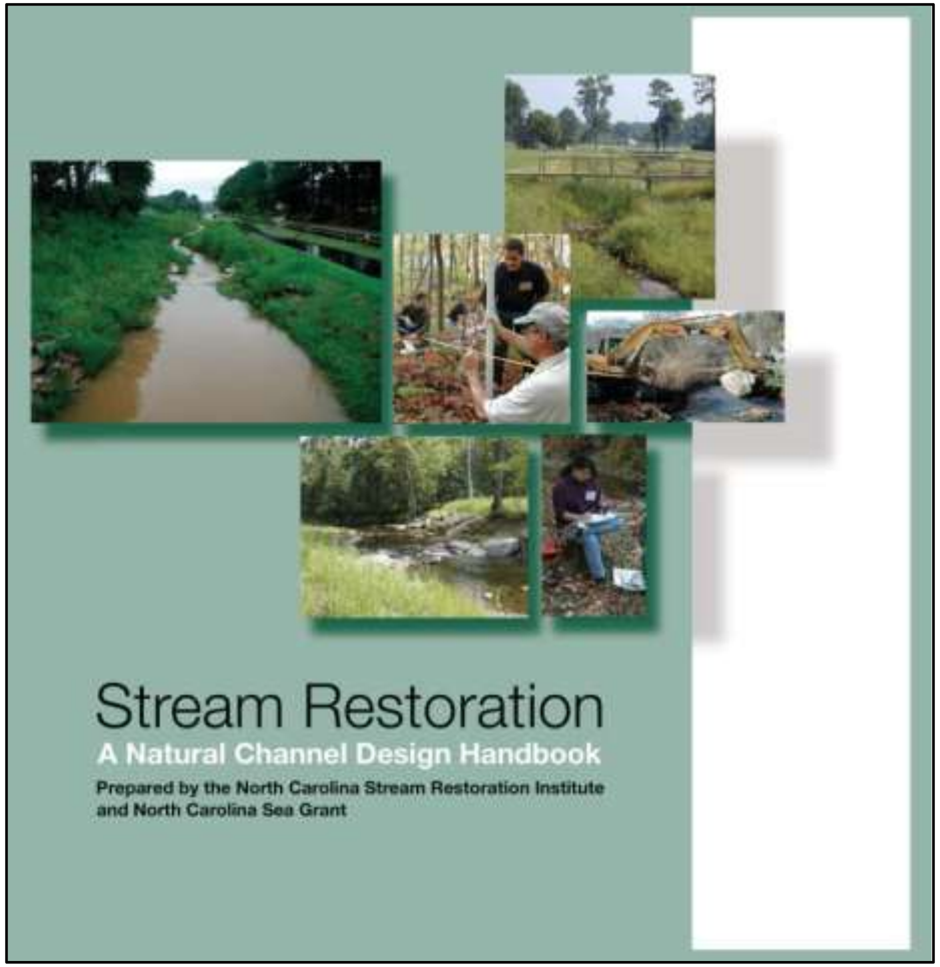


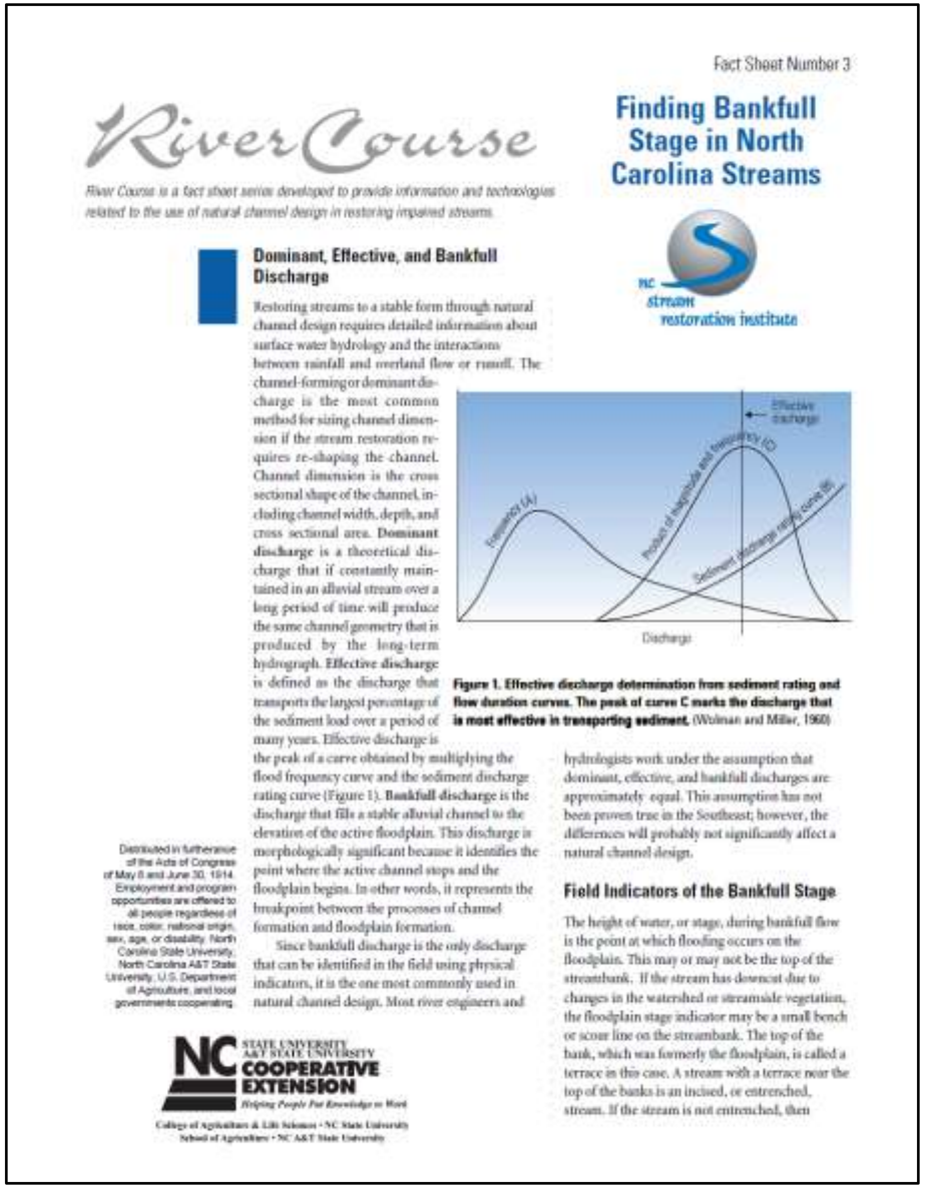
Construction (Certification)

- Partner with NC Ecosystem Enhancement Program (Mitigation Services)
- 3-day “hands-on” training for 40 contractors & construction supervisors
- Examination leads to certification

Technical Resources

- Fact Sheets
- Design Handbook
- Regional Curves for Hydraulic Geometry





Fact Sheet Number 3

RiverCourse

River Course is a fact sheet series developed to provide information and technologies related to the use of natural channel design in restoring impaired streams.

Finding Bankfull Stage in North Carolina Streams

NC stream restoration institute

Dominant, Effective, and Bankfull Discharge

Restoring streams to a stable form through natural channel design requires detailed information about surface water hydrology and the interactions between rainfall and overland flow or runoff. The channel-forming or dominant discharge is the most common method for sizing channel dimension if the stream restoration requires re-shaping the channel. Channel dimension is the cross sectional shape of the channel, including channel width, depth, and cross sectional area. **Dominant discharge** is a theoretical discharge that if constantly maintained in an alluvial stream over a long period of time will produce the same channel geometry that is produced by the long-term hydrograph. **Effective discharge** is defined as the discharge that transports the largest percentage of the sediment load over a period of many years. Effective discharge is the peak of a curve obtained by multiplying the flood frequency curve and the sediment discharge rating curve (Figure 1). **Bankfull discharge** is the discharge that fills a stable alluvial channel to the elevation of the active floodplain. This discharge is morphologically significant because it identifies the point where the active channel stops and the floodplain begins. In other words, it represents the breakpoint between the processes of channel formation and floodplain formation.

Since bankfull discharge is the only discharge that can be identified in the field using physical indicators, it is the one most commonly used in natural channel design. Most river engineers and hydrologists work under the assumption that dominant, effective, and bankfull discharges are approximately equal. This assumption has not been proven true in the Southeast; however, the differences will probably not significantly affect a natural channel design.

Frequency (A)
Product of magnitude and frequency (C)
Sediment discharge rating curve (B)
Effective discharge
Discharge

Figure 1. Effective discharge determination from sediment rating and flow duration curves. The peak of curve C marks the discharge that is most effective in transporting sediment. (Wolman and Miller, 1960)

Field Indicators of the Bankfull Stage

The height of water, or stage, during bankfull flow is the point at which flooding occurs on the floodplain. This may or may not be the top of the streambank. If the stream has downcut due to changes in the watershed or streamside vegetation, the floodplain stage indicator may be a small bench or scour line on the streambank. The top of the bank, which was formerly the floodplain, is called a terrace in this case. A stream with a terrace near the top of the banks is an incised, or entrenched, stream. If the stream is not entrenched, then

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NC State University / A&T State University Cooperative Extension
Helping People Put Knowledge to Work
College of Agriculture & Life Sciences • NC State University
School of Agriculture • NC A&T State University

Regional Conference - EcoStream

Purpose:

Exchange ideas and experiences

Promote research and advancement

Conference Includes:

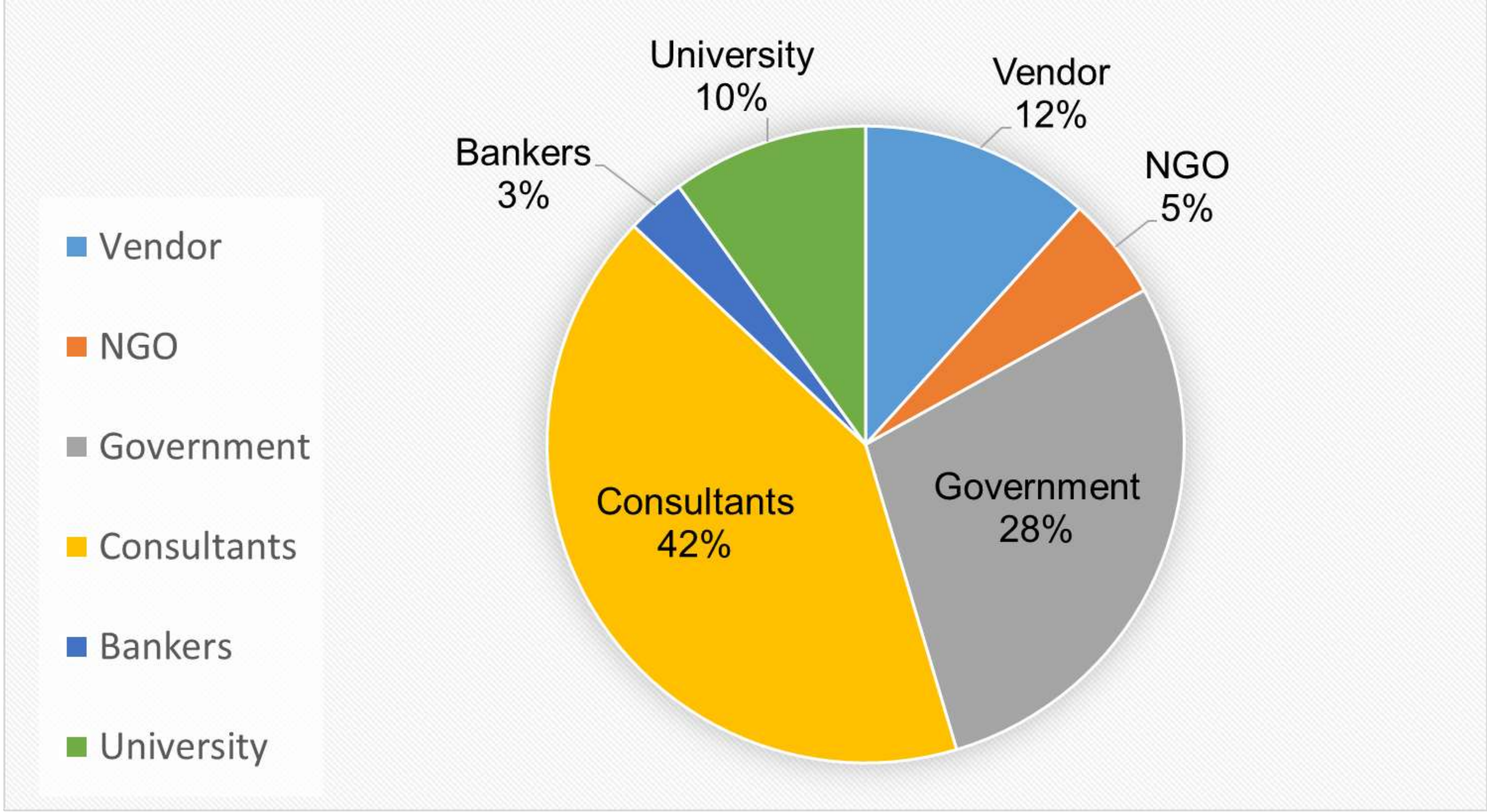
- Learning and Networking Opportunities
- Presentations & Posters
- Workshops
- Corporate Exhibits
- Field Tours

EcoStream
Stream Ecology and Restoration Conference

13 Conferences with Attendance of 150-500

- ***Elkin 1998***
- ***Asheville 1999***
- ***Boone 2000***
- ***Raleigh 2001***
- ***Wilmington 2002***
- ***Winston-Salem 2004***
- ***Charlotte 2006***
- ***Asheville 2008***
- ***Raleigh 2010***
- ***Wilmington 2012***
- ***Charlotte 2014***
- ***Asheville 2016***
- ***Asheville 2018***

Attendee Profile



Demonstration Projects

- Various watershed conditions
- Teaching & long-term evaluation

Rocky Branch, NC State University

Urban stream restoration & stormwater management (NC CWMTF, NC DENR 319, NC DOT, FEMA)

Design, Construction, Monitoring: 2001-2012

Rendezvous Mountain State Forest

Rural high-gradient trout stream & wetland restoration (NC DFR, NC CWMTF)

Design, Construction, Monitoring: 2005-2009

Research Projects

- Restoration Design
  - Hydraulic Geometry
  - Channel Morphology
  - Sediment Transport
  - Innovative Design Techniques
- Restoration Effectiveness
  - Biological Indicators
  - Eco-geomorphological Performance
  - Water Quality Impacts
  - Structure Performance
  - Culvert Impacts on Fish Passage




Structure Performance

Rock Cross Vane Function & Performance: Paige Puckett, PhD, 2007

- 3 Factor, 3 Level Study

  Arm Angle (deg), Arm Slope (ft/ft), Drop (ft/bkfd)

- Response variable

  Flow Contraction = V_{center}/V_{outer}

Findings:

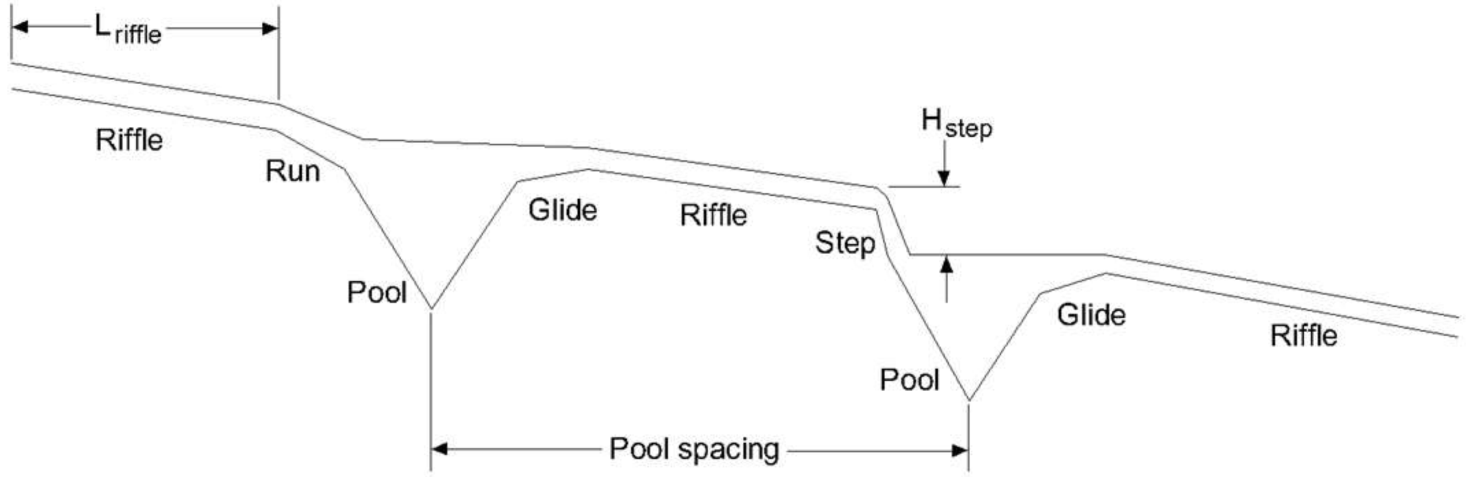
- Drop has the greatest impact on flow contraction.
- As drop decreases, slope effects are more predominant than angle effects.
- At higher drops, angle effects are more predominant than slope effects.

Channel Bedform Characterization

Morphology survey of two streams, Joyce Kilmer Wilderness Area, Western N.C.: Jason Zink, PhD 2012.

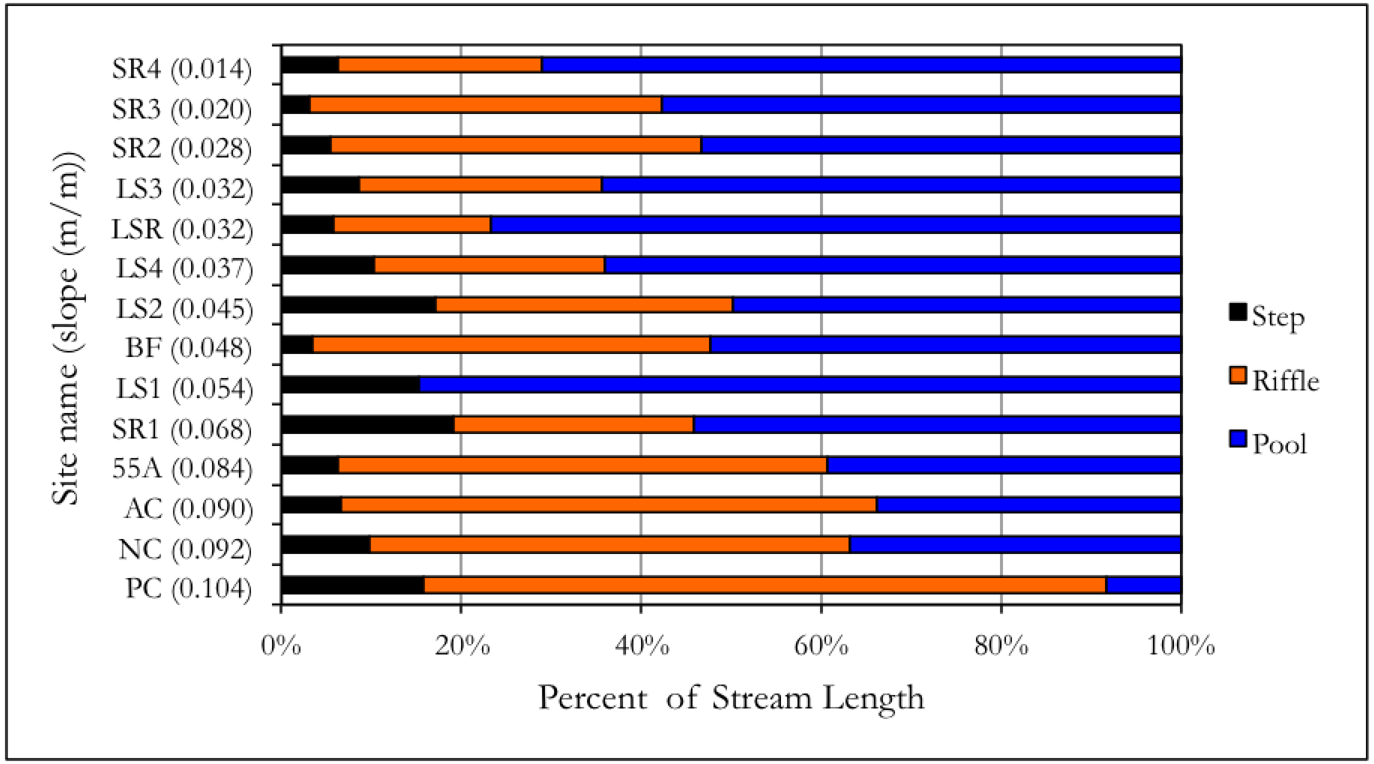
From longitudinal profile:

- length: pool, riffle
- slope: pool, riffle, reach
- height: step
- spacing: pool



Longitudinal Profile: Bedform Morphology

Percent of Stream Length Occupied by Steps, Riffles, Pools

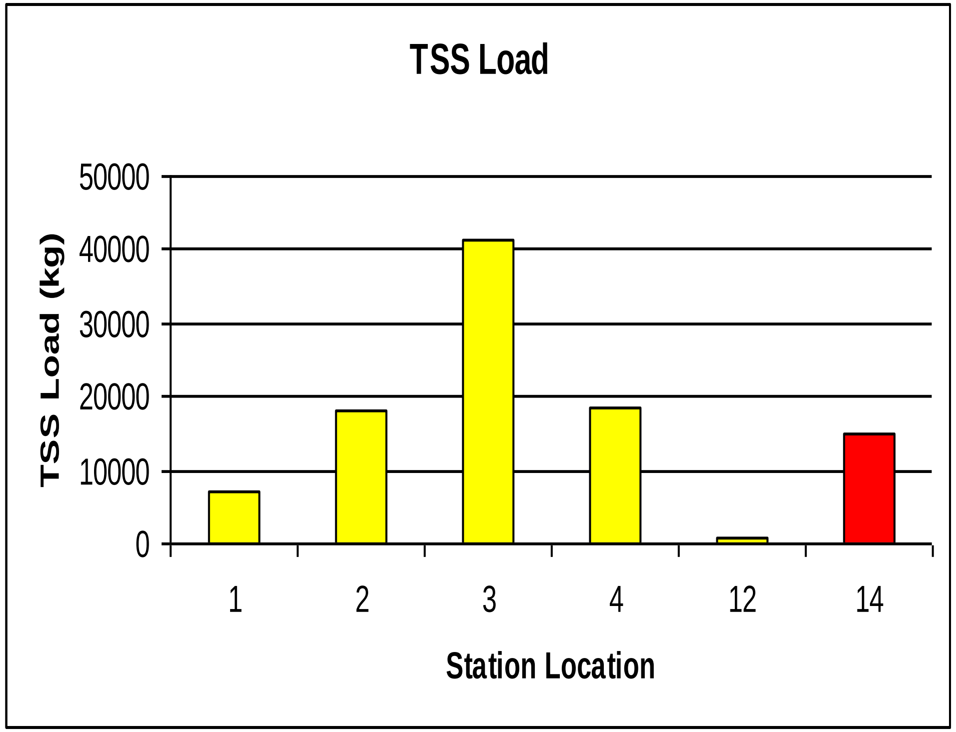


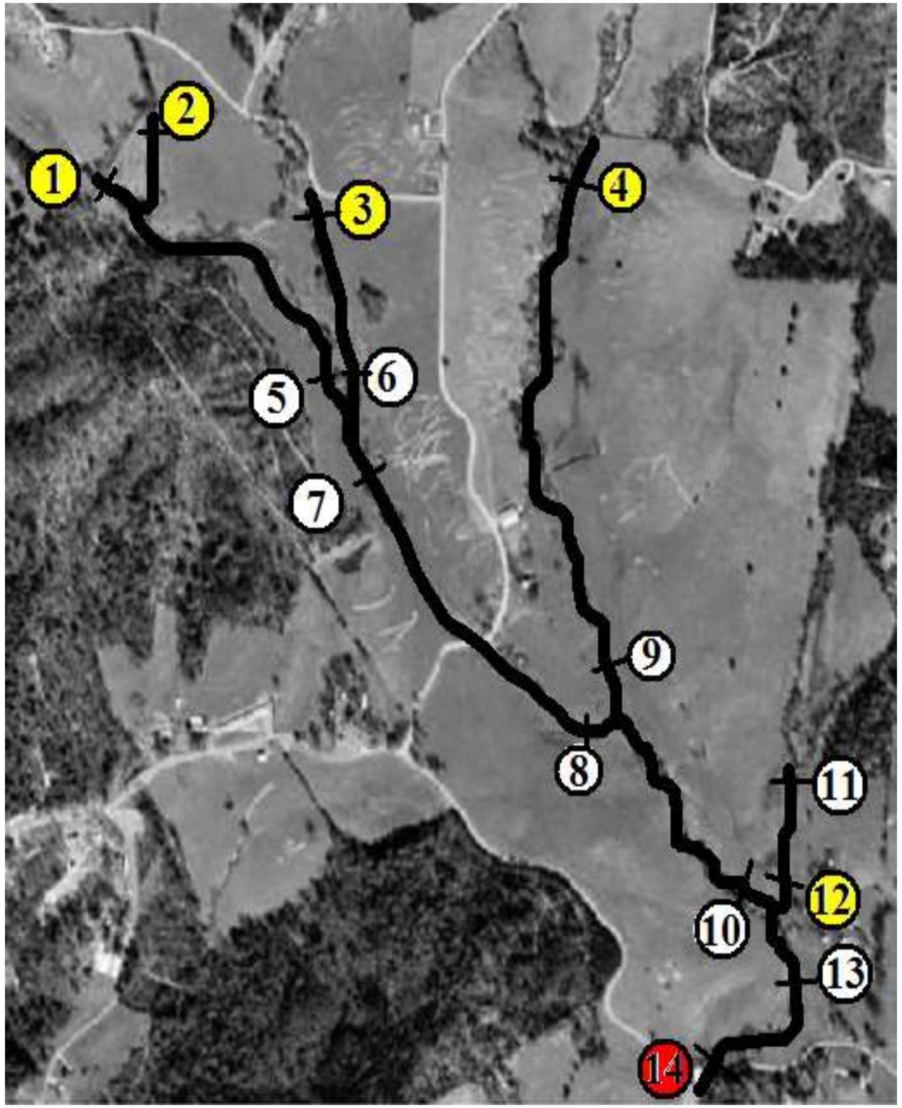
Pools: >50% length for all streams with slope 0.07 ft/ft
Riffles/Steps: both exist across entire range of slopes
Most common sequence: step-pool-riffle

Water Quality Impacts

Purlear Creek restoration evaluation by Justin Spangler, MS 2007

TSS Load





Total Inflow Load:

86 Mg

Total Outflow Load:

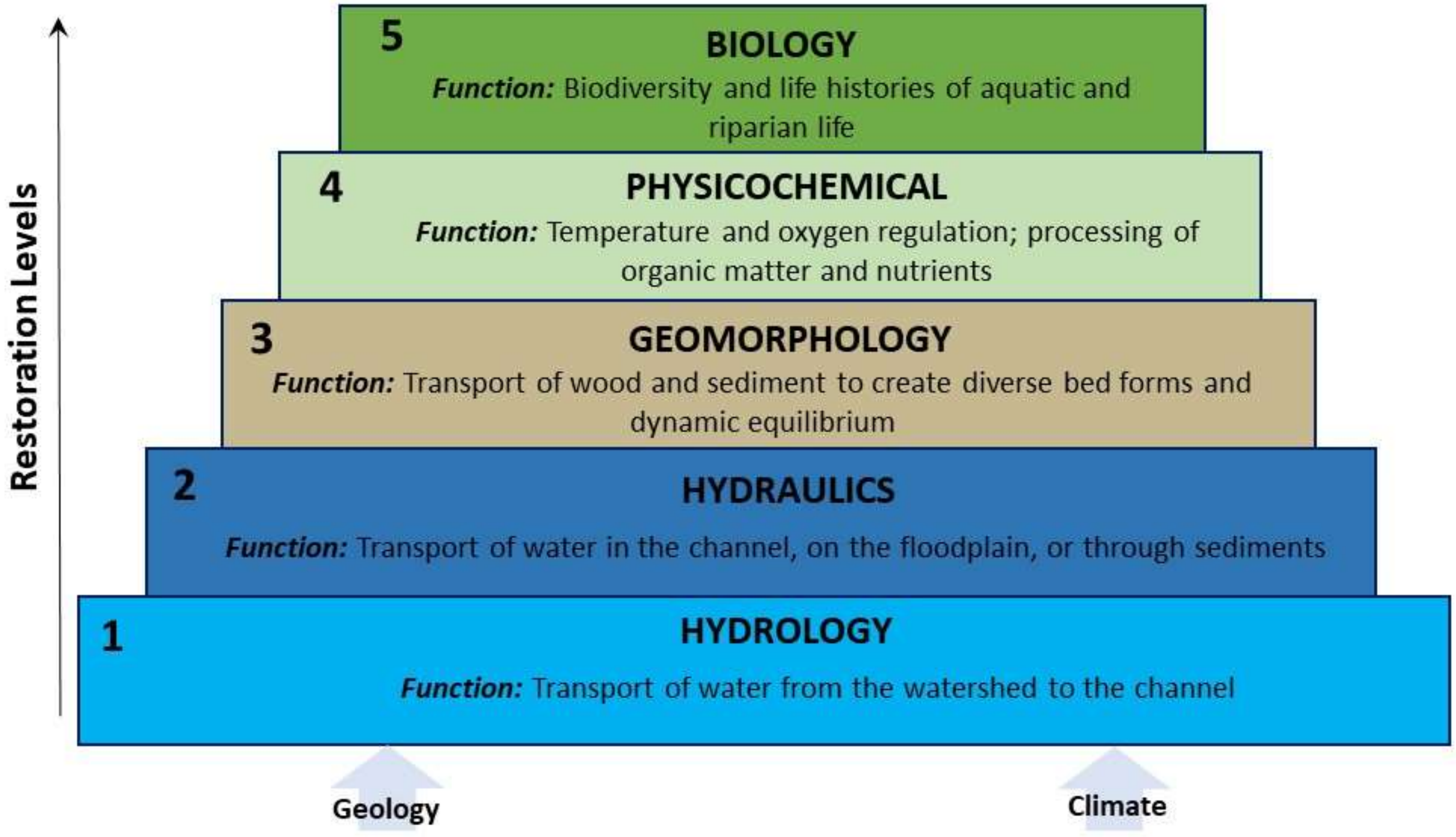
15 Mg

Decrease of:

71 Mg

83%

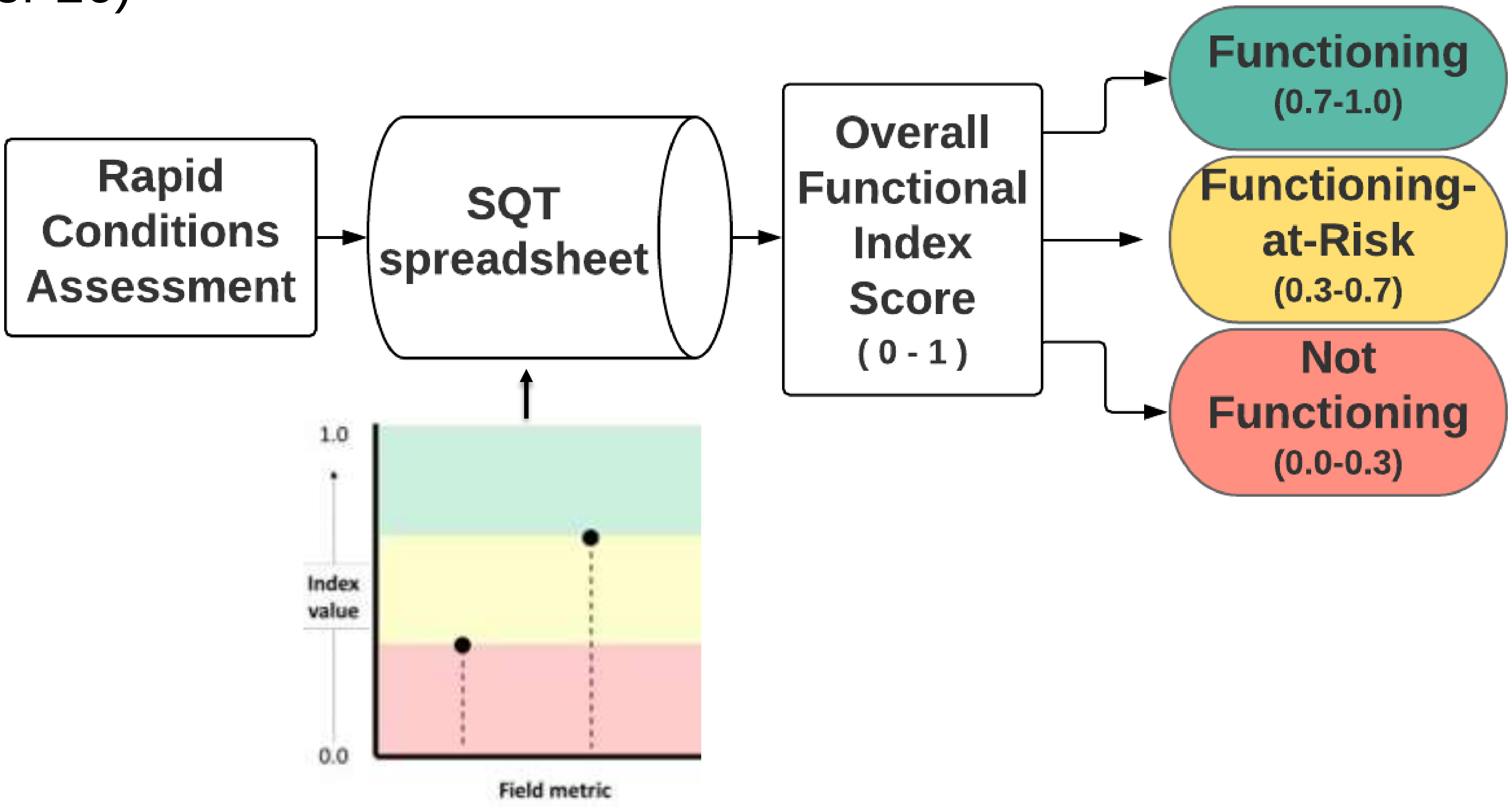
Stream functions pyramid framework



Adapted from Harman et al., 2012, *US EPA*

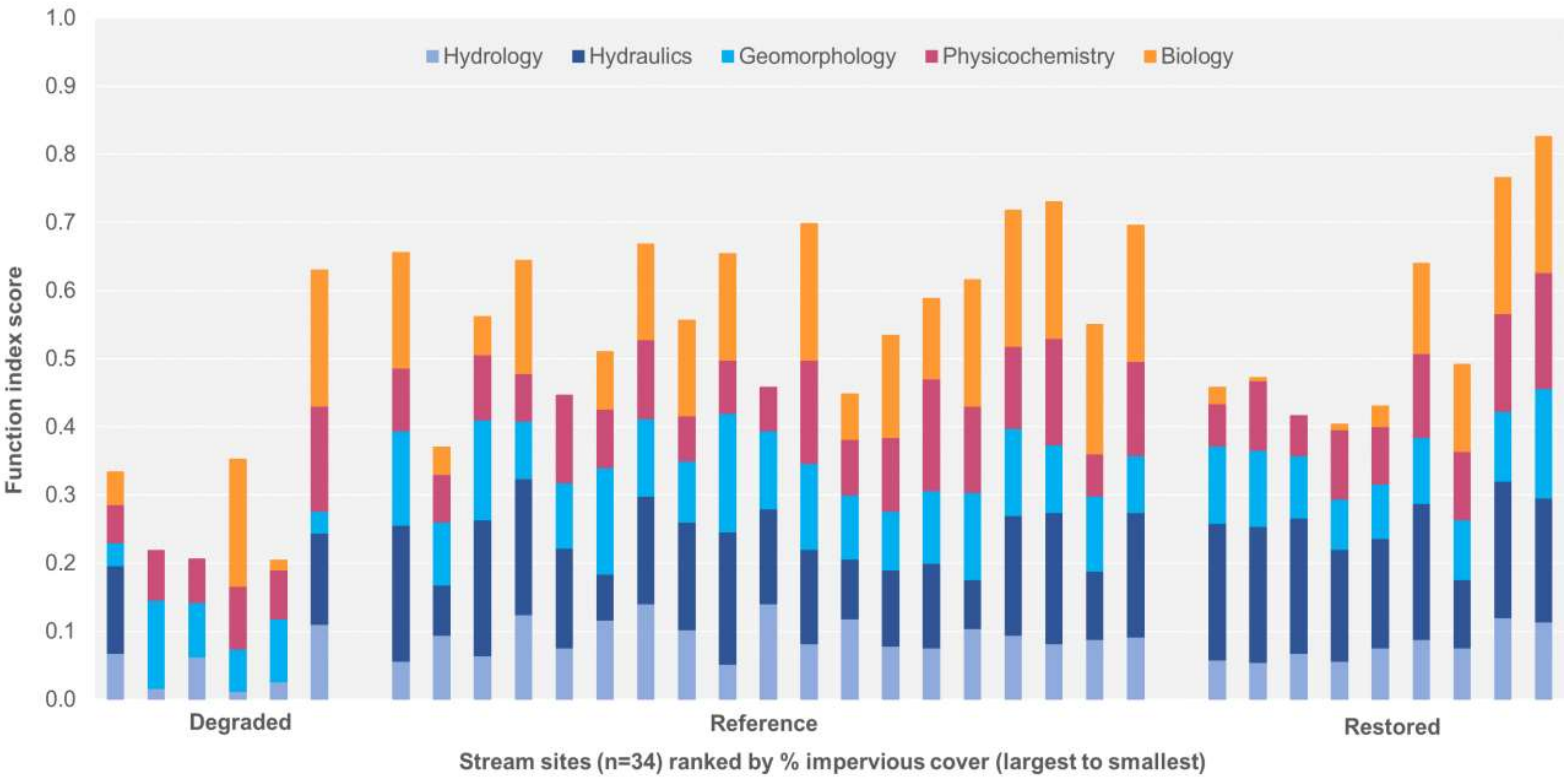
Evaluating the Stream Quantification Tool (SQT)

Evaluate the SQT for measuring ecological functional uplift for stream restoration efforts: Sara Donatich, MS, 2019 (defense November 26)



SFAM, Version 1.0, *US EPA*, 2018

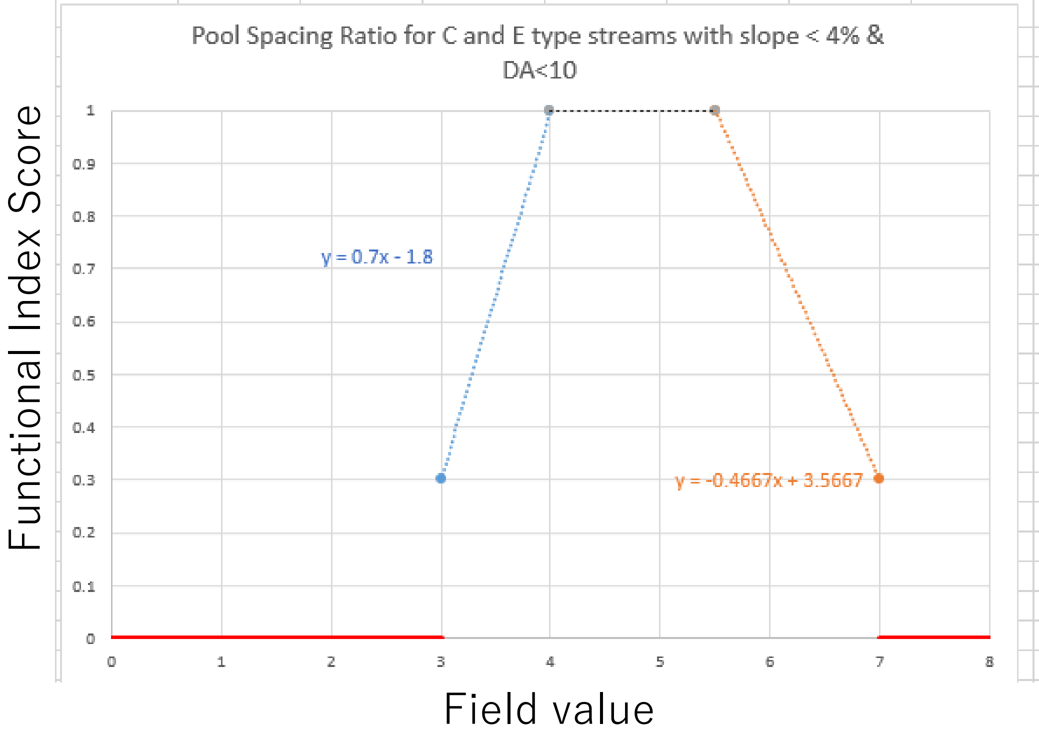
Adapted from Harman et al., 2017

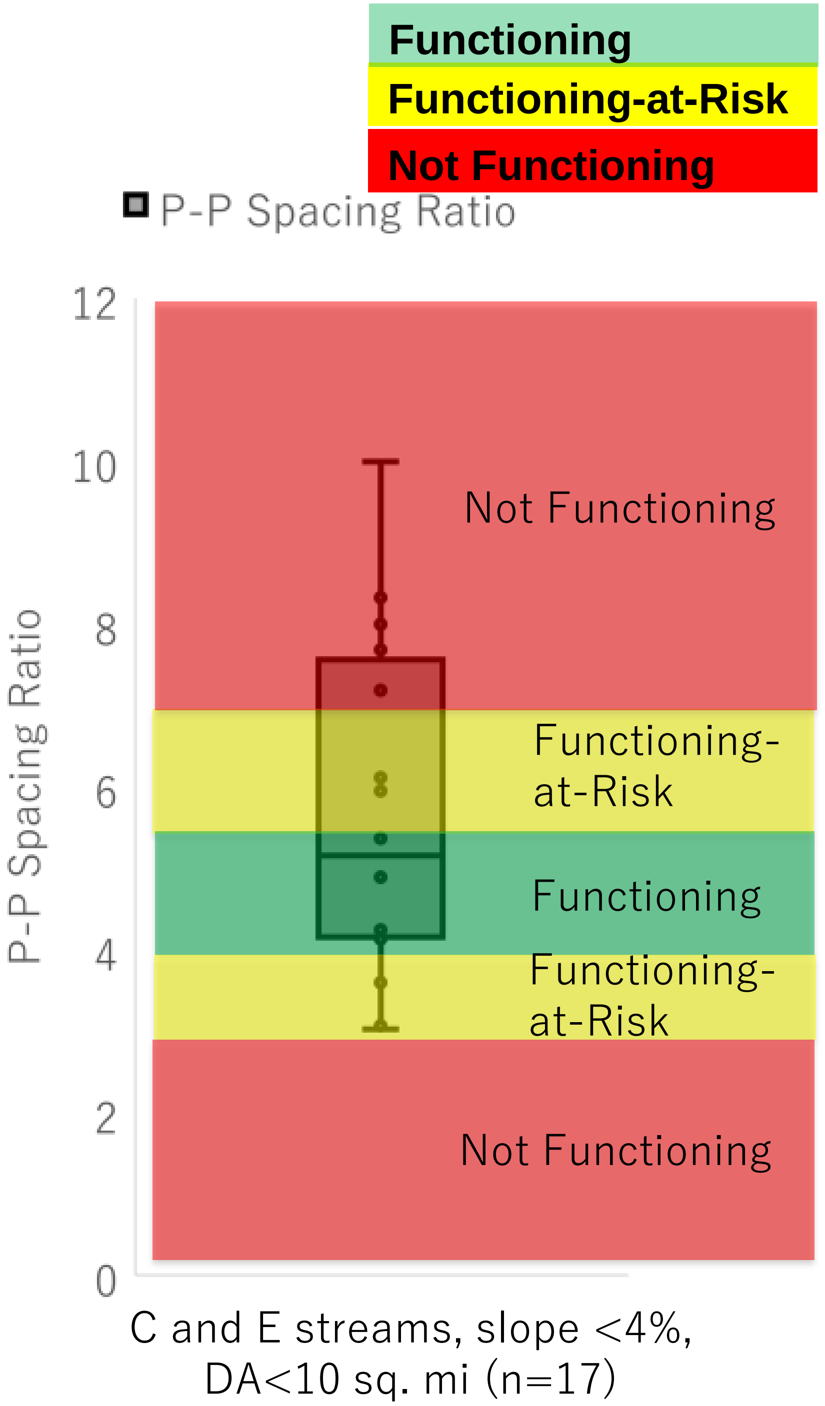

Hydrology
Hydraulics
Geomorphology
Physicochemistry
Biology
Function index score
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
Degraded
Reference
Restored
Stream sites (n=34) ranked by % impervious cover (largest to smallest)

Pool-to-Pool Spacing Ratio (C and E streams)

Field Value			3 7			4 5.5	5.5
Index Value	0	0.29	0.3	0.69	0.7	1	1

	Coefficients - Y = a * X + b	
	Field < 4	Field > 5
a	0.7	-0.4667
b	-1.8	3.5667





Channel Adjustment

NC Division of Mitigation Services Database of all Piedmont Restored Streams for Mitigation

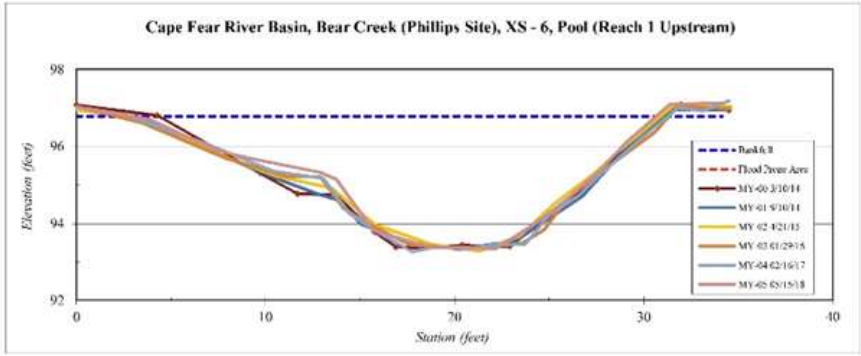
Summary	Value
Total Number of Projects	44
Total Number of Reaches	107
Total Riffle Cross Sections	207 (129 complete)
Total Pool Cross Sections	155 (102 complete)

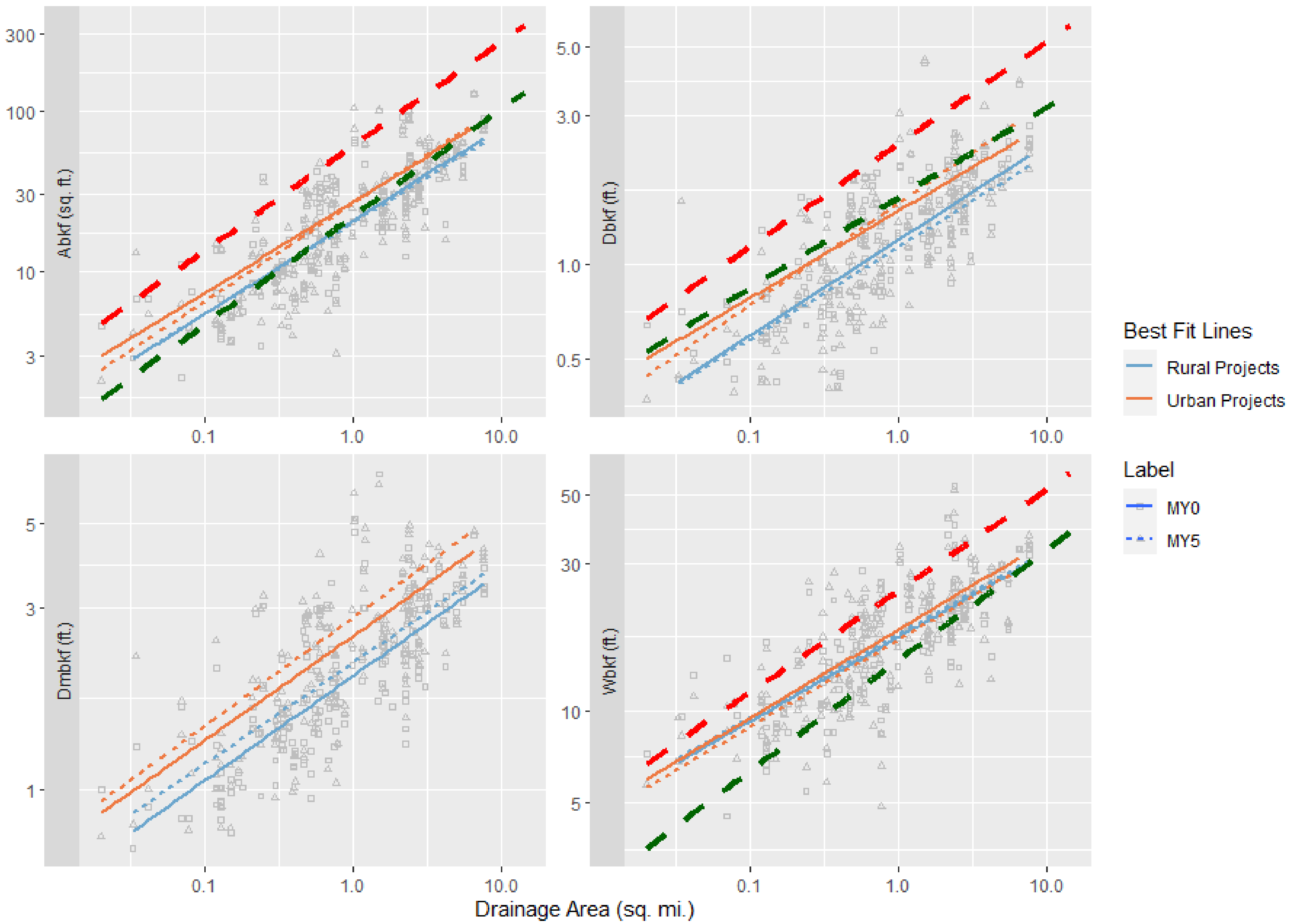
River Basin:	Cape Fear
Site Name	Bear Creek (Phillips Site)
XS ID	XS - 6, Pool (Reach 1 Upstream)
Drainage Area (sq mi):	4.08
Date:	5/15/2018
Field Crew:	Perkinson, Keith

Station	Elevation
0.0	97.0
3.9	96.7
7.5	95.9
9.5	95.7
12.9	95.3
13.8	95.1
15.7	93.8
18.8	93.4
20.4	93.4
22.1	93.3
23.7	93.8
24.9	94.2
26.1	94.7
27.8	95.44
29.1	96.11
31.4	97.09
34.2	97.13

SUMMARY DATA	
Bankfull Elevation:	96.8
Bankfull Cross-Sectional Area:	51.1
Bankfull Width:	27.7
Flood Prone Area Elevation:	-
Flood Prone Width:	-
Max Depth at Bankfull:	3.4
Mean Depth at Bankfull:	1.8
W / D Ratio:	-
Entrenchment Ratio:	-
Bank Height Ratio:	1.00

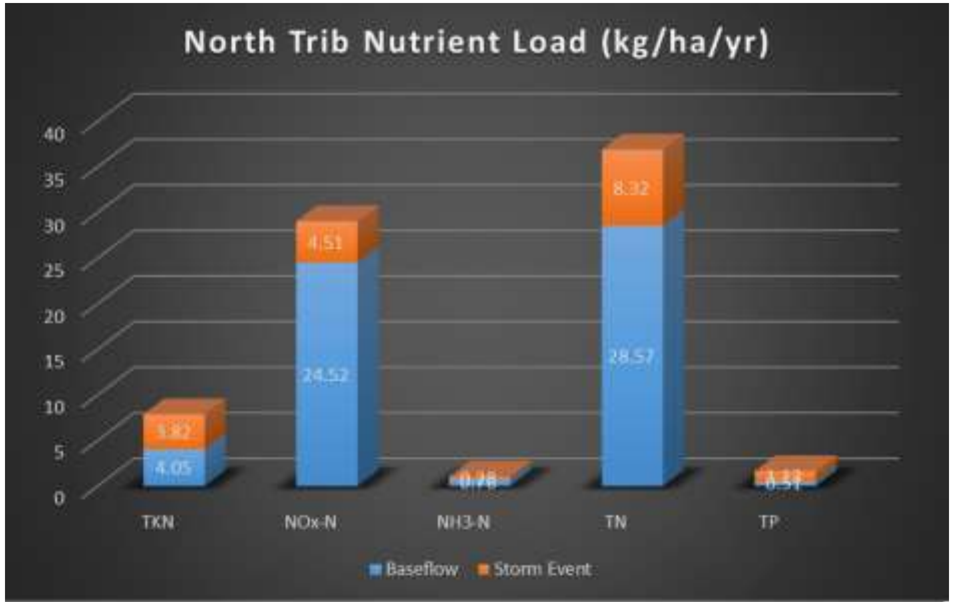
Stream Type	C

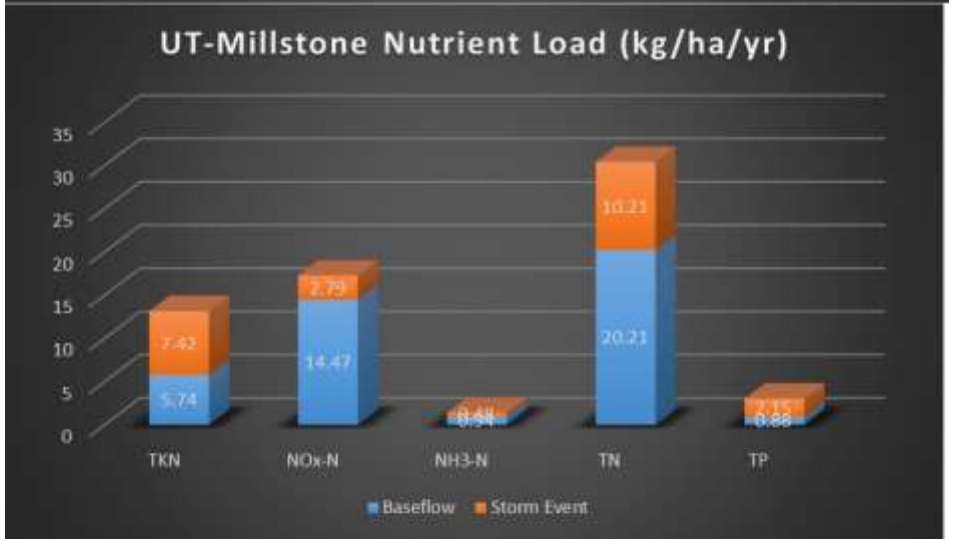




Abkf (sq. ft.)
300
100
30
10
3
Dbkf (ft.)
5.0
3.0
1.0
0.5
Dmbkf (ft.)
5
3
1
Wbkf (ft.)
50
30
10
5
0.1
1.0
10.0
Drainage Area (sq. mi.)
Best Fit Lines
Rural Projects
Urban Projects
Label
MY0
MY5

Millstone Creek: Test Regenerative Stormwater Conveyance (RSC) in Agricultural Setting





Peer-Reviewed Publications

Doll, B., Kurki-Fox, J. J., & Line, D. E. **2020.** A Framework for Planning and Evaluating the Role of Urban Stream Restoration for Improving Transportation Resilience to Extreme Rainfall Events. ***Water.***

Donatich, S., Doll, B., Page, J., & Nelson, N. **2020**. Can the Stream Quantification Tool (SQT) Protocol Predict the Biotic Condition of Streams in the Southeast Piedmont (USA)? ***Water***.

Doll, B., Kurki-Fox, J. Page, J., Nelson, N., Johnson, J. 2020 Flood Flow Frequency Analysis to Estimate Potential Floodplain Nitrogen Treatment during Overbank Flow Events in Urban Stream Restoration Projects. ***Water***.

Doll, B.A., Jennings, G.; Spooner, J.; Penrose, D.; Usset, J.; Blackwell, J.; Fernandez, M. **2016**. Can Rapid Assessments Predict the Biotic Condition of Restored Streams? ***Water*** 8:143.

Doll, B.A.; Jennings, G.; Spooner, J.; Penrose, D.; Usset, J.; Blackwell, J.; Fernandez, M. **2016**. Identifying Watershed, Landscape, and Engineering Design Factors that Influence the Biotic Condition of Restored Streams. ***Water*** 8:151.

Doll, B.A.; Jennings, G.D.; Spooner, J.; Penrose, D.L.; Usset, J.L. **2015**. Evaluating the eco-geomorphological condition of restored streams using visual assessment and macroinvertebrate metrics. ***Journal of the American Water Resources Association***. 51:68–83.

Zink, J. M., and G. D. Jennings. **2014**. Channel Roughness in North Carolina Mountain Streams. ***Journal of the American Water Resources Association***.

McMillan, S. K., A. K. Tuttle, G. D. Jennings, and A. Gardner. **2014**. Influence of Restoration Age and Riparian Vegetation on Reach-Scale Nutrient Retention in Restored Urban Streams. ***Journal of the American Water Resources Association***.

Tuttle, A. K., S. K. McMillan, A. Gardner, and G. D. Jennings. **2014**. Channel complexity and nitrate concentrations drive denitrification rates in urban restored and unrestored streams. ***Ecological Engineering***.

Peer Reviewed Publications Continued

Tillinghast, E. D., W. F. Hunt, G. D. Jennings, and P. D'Arconte. **2012**. Increasing stream geomorphic stability using stormwater control measures in a densely urbanized watershed. ***Journal of Hydrologic Engineering*** 17(12):1381-1388.

Zink, J. M., G. D. Jennings, and G. A. Price. **2012**. Morphology characteristics of Southern Appalachian wilderness streams. ***Journal of the American Water Resources Association***. 48(4):762-773.

Tillinghast, E. D., W. F. Hunt, and G. D. Jennings**. 2011**. Stormwater control measure (SCM) design standards to limit stream erosion for Piedmont North Carolina. ***Journal of Hydrology*** 411(3-4):185-196.

Tullos, D. D., D. L. Penrose, G. D. Jennings, and W. G. Cope. **2009**. Analysis of functional traits in reconfigured channels: implications for the bioassessment and disturbance of river restoration. ***Journal of the North American Benthological Society***. 28(1):80-92.

Tullos, D. D., D. L. Penrose, and G. D. Jennings**. 2006**. Development and application of a bioindicator for benthic habitat enhancement in the North Carolina Piedmont**.** ***Ecological Engineering*** 27(2006)228-241.

Web Site: *www.ncsu.edu/srp*