

# NC SRI SOUTHEASTERN REGIONAL CONFERENCE ON STREAM RESTORATION



June 21-24, 2004

Adam's Mark Winston Plaza Hotel  
Winston-Salem, North Carolina



Sponsored by:

NC State University Stream Restoration Institute  
North Carolina Sea Grant  
and N.C. Cooperative Extension Service





# **Conference Proceedings**

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### **Conference Sponsors**

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*Published by NC State University Stream Restoration Institute  
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## About the Conference

On behalf of the planning committee, I want to thank you for participating in the first Southeastern Regional Conference on Stream Restoration.

This conference showcases stream and wetland restoration efforts from Maryland to Florida. Professionals from the southeastern US and beyond will have an opportunity to present and discuss topics related to the field of restoration. Research and results will be the primary focus of this four-day event, including topics such as sediment transport, in-stream structures, and monitoring and evaluation. Habitat issues, ecosystem assessments, mitigation, funding sources as well as other topics associated with restoration will also be highlighted. Case studies of projects that are complete and have been monitored for at least one year will also be featured. The conference strives to move "beyond construction" in our discussions about restoration and to learn from the variety of research and restoration efforts being conducted throughout the Southeast.

We hope you will find educational resources to enhance your knowledge and skills in stream restoration and protection. Please contact us with any suggestions for future educational programs.

Karen R. Hall

A handwritten signature in cursive script that reads "Karen R. Hall". The signature is written in a dark ink and is positioned below the printed name.

Conference Chair

# NC SRI Southeastern Regional Conference on Stream Restoration

## SCHEDULE OF EVENTS

**MONDAY, JUNE 21, 2004**

**1-5p.m. Pre-conference workshop**

### **Ecological Restoration of Stream Corridors**

Stream restoration work historically has concentrated on redesigning the dimension, pattern and profile of impacted stream reaches. Designs often are patterned after reference-reach streams and focus on reducing bank erosion and providing effective sediment-transport. Restoration and enhancement projects generally also address the restoration of the riparian canopy. However, the restoration of in-stream habitat has not been addressed as thoroughly as channel stability and riparian vegetation. It is known that many benthic organisms can seasonally prefer one type of microhabitat and that certain fish species require specific habitat types. Good in-stream habitat is structurally complex and is composed of both inorganic and organic components. This workshop will focus on the in-stream structures and other stream and floodplain habitat features that can be incorporated into the restoration design.

**1:00 Welcome and Introductions** - Barbara Doll, NC Sea Grant

**1:10 The Habitat Role of Large Woody Material** - Dr. Andrew Dolloff, US Forest Service, Southern Research Station, Dept. of Fisheries & Wildlife, Virginia Tech.

**2:10 BREAK**

**2:25 Identification and Evaluation of In-Stream Habitat Structures** - Dave Penrose, NC State University

**3:25 BREAK**

**3:40 Floodplain and Wetland Habitat** - Alvin Braswell, N.C. Museum of Natural Sciences

**4:40 Discussion/Question & Answer**

**5:00 ADJOURN**

## Pre-Conference Speakers

### Ecological Restoration of Stream Corridors

**Dr. Andrew Dolloff** is the Project Leader and a Research Fisheries Scientist in the Coldwater Streams and Trout Habitat Research Unit, USDA Forest Service Southern Research Station in Blacksburg, Va. He received his B.S. in Wildlife Science from the University of Maine, his M.S. in Zoology from North Carolina State University, and his Ph.D. in Fisheries and Wildlife Management from Montana State University. Dr. Dolloff actively participates in the teaching and research programs at several universities and currently holds adjunct faculty appointments at Virginia Tech, James Madison and Clemson. His research interests include the influence of natural and anthropogenic disturbance on stream communities, riparian ecology, and management of coarse woody debris. In addition to these research pursuits, Dr. Dolloff is involved in the development of management strategies and practices for the protection or recovery of aquatic and riparian ecosystems.

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**Dave Penrose** is a biologist with NCSU Water Quality Group. Dave formerly worked for the N.C. Division of Water Quality (DWQ) in Raleigh, N.C. for 27 years, spending most of his career with the Biological Assessment Group where he was responsible for assessing water quality using aquatic insects as indicators of point and non-point source pollution. More recently he has worked with the 401 Certification Unit and has developed criteria to assess the ecological functions of stream restoration projects. Mr. Penrose was also responsible for determining intermittent and perennial stream systems. He has a B.S. from Northern Michigan University and a M.S. from University of Michigan.

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**Alvin Braswell** is head of the Herpetology Unit and Director of the Research Laboratory at the NC Museum of Natural Sciences in Raleigh, N.C. Mr. Braswell has worked for the NC State Museum of Natural Sciences for over 29 years in a curatorial role with amphibians and reptiles. Through statewide and regional study of amphibians that depend on aquatic systems associated with stream corridors, Mr. Braswell has learned much about the biology of the organisms that use those habitats and the dynamics of the ecosystems. He has a BS in Wildlife Biology and a MS in Zoology from NC State University, and holds an adjunct faculty position with NC State University. Mr. Braswell's recent research has centered on amphibians dependent on ephemeral wetlands.

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## Keynote Speakers:

**Dr. Greg Jennings, PhD, PE** is a Professor of Biological & Agricultural Engineering at North Carolina State University and Associate Director of the Water Resources Research Institute. He provides leadership for teaching, research, and extension programs on water quality, ecological engineering, stream restoration, nonpoint source pollution control, and watershed management. Dr. Jennings holds a PhD in agricultural engineering from the University of Nebraska, and BS and MS degrees in Agricultural Engineering from Pennsylvania State University.

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**Robin Goodloe** is a biologist with the Fish and Wildlife Service, Georgia Ecological Services, in Athens. She primarily works on watershed conservation issues in basins with listed or rare aquatic species and on regulatory issues associated with Federal Projects. She holds a B.S. in biology from The College of William and Mary in Virginia, a M.S. in Wildlife Biology from Louisiana State University, and a Ph.D. in Forest Resources from the University of Georgia.

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**Dr. Jeff Jack, PhD** is Assistant Professor of Biology at the University of Louisville. In addition to academic responsibilities, he is currently involved in stream restoration projects in Bernheim Forest and Wilson Creek in Kentucky, assessing the effectiveness of current restoration strategies in restoring ecological structure and function to streams. He is also currently working with the Kentucky Water District, studying the effects of mining and mountain-top removal. Dr. Jack holds a M.S. from Wake Forest University and a PhD in biology from Dartmouth College.  
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## Tuesday, June 22, 2004

### General Session: Keynote

8:15 a.m.     **Welcome** - Karen Hall, NC State University  
Dr. Greg Jennings, NC State University - Stream Restoration in the Southeast:  
Where Do We Go From Here?  
Dr. Jeff Jack, University of Louisville - Ecological Evaluation of Stream Restoration:  
How Do We Know What Works?  
Robin Goodloe, U.S. Fish & Wildlife Service - Putting the Biology in Stream  
Restoration

10:00 - 10:30 **BREAK**

### Concurrent Session A

Watershed-Based Restoration - Moderator: Dani Wise Johnson  
10:30 - 10:55 Will Harman, Buck Engineering - Mitchell River Watershed Stream Restoration  
10:55 - 11:20 Dr. John Schwartz, University of Tennessee at Knoxville - Stream Restoration  
Activities in the Knoxville, Tennessee Metro Area  
11:20 - 11:45 Dr. Robert Evans, NC State University - Innovative Approaches for Coastal Plain  
Agricultural Ditches

### Concurrent Session B

Fish Passage and Bedload Monitoring - Moderator: Laura Fogo  
10:30 - 10:55 David Braatz, Streamside Systems, LLC - A New Series of Sediment Collectors for  
Monitoring True Bedload  
10:55 - 11:20 Joshua Gilman, KCI Technologies, Inc. - Challenges Associated with Designing  
Natural Fish Passage Structures  
11:20 - 11:45 Eric Karch, Greenman-Pedersen, LLC - Construction Rock Weir Fishways:  
The Subtle Hydraulic Dynamics

11:45 - 1:00 **LUNCH**

### Concurrent Session A

Watershed Assessment - Moderator: Wendy Patoprsty  
1:00 - 1:25 Seth Brown, GKY & Associates, Inc. - From Rhetoric to Restoration: A Case Study of  
Jumping Hurdles  
1:25 - 1:50 Jason Doll, Tetra Tech, Inc. - A Functional Watershed Assessment and Planning  
Protocol to Target Stream Restoration  
1:50 - 2:15 Don Meals, Ice Nine Environmental Consultants - Water Quality Response to  
Riparian Restoration in Two Vermont Agricultural Watersheds  
2:15 - 2:40 Mary Kay Murray, City of Charlotte Storm Water Services - Development of Stream  
Restoration Mitigation Credits Using a Watershed Approach

### Concurrent Session B

Special Restoration Design Topics - Moderator: Mac Haupt  
1:00 - 1:25 Will Harman, Buck Engineering - Design Improvements of Meander Bend Protection  
Using Root Wads

- 1:25 - 1:50 Scott Lowe, KCI Technologies, Inc. - The Morphological Influence of Isolated Rock Ramp Construction on Stream Channels
- 1:50 - 2:15 Robbie Frizzell, J.B. Trimble, Inc. - Stream Channel Restoration at Bridge Sites
- 2:15 - 2:40 Andrew Burg, EGAPS - FEMA, Flood Hazard Mitigation and the Elusive "No-Rise" Certification
  
- 2:40 - 3:05 **BREAK**

#### Concurrent Session A

Watershed-based Restoration/Stormwater Management - Moderator: Jon Calabria

- 3:05 - 3:30 Callie Dobson, Hiwassee River Watershed Coalition - Restoration Based on a Watershed Approach
- 3:30 - 3:55 Doug Redmond, Maryland National Park and Planning Commission - Sligo Creek Watershed Restoration - 15 Years Later
- 3:55 - 4:20 Kelly Brennan, Parsons Brinckerhoff, Inc. - Gwynns Falls Water Quality Management Plan: A Case Study in Stream Assessment
- 4:20 - 4:45 Chris Estes, Estes Design, Inc. - LID - Protection of Headwaters

#### Concurrent Session B

Case Studies: Rural - Moderator: Dave Penrose

- 3:05 - 3:30 Kevin Tweedy, Buck Engineering - Case Studies and Lessons Learned in the Restoration of Sand Bed Channels
- 3:30 - 3:55 Jonathan Smith, NC State University - Evaluation of Stream and Riparian Wetlands Restoration in the Chowan River Basin
- 3:55 - 4:20 Will Wilhelm, Kimley-Horn and Associates, Inc. - Purlear Creek Stream/Wetland Restoration
- 4:20 - 4:45 Barbara Doll, NC Sea Grant - Yates Millpond Stream Restoration

5:05 **ADJOURN**

5:05 - 6:00 **Poster Session - Exhibit Hall (light refreshments served) sponsored by Buck Engineering, North State Environmental, Sepi Engineering Group, and NC Association of Environmental Professionals**

6:30 - 9:00 **Social Event - sponsored by Buck Engineering, North State Environmental, ARCADIS G&M of North Carolina, Estes Design, Hayes, Seay, Mattern and Mattern, Kimley-Horn & Associates, M A Engineering Consultants, and Stantec Consulting.**

Please join us for hors d'oeuvres and drinks at The Sawtooth Center, 226 N. Marshall Street, Winston-Salem. The Sawtooth Center is a facility of The Arts Council of Winston-Salem and Forsyth County. The Social will be from 6:30pm to 9:00pm in the RJR Gallery. Please see page 13 for information and map.

## Wednesday, June 23, 2004

### Concurrent Session A

Stream Hydrology and Assessment - Moderator: Tim Trautman

- 8:00 - 8:25 Samuel Austin, Virginia Department of Forestry - Using Forest Reference Streams to Aid our Understanding of Natural Channel Geomorphology and Water Quality
- 8:25 - 8:50 Adam V. McIntyre, Arcadis - Development of South Carolina Rural Piedmont Regional Curves for the SC Department of Transportation
- 8:50 - 9:15 Dr. Randy Forsythe, Terradigital, Inc. - Regime and Design Issues for Urban Piedmont Streams
- 9:15 - 9:40 Angela Jessup, Natural Resources Conservation Service - Sediment in our Streams: Upland and Streambank Erosion in North Carolina

### Concurrent Session B

Vegetation Issues for Stream Restoration - Moderator: Mark Cantrell

- 8:00 - 8:25 Ellen Colodney, Coastal Plain Conservation Nursery - Restoring Streambank Vegetation
- 8:25 - 8:50 William Cure, Cure Nursery - Trees and Shrubs for Riparian Areas in the Piedmont: A Grower's Perspective
- 8:50 - 9:15 Dr. Jean Spooner, NC State University - Control of Invasive Plants on North Creek, NC State University
- 9:15 - 9:40 Karen Hall, NC State University - Measuring Success of Vegetation Establishment

9:40 - 10:05 **BREAK**

### Concurrent Session A

Monitoring & Assessment of Restoration Projects - Moderator: Micky Clemmons

- 10:05 - 10:30 Desiree Tullos, NC State University - Determination of Critical Monitoring Components for Stream Restoration in North Carolina
- 10:30 - 10:55 Kirsten Young, Clemson University - Physical and Biological Evaluation of a Restored Sand-Bed Stream
- 10:55 - 11:20 Andrea Dvorak-Grantz, Stantec Consulting Services, Inc. - The Re-Establishment of a Benthic Community Within a Unique Restored Stream
- 11:20 - 11:45 Elizabeth Sudduth, University of Georgia - Effects of Bioengineered Bank Stabilization on Bank Macroinvertebrate Communities in Urban Streams

### Concurrent Session B

Case Studies: Urban - Moderator: Dan Clinton

- 10:05 - 10:30 Rocky Powell, Clear Creeks Consulting - Salem Creek at Civitan Park: A Comprehensive Approach to Stream Restoration
- 10:30 - 10:55 Darrell Westmorland, North State Environmental - Construction of the Salem Creek Stream Restoration
- 10:55 - 11:20 Chris Matthews, HDR - Little Sugar Creek Environmental Restoration Initiative - Freedom Park
- 11:20 - 11:45 Vincent Sortman, Biohabitats, Inc. - Anatomy of a Successful Urban Stream Restoration Project

11:45 - 1:00 **LUNCH - Sponsored by Buck Engineering, Cure Nursery, Natural Systems Engineering, and North State Environmental**

### Concurrent Session A

Case Studies - Moderator: Greg Jennings

- 1:00 - 1:25 Ellen McClure, Biohabitats, Inc. - Adding Some Green to Brown Branch: Stream Restoration in the Rural Piedmont
- 1:25 - 1:50 Rosty Caryk, Stantec Consulting Services, Inc. - Design, Construction, and Post-Construction Monitoring for Relocation of 5, 228 ft. of Stream Channel in New Hartford, New York
- 1:50 - 2:15 Melanie Carter, NC State University- Estimating Channel Degradation Rates in a Rapidly Developing Watershed

### Concurrent Session B

Stream Restoration Assessment - Moderator: Angela Jessup

- 1:00 - 1:25 Conor Shea, Parsons Brinckerhoff, Inc. - It Wasn't Supposed to Do That: Analysis of Planform Adjustments After Stream Restoration
- 1:25 - 1:50 Dan Clinton, NC State University - The Development of Stream Restoration Monitoring Standards
- 1:50 - 2:15 Dani Wise Johnson, NC State University - Evaluating Monitoring Requirements for Stream Mitigation Projects
- 2:15 - 2:40 **BREAK**

### General Session

Stream Restoration Cost & Mitigation - Moderator: Barbara Doll

- 2:40 - 3:05 Jeff Jurek, Ecosystem Enhancement Program - Analysis of Stream Restoration Costs in the North Carolina Ecosystem Enhancement Program
- 3:05 - 3:30 Mac Haupt, Ecosystem Enhancement Program - Maintenance Costs of Stream Restoration Projects in the Ecosystem Enhancement Program
- 3:30 - 3:55 Scott McClendon, US Army Corps of Engineers - Stream Impacts and Mitigation: A Regulatory Perspective
- 4:20 **ADJOURN**

## Thursday, June 24, 2004

8:00 am - 3:00 pm

### Rural Tour

This tour will include four rural restoration sites in Surry County. Each project is unique with regard to size, design parameters, cause of original impairment and years since construction. Each site has been monitored since construction. Monitoring results will be discussed including bank stability, vegetation success, macroinvertebrate health and fish repopulation. Stream designers will be onsite to discuss design parameters, landowner concerns, and lessons learned. Lunch will be provided for you to enjoy on the banks of the South Fork of the Mitchell River.

8:00 - 3:00 pm

### Urban Tour

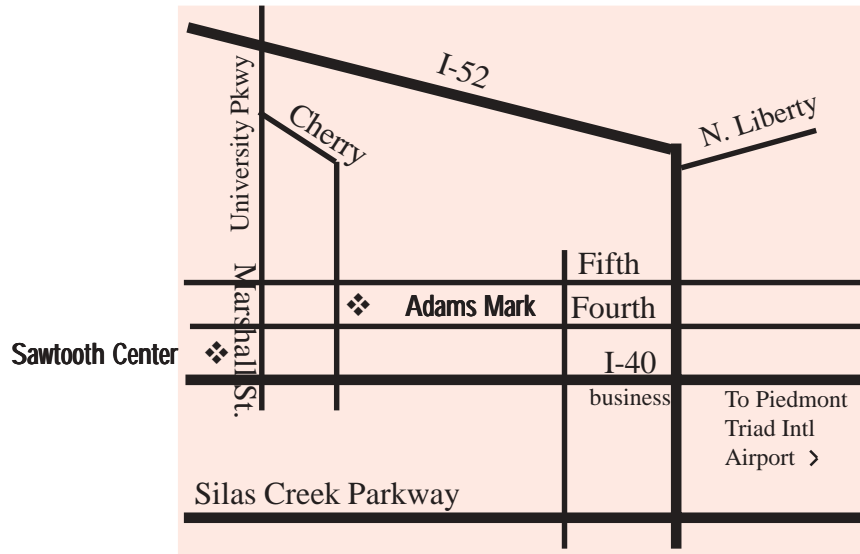
This tour will introduce you to five restoration sites in various stages of completion in a highly urbanized area of Winston-Salem. All five projects are located in Winston-Salem. Issues including stormwater management, utility constraints, park environment, and heavy use conditions will be discussed. The stream restoration contractor will be on-site to discuss construction techniques in an urban setting. Lunch will be provided.

# CONFERENCE SOCIAL

**Tuesday Evening, June 22, from 6:30 - 9 p.m.**

**Social Gathering at The Sawtooth Center, 226 N. Marshall Street, Winston-Salem**  
**Meet you in the RJR Gallery - thanks to the generous support of**

**ARCADIS G&M of North Carolina**  
**Buck Engineering**  
**Estes Design, Inc.**  
**Hayes, Seay, Mattern and Mattern, Inc.**  
**Kimley-Horn and Associates, Inc.**  
**M A Engineering Consultants, Inc.**  
**North State Environmental, Inc.**  
**and Stantec Consulting, Inc.**



The Sawtooth Center is within walking distance of the Adam's Mark Hotel. Go left when exiting the hotel (Cherry St.) and turn right on 4th Street. Turn left on Marshall St. and walk one block.

The RJR Gallery is on the lower level of the Sawtooth Center.

*Notes:*

## MITCHELL RIVER WATERSHED – STREAM RESTORATION

William A. Harman, PG<sup>1</sup> and J. Richard Everhart<sup>2</sup>

1 *Buck Engineering, Cary NC.*

2 *Natural Resources Conservation Service, Dobson NC.*

The Mitchell River watershed is located in the foothills of the Blue Ridge Mountains in Surry County, North Carolina. The watershed drains 105 square miles and is divided between two large sub-watersheds, the Mitchell River and South Fork Mitchell River. While the Mitchell River is classified as an Outstanding Resource Water (ORW), North Carolina's highest water quality classification, the South Fork Mitchell River is impaired by sediment and fecal coliform. Watershed assessments have determined these pollutants primarily enter the South Fork from eroding streambanks and cattle access to the stream. Other land uses that may contribute to impairment include cropland, pastureland, and silviculture.

In 1997, the Mitchell River Watershed Coalition was formed to address water quality issues in the Mitchell River Watershed with a special focus in the South Fork. The Coalition is comprised of local, state, and federal agencies; landowners; and private corporations. The Coalition is supported locally by the Surry County Soil and Water Conservation District, Natural Resources Conservation Service, and NC Cooperative Extension Service, with funding support from the NC Clean Water Management Trust Fund, NC Division of Water Resources, and the NC Division of Water Quality. The Coalition's goal is to improve water quality in the South Fork to achieve the ORW status of the Mitchell River and to protect and improve water quality in the Mitchell River. Because streambank erosion and cattle access are the major causes of impairment, livestock exclusion and stream restoration practices have been the primary techniques used to meet these goals.

This presentation will focus on several stream restoration projects that have been completed in the watershed over the past three years. The presentation will include projects in both steep gradient colluvial valleys and low gradient alluvial valleys. An evaluation of project success will include quantitative and qualitative assessment results from a monitoring program funded by the NC Clean Water Management Trust Fund.

Keywords: *stream restoration, Mitchell River, evaluation*

*About the speaker:*

**Mr. Harman** is the founder and Vice President of Buck Engineering, a 50-person firm specializing in stream and wetland restoration throughout the eastern US. Mr. Harman holds a bachelors degree and masters degree in geography and is a licensed professional geologist in North Carolina.

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## **STREAM RESTORATION ACTIVITIES IN THE KNOXVILLE, TENNESSEE METRO AREA**

John S. Schwartz, Ph.D., P.E.

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State, county, and city government, together with non-governmental organizations (NGOs) have been engaged over the past ten years rehabilitating streams in Knox County, Tennessee. Knox County and surrounding counties have recently faced rapid urbanization resulting in poor water quality from siltation, habitat loss, excessive bank erosion, and local flooding in its streams. Any construction activity or modification to a stream channel requires an Aquatic Resource Alteration Permit (ARAP) administered by the Tennessee Department of Environment and Conservation (TDEC). This permitting program is divided into a general permit process for major activities (i.e., stream relocation) and minor activities (e.g., bank stabilization, road maintenance and crossings, utility line crossings, bridge scour repair, stream restoration and habitat enhancement, wet weather conveyances, etc.). For the Knoxville metro area during 2002, TDEC minor ARAP permits were related mostly to road crossings and maintenance (42.6%), followed by wet weather conveyances (20.9%), bank stabilization (8.7%), utility crossings (7.8%), and stream restoration and habitat enhancement (7.4%). Few stream relocations are permitted, but one recent example was Lyon Creek in which 1000 feet of stream was moved for a large shopping mall. NGOs have completed several restoration projects attempting to rehabilitate damaged stream and riparian corridors. Bank stabilization projects comprise the majority of the local efforts, though other projects do include habitat enhancement, hydraulic controls, and riverine wetlands rehabilitation. For example, rehabilitation of Williams Creek included bank stabilization and habitat enhancement. Very active local NGOs in the Knox County area include the Beaver Creek Watershed Association, Beaver Creek Task Force, Stock Creek Watershed Association, and the Friends of Little River. An overview of the stream restoration activities in the Knoxville metro area will be presented focusing on the state regulatory framework, general design methodologies employed, and descriptions of project examples.

Keywords: *stream restoration, bank stabilization, Knoxville, Tennessee*

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## INNOVATIVE APPROACHES FOR COASTAL PLAIN AGRICULTURAL DITCHES

R.O. Evans<sup>1</sup>, R.D. Hinson<sup>2</sup>, R. Johnson<sup>3</sup>, M. Doxey<sup>4</sup>, K.L. Bass<sup>5</sup>, J.T. Smith<sup>6</sup>

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*2 USDA Natural Resources Conservation Service, Edenton, NC*

*3 USDA Natural Resources Conservation Service, Edenton, NC*

*4 Currituck Soil and Water Conservation District, Currituck, NC*

*5 NCSU Water Quality Group, Raleigh, NC*

*6 NCSU Department of Biological and Agricultural Engineering, Raleigh, NC*

Drainage is an important and necessary component of land management in eastern North Carolina where more than 50 percent of soils require improved drainage for efficient production and other uses. For more than 250 years, drainage practices have focused on straightening and deepening natural channels to increase their hydraulic capacity and minimize upstream flooding. Today, there are very few un-channelized streams remaining. In most cases, traditional channel improvements have disassociated the channel from the natural floodplain degrading riparian floodplain ecological functions. Woody riparian vegetation along the sides of the streams have been removed and ditch banks are routinely mowed to provide access for periodic clean-out and removal of silt. In many channelized streams, most storm flows are now confined predominately to the main channel. The riparian floodplain that once routinely remained soaked or inundated during the winter and spring for months at a time now only flood during very large storms. In bypassing the floodplain, there is less opportunity for potential pollutants in the drainage water to be filtered and assimilated. While wetness is still a major concern to landowners, intensive drainage systems sometimes remove more water than necessary especially during drier periods, leading to over drainage.

Pilot studies have been established in northeastern North Carolina to investigate, evaluate, and demonstrate alternative channel design geometries and management to enhance ecological and water quality functions while maintaining the necessary drainage function. Channel alternatives have included establishment of in stream wetlands, lowering of the floodplain to reconnect the channel with the floodplain (priority II restoration), redesign of channels using natural channel design principles to reconnect the channel with the natural floodplain (priority I restoration), and establishment of conservation easements to eliminate traditional ditch bank mowing to encourage establishment of perennial riparian vegetation.

The Tulls creek project was initiated in 1994 in Currituck County. The study site was a one mile reach of the main canal system draining approximately 200 acres of cropland. One reach of the canal was managed in the traditional “free” drainage mode, a second reach was managed in the “controlled” drainage mode, and the third reach was planted with a variety of wetland plants to provide a combination in stream wetland/controlled drainage system. In general, nitrogen concentrations were higher while phosphorus concentrations were lower with drainage control both with and without the addition of wetland plants. Total flow, phosphorus and sediment transport were significantly lower with both controlled drainage treatments. The addition of plants did not appear to provide an additional water quality benefit other than an improvement in water clarity over drainage control alone. Habitat benefits may have been enhanced by the plants, but habitat benefits were not evaluated. This project demonstrated that it is possible to maintain wetland plants in drainage ditches without adversely impacting the drainage performance of the ditch.

The Edenton urban project was initiated in 1997 and involved construction to lower the floodplain along approximately 1000 linear feet of stream and create approximately 2.5 acres of in stream wetlands. The drainage area contributing flow to the wetland included approximately 400 acres of agriculture and 100 acres of urban area with over 50 acres of impervious surface. Base flow attenuation within the constructed wetland was approximately 7 days with no impact on large storm flows. Approximately 20 % of the total nitrogen entering the wetland was assimilated within the wetland. This project, located near the county high school, has provided living labs for both biology and physical science classes.

Currituck County is one of the fastest growing counties in North Carolina resulting from urban sprawl from Tidewater Virginia. The Guinea Mill watershed project was initiated in 1999 to address drainage and water quality issues arising from rapid urbanization of a predominately rural county. Riparian buffers were established along 45,700 feet of the Guinea Mill Canal. Vegetation in the buffers is maintained 1 to 3 feet high. A tax-supported Service District was formed by the Currituck County commissioners to assure the future maintenance and persistence of the project components. Permanent conservation easements involving 49 acres along both sides of the canal were purchased and are managed by the county utilizing an advisory board comprised of five landowners in the watershed. The advisory Board is charged with the duty of investigating, studying and making recommendations to the Board of Commissioners pertaining to the construction, enlargement, improvement, maintenance, operation and regulation of the Service District. A county ordinance was established requiring all new subdivisions and any landowners encroaching on the easement and canal to submit a plan for their encroachment (i.e., culvert, drainage swale, etc) to the Service District prior to installation. In stream constructed wetlands were installed on 8.4 acres within the Guinea Mill Canal. A rock weir water control structure was installed to enhance hydrologic function at low flows.

A similar tax supported Service District project was initiated in the Newland Watershed in Pasquotank County in 1998. The watershed Service District encompasses approximately 17,000 acres. The US 158 Canal and Shepard Ditch are the primary outlets for the southeastern section of the Dismal Swamp Wildlife Refuge. In recent years, landowners downstream of the refuge have been subjected to flooding resulting from failure and overtopping of the refuge dyke. This project involved development of a conceptual water management plan for the refuge that balanced the water management needs of the refuge with the drainage and water quality needs of the downstream landowners and citizens. Vegetative buffers were established along 14,000 feet of the 158 Canal and 11,800 feet on Shepard Ditch. The ditch bottoms were excavated to establish 2.6 acres of in stream constructed wetlands. Five associated rock weir water control structures were installed to enhance base flow hydrology and ecological function. Annual inspections are made by the Advisory Board and the Pasquotank SWCD Board with their respective reports submitted to the County commissioners.

The Edenton Airport and Industrial Park restoration and enhancement project in Chowan County was initiated in 2000. As part of the construction and development of the Edenton Army Base in the 1930's, the lower stream of the watershed was channelized with the spoil deposited in the adjacent floodplain and a short circuit cutoff constructed that shortened (by almost a mile) the flow path of drainage water to the Albemarle Sound. This project involved three hydrologic enhancements. The first involved restoration of stream and riparian floodplain functions in the lower stream segment. Spoil piles were removed to restore some hydrologic functions to the floodplain. Re-growth maples

were replaced with cypress and mixed bottomland hardwood species. At several locations, the straightened, channelized stream was re-routed back through its original floodplain. The second involved construction of a 1000 foot reach of stream and riparian floodplain. Final design consisted of an 800 foot stream/wetland valley with wetland width varying from 20 to 30 feet. The stream was designed to meander within the wetland valley. The stream/wetland system was designed to be from 1.5 to 4 feet below original grade. Lastly a series of 3 storm water wetlands were constructed between the constructed and restored stream reaches. Hydrologic and water quality functions of the three wetland system continues to be evaluated.

Lastly, an innovative approach was initiated in 2003 to manage drainage and stormwater at the Chowan Country Club. Existing drainage ditches were redesigned utilizing natural channel design concepts and interconnected to a network of constructed stormwater wetlands. Again all stormwater conveyance channels and wetlands are protected by a permanent conservation easement under the control of the County Commissioners. Nutrient and water management plans are being developed for the golf course. Once the management plans are adopted, modifications will require the approval of the County Commissioners. The wetland system is designed to treat and retain the first two inches of runoff which will be recycled back on the course through irrigation resulting in a nearly “closed” system. The hydrologic and water quality performance of this system will be evaluated over the next three years. Construction was completed in May and the course is scheduled to reopen in September.

All of the projects discussed herein were supported by a combination of grants from the North Carolina Clean Water Management Trust Fund and N.C. Department of Environment and Natural Resources 319(h) program; and/or N.C. Agricultural Cost Share and Conservation Reserve and Enhancement Program, along with local government and landowner in kind contributions.

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# A NEW SERIES OF SEDIMENT COLLECTORS FOR MONITORING TRUE BEDLOAD

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Streamside Systems offers a variety of bedload monitoring collectors to sample targeted sizes of bedload sediment. Prototypes of portable units have been tested for continuous operation (3 to 5-month periods) for sand to medium gravel moving as bedload. The Streamside collectors sample true bedload, and avoid the collection of suspended sediment and organic matter. Bedload net samplers such as the Helley-Smith are exposed to a partial cross-section of the water column for a short period of time; they are highly variable, they can become blocked by the inclusion of organic matter, and they are biased by including suspended sediments (from near the bottom of the stream, where suspended sediment concentrations are highest). In low-gradient streams, the Streamside collectors are pumped out, and can easily be backflushed or “zeroed” with no safety hazard (re: need to enter a flooded stream). In higher-gradient streams, a siphon removal system will work continuously with a localized drop adequate to flush the sediments (e.g., 20 to 25 gpm through a 24-inch collector, using a 2-inch hose). The outlet hose allows samples to be collected safely from the shoreline, even under high flow conditions, and for any desired sample period (seconds to months). The collectors can continue to operate unattended, and can stockpile bedload material for later sieve analyses. For medium and large gravel, cobble, and even boulders, Streamside bedload collectors utilize removable hopper assemblies downstream from the pumpout or siphon hopper for fines; this is a clear design advantage over pit traps for large material, in that fine sediments are removed on a continuous basis and will not fill the collector basin(s) intended for coarser material. In contrast to small (3 or 6-inch) bedload samplers used for short-duration samples, Streamside Systems’ bedload samplers can virtually eliminate subsample variability by targeting total bedload over extended periods. This ability to selectively remove and measure targeted sizes of bedload sediments on a large scale also allows the collection of bedload transport data on that material as a side benefit from programs designed for remediation of sedimentation impacts (such as restoration of sediment-impacted substrates, reduction of reservoir sedimentation, reintroduction of sediments below dams, and prevention of sediment impacts below dam-removal projects).

Keywords: *fluvial sediment, monitoring, bedload, sediment sampling, restoration, methods*

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*About the speaker:*

**Dave Braatz** is an aquatic ecologist with a graduate degree in Fisheries from the University of Wisconsin, and over 30 years of experience on the streams and reservoirs of the Carolinas. For the past fifteen years, he has worked primarily on sediment transport issues, land use impacts on water quality, and stream restoration. He is currently a partner in Streamside Systems, a relatively new company offering a variety of equipment for measuring bedload sediment transport, for preventing reservoir sedimentation, for moving sediments in aquatic systems (e.g., sand mining, or beach nourishment), and for restoration of sediment-impacted habitats.

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## CHALLENGES IN DESIGN OF NATURAL FISH PASSAGE STRUCTURES

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Only recently has fish passage gained recognition as an integral component of compensatory mitigation for construction projects under the Nationwide Permit program (Army Corps of Engineers, 2000). As a result, a variety of treatments intended to promote passage of fish over recognized obstacles or blockages have been attempted and documented in the American Rivers Illustrative Handbook on Nature-Like Fishways (American Rivers, 2003). Among those exhibiting success are step-pool and rock ramps similar to those designed by Newbury Hydraulics, Ltd. (Newbury, 1993). Critical to compliance with compensatory mitigation requirements is the determination of target species and individual needs of those target species. The author will discuss development of hydraulic fish passage criteria including depth, velocity and resting area requirements.

Attempts to accurately design and implement facilitative structures provide an array of unforeseen challenges. Of primary importance are deviations between modeled versus constructed flow and sediment transport characteristics. These deviations may stem from the assumptions associated with one-dimensional hydraulic and transport computations. One-dimensional hydraulic and transport models ignore components of shear stress that act vertically and/or lateral to the longitudinal flow direction and may have a profound effect on the stability of the prescribed structure. Additional sources of deviation between modeled and constructed conditions may include the use of non-calibrated Manning's  $n$  values. Much of the data that exists with respect to Manning's  $n$  applies to a broader scale reach level assessment and may not apply to the finer scale feature level assessment. This is of major importance when designing for fish passage at low flow conditions. The final source of deviation between the modeled proposed conditions and constructed conditions is associated with the assumed level of conformance of construction with design. Oftentimes construction contractors will modify designed sequences of construction and other methodology to achieve goals associated with schedule and budget concerns. These deviations, though more practical from a constructability perspective, may compromise the intent of the design.

Throughout this topic, the author will focus on the appropriate values with which to weigh modeling in the design process, the details of modeled and actual conditions, and how to correct and avoid such discrepancies.

Keywords: *stream, mitigation, fish passage, design*

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*About the speaker:*

**Josh Gilman** has worked over three years as a stream restoration designer/engineer for KCI. Prior to working at KCI, Josh received his Bachelor of Civil Engineering and Certificate in Land Development from the Georgia Institute of Technology. Josh later was involved in stream research in Northern Arizona University, where he worked toward a Master of Science in Forestry, specializing in forest hydrology. Josh is currently enrolled at Johns Hopkins University as a candidate for Master of Environmental Engineering.

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# CONSTRUCTING ROCK WEIR FISHWAYS: THE SUBTLE HYDRAULIC DYNAMICS (HOW TO MAKE SURE YOUR FISH DON'T GET FLUSHED.)

Eric Karch\*, Rachel Shea\*, and Dennis McMonigle

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This case study presents the use of a series of rectangular broad-crested rock weirs that provide fish passage by ensuring “surface wave flow” hydraulics in addition to designing for the immediately apparent biological factors of velocity and depth of flow. Engineers and biologists must account for flow type to ensure high passage efficiency due to its direct relationship to the location of recirculation zones and turbulence immediately downstream of the structure. Subtle variations in structure dimensions create a hydraulic jump, plunging jet, or surface jet that are each ineffective for fish passage. Field application confirms previous flume studies showing that tailwater depth and relative weir crest length are the most important factors in achieving the surface wave flow type. The current study area is Sawmill Creek in urban Anne Arundel County Maryland, targeted by county initiatives to open 3.5 miles to free movement of resident fish populations through various urban obstacles. Two points of impass include a degraded culvert & concrete swale junction and an exposed concrete-encased sewer crossing.

Each point of impass is fitted with a low-maintenance natural-channel fish passage structure composed of large boulders that will backwater baseflow over the impass in a stepwise fashion, according to the necessary biological and geometric requirements identified for resident fish. Design of the baseflow weir is found to be most hydraulically similar to a rectangular broad-crested weir. This in-stream structure also accounts for geomorphically stable storm flow hydraulics with respect to the readily mobile gravel bed and floodplain access, without significantly increasing the floodplain onto adjacent residential private property.

Keywords: *fish passage, surface wave flow, weir, natural channel*

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## *About the speaker:*

**Eric Karch** is an M.S. graduate of Virginia Tech and Rachel Shea is an M.S. graduate of Johns Hopkins University. Both speakers live and work in Maryland and frequently design projects for the Anne Arundel County Department of Public Works and other Maryland municipalities. Under the direction of Mrs. Shea, GPI has successfully designed and completed construction of several stream restoration projects over the past seven years. The Department of Natural Resources lent vast expertise to provide biological specifications and perform monitoring for the sites in this case study.

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## FROM RHETORIC TO RESTORATION: A CASE STUDY IN JUMPING HURDLES

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The goal of translating words into action can be an arduous task. As Abigail Adams once said in a letter to her husband, John, “we have too many high sounding words, and too few actions that correspond with them.” Many watershed plans incorporate many “high sounding words”, however, far too often these words remain silent without the force of action behind them. This document will discuss one example of a community, Reston, Virginia, who has successfully progressed from plan to action.

Reston, home to the second largest planned community in the country, was established over 35 years ago. Located in suburban Washington, D.C., Reston has experienced an explosion of urbanization along with the rest of the region, growing to a total population of approximately 62,000. Reston has grown, and so have the problems associated with increased urbanization. These problems include severe channel erosion, high rates of sediment deposition in lakes, and a decrease in overall water quality; all of which directly affect the biological health of water bodies in the area. Since Reston is located at the headwaters of two major stream systems that empty into the Potomac River (Difficult Run and Sugarland Run), these effects are especially crucial.

With a total area of approximately 12 square miles, Reston is home to over 19 miles of perennial streams, 130 acres of lakes and ponds, and over 1000 acres of stream buffer zones and natural habitat areas. To protect these natural resources, Reston Association (RA), the local homeowners’ association, performed a watershed assessment and management plan in 2001. This plan assessed the physical and biological conditions of over 1/3 of the streams in Reston.

To ensure that study would lead to action, a major goal of the plan was to identify the most impaired stream reaches, which were considered areas of immediate action. Specific proposed projects were identified in these areas, including conceptual designs with corresponding cost estimates. The first project identified in the watershed plan is Upper Snakeden Branch, located in the headwaters of Difficult Run. This restoration effort focused on reconnecting Upper Snakeden Branch with its floodplain as well as reconfiguring the stream geometry to reduce bank erosion (a major source of sediment in downstream lakes) and improve benthic habitat. Instream rock structures such as rock and cross vanes, and imbricated rock walls were employed, as well as more “natural” solutions, such as the use of log vanes and coir biologs. Along with these structures, a comprehensive planting plan and schedule was developed.

Simply identifying the best location for a project was only a start. To effectively translate plan to action, RA had to face issues of funding, permitting, plan review, favorable public will, adjacent homeowner acceptance, and many, many other issues. Also, RA had to coordinate with two other

entities who also were directly involved with restoration efforts in the same reach of stream. Since this was the first project of its kind done within Reston, much was learned about the process of going from plan to action.

Keywords: *watershed plan, stream restoration, stream mitigation*

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*About the speaker:*

**Seth Brown** is received his BS in civil engineering in 1995 from Christian Brothers University in Memphis, Tennessee, and he received his MS in civil engineering from the University of Maryland at College Park in 1999. His thesis focused on stream geometry change due to the influence of urbanization. Mr. Brown is a registered professional engineer in the state of Maryland, and has worked in the consulting industry for over 6 years, focusing on stream restoration design, hydraulic and hydrologic modeling, watershed planing, GIS analysis, and adult education in technical subjects including erosion and sediment control. Mr. Brown currently works for GKY & Associates located in the Northern Virginia region of Washington, D.C.

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# A FUNCTIONAL WATERSHED ASSESSMENT AND PLANNING PROTOCOL TO TARGET STREAM RESTORATION

Jason Doll, Project Manager

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Tetra Tech has developed and applied a protocol for functional assessment of watershed conditions to support targeting of mitigation funds by the North Carolina Ecosystem Enhancement Program (NCEEP) toward projects that will provide the most benefit to the watershed. NCEEP is a non-regulatory program established by the North Carolina General Assembly in 1996 charged with directing mitigation funding to restoration and preservation projects statewide to satisfy Clean Water Act Section 401/404 mitigation requirements for stream and wetland impacts. NCEEP has sought to integrate mitigation projects into comprehensive local watershed assessment and planning to increase the ecological effectiveness of wetland, stream, and riparian corridor restoration projects. Working with NCEEP staff and teams of local stakeholders, Tetra Tech is conducting technical assessments and providing local watershed planning support in several targeted 14-digit hydrologic units, ranging from approximately 10 to 60 square miles in size, in the Upper Cape Fear River Basin. The initial scoping phase of the protocol involves characterization of the watersheds and development of a conceptual understanding of the key stressors that are degrading or have the potential to degrade existing and future watershed hydrology, water quality, and habitat functions. The scoping phase integrates analysis of existing data with visual field assessment and stakeholder (including resource agency experts) input to hypothesize the links between impacts, stressors, and their sources. A detailed assessment phase is then performed to validate or reject those hypothesized links. Additional data are collected as needed, and as resources allow, to conduct assessments of indicators established for each stressor source and management objective. Results are compared to evaluation criteria to determine the relative level of risk posed to watershed functions. Under a final targeting phase, results are then integrated across the indicators to target high-risk degraded areas for restoration and sensitive areas with the least disturbed conditions for preservation. In addition, those subwatersheds found to have the greatest risk for future degradation are targeted for the development of management and protection measures to prevent functional losses. Also under the final phase, management opportunities for the targeted areas are identified and evaluated, and recommendations are documented in a local watershed management plan. This presentation will provide an overview of the protocol and real-world examples from applications of the protocol to several urbanizing watersheds in the Upper Cape Fear River Basin. The examples include cutting edge use of GIS, stream survey data, predictive modeling, geomorphological analysis, and statistical analysis. Emphasis is placed on urban issues including streambank stability, habitat condition, and flooding potential. Targeted areas will be presented along with example evaluations of management opportunities and decisions for the studied hydrologic units.

Keywords: *watershed, assessment, functions, indicators, stressors, restoration, protection, preservation*

*About the speaker:*

**Jason Doll** graduated from N.C. State University in 1987 with a B.S. in Fisheries and Wildlife Science. Mr. Doll has 11 years experience as an environmental scientist and GIS analyst specializing in watershed planning, water quality modeling and spatial data analysis, six years as a Water Quality Modeler with the N.C. Division of Water Quality and five years in private consulting with Tetra Tech. Since joining Tetra Tech, he has managed several local watershed planning projects integrating stream corridor and wetland restoration with other NPS management strategies in a watershed planning framework to build a comprehensive strategy to improve and protect watershed functions.

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## WATER QUALITY RESPONSE TO RIPARIAN RESTORATION IN TWO VERMONT AGRICULTURAL WATERSHEDS

Donald W. Meals

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Achievement of management goals for Lake Champlain (Vermont/New York, USA and Quebec, Canada) will require significant reductions of phosphorus (P) loads from agriculture, the dominant nonpoint source (nps) in the Basin. Furthermore, many Vermont streams fail to meet bacteriological water quality criteria due to agricultural nps pollution. Cost-effective nps reduction strategies must be based on reliable treatment techniques beyond the basic erosion control and animal waste storage practices promoted in the past.

*The Lake Champlain Basin Agricultural Watersheds National Monitoring Program (NMP) Project* evaluated the effectiveness of low-cost livestock exclusion, streambank protection, and riparian restoration practices in reducing concentrations and loads of nps pollutants from grazing land at the watershed level. Two treatment and one control watershed in northwestern Vermont were monitored from 1994 through 2000 in a paired-watershed design. Monitoring included stream discharge recording, flow-proportional sampling for nutrients and suspended solids, intensive grab sampling for indicator bacteria, assessments of macroinvertebrate and fish communities, and tracking of land use and agricultural management in the watersheds. The project was one of twenty-three special nps control projects in the National Monitoring Program (NMP), funded in part by the U.S. EPA under Section 319 of the Clean Water Act

Strong statistical calibration between the control and treatment watersheds was achieved. Treatment (riparian fencing, alternative water supplies, protected stream crossings, and streambank bioengineering) was completed in 1997 at a cost of ~\$40,000. Landowner participation in land treatment was entirely voluntary and all treatments were 100% cost-shared by the project and cooperators. The paired-watershed design was effective in controlling for the influence of extreme variations in precipitation and streamflow over seven years of monitoring. Post-treatment data documented significant reductions in nutrient and suspended solids concentrations and loads (~20-50%) and bacteria counts (~40-60%) from both treated watersheds. Riparian zone treatments had a positive effect on stream biota, although community composition continued to indicate impacts of moderate organic enrichment. Two years of improvements in both water quality and stream biota in one treated watershed were reversed in the final project year due to catastrophic pollutant loading from farm mismanagement upstream, demonstrating the potential for a single acute problem to offset management improvements elsewhere in the watershed

The strong response occurred even though treatment was applied to less than 10% of total watershed stream length and less than 50% of watershed grazing land. The specific mechanisms responsible for the observed pollutant removal were probably related to reduction of direct deposit of nutrients, bacteria, and organic matter from livestock in or near the stream and to reduction of streambank erosion. The performance of the riparian zones as “vegetated filter strips,” was probably of lesser importance because no attempt was made to promote sheet flow or prevent concentrated overland flow through the protected riparian zones.

The project clearly demonstrated the potential for inexpensive livestock exclusion and riparian zone restoration to reduce nps pollution from grazing lands.

Keywords: *bacteria, livestock exclusion, nonpoint source pollution, paired-watershed, phosphorus, riparian zone, Vermont*

*About the speaker:*

**Don Meals** has degrees in biology and natural resources from Dartmouth College and the University of Vermont. He has worked for more than 25 years in the field of agricultural nonpoint source pollution, focusing on evaluating the effectiveness of individual BMPs at the edge of field scale and assessing BMP programs at the watershed level. He has extensive experience in water quality monitoring and evaluation and has worked on large-scale agricultural watershed programs for USDA and EPA. Don is currently principal of Ice.Nine Environmental Consulting, working on watershed phosphorus modeling and research into methods to reduce pathogen losses in agricultural runoff.

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## DEVELOPMENT OF STREAM RESTORATION MITIGATION CREDITS USING A WATERSHED APPROACH

Mary Kay Murray<sup>1</sup>, William A. Kreutzberger<sup>2</sup>

*CH2M HILL, Charlotte, NC*

The Edward's Branch Watershed Improvement Project represents an effort to address water quality and quantity issues with a comprehensive watershed management approach. Charlotte Storm Water Services (CSWS) will receive approximately 11,600 linear feet of compensatory stream restoration credit for the watershed approach. This is almost twice the credit that would have been received for the implementation of the stream restoration and preservation components of the watershed enhancements (6,100 linear feet). The City of Charlotte intends to utilize a mitigation bank to manage the compensatory mitigation credit associated with this project.

The Edwards Branch Watershed Improvement Project will implement water quantity controls and water quality improvements plus extensive habitat improvements through stream restoration in an effort to enhance water quality and restore streams in a small (less than 1 square mile) urbanized watershed draining to Edwards Branch in the Briar Creek portion of the Little Sugar Creek basin in Charlotte, North Carolina. The project components include: wet detention ponds, extended dry detention, riparian buffers, treatment wetlands, grass swale/level spreader, stream restoration, and stream/buffer preservation.

Edwards Branch watershed is located in the Catawba River Basin, in Mecklenburg County and the City of Charlotte. It is a highly urbanized watershed including single and multi-family residential, commercial, and industrial land uses along with public parks, a cemetery, public and private schools, and churches. The stream experiences significant flooding due to the highly developed nature of the watershed, severe stream bank erosion/channel sloughing, and prior channelization. Aquatic habitat is severely degraded, biological conditions are rated as poor, very poor, and this portion of the Briar creek watershed is considered impaired by the Division of Water Quality [2002 303(d) list]. A local watershed planning (LWP) study conducted for the NC Wetlands restoration program identified degraded habitat and sediment as the major causes of impairment.

A total of 11 specific projects have been identified in the watershed for the purpose of restoring water quality and biological integrity of the system. CSWS has worked closely with regulatory agencies through a Mitigation Banking Review Team (MBRT) to obtain credit for all watershed improvement projects including stream restoration/preservation and stormwater best management practices. BMP receive credit for length of stream that they influence within the watershed at ratios ranging from 1:1 to 5:1. This presentation will review the history of the watershed improvement project and the process used to develop the credit scheme. The cost of the BMP projects and credit received will also be compared to the cost of credit received directly from urban stream restoration projects.

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## DESIGN IMPROVEMENTS OF MEANDER BEND PROTECTION USING ROOT WADS

William A. Harman, PG

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Root wads are a common technique for providing bank stability and aquatic habitat in natural channel designs. Root wads are the root mass of a tree, usually hardwoods, along with ten to fifteen feet of attached trunk. The root wads are inserted into the streambank alone or in combination to provide a structural barrier between the stream flow and the stream bank. They are placed around the outside of the meander bend where velocity and shear stress are highest.

Over the past ten years, root wads have been used in natural channel designs with varying degrees of success. The biggest problems have been erosion downstream of the last root wad, especially near the end of the bend, and erosion of the stream bank above the root wad. The later case is especially prevalent in channels with sandy soils and high banks. In all cases, root wad failure is most prevalent in the first year after construction and before permanent vegetation has become established. In cases where root wads have worked successfully, exceptional habitats have been observed, including: deep pools, cover for fish, and accumulations of organics and woody debris. For these habitat reasons, efforts have been made to improve the stability component of the root wad design.

The purpose of this paper is to provide proven design improvements for incorporating root wads into natural channel designs for dual purposes of stability and habitat creation. These design improvements include several modifications to traditional approaches. These modified techniques include: 1) Root Wad Clusters with Transplants, 2) Root Wad Clusters with Brush Layers/Mattresses, and 3) Root Wad Clusters with Coir Fiber Matting and Berms. A detailed description of each technique along with cases studies and evaluation data will be presented.

Additionally, comparisons between root wad bends and other techniques such as rock vanes/J-hooks will be provided. Preliminary monitoring data show that root wad bends have several benefits over vane bends in gravel and sand bed streams with drainage areas less than five square miles. These benefits include: deeper pools, larger pools (volume), improved aquatic habitat, and equal or better stability. By incorporating these new techniques into root wad designs, stream restoration projects can achieve higher biological function while maintaining bank stability.

*Keywords: root wads, rock vanes, J-hook vanes, bank stability, pool habitat*

*About the speaker:*

**Mr. Harman** is the founder and Vice President of Buck Engineering. Buck Engineering is a 50 person firm that specializes in stream and wetland restoration throughout the eastern U.S. Mr. Harman holds a bachelors degree and masters degree in geography and is a licensed geologist in North Carolina.

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# THE MORPHOLOGICAL INFLUENCE OF ISOLATED ROCK RAMP CONSTRUCTION ON STREAM CHANNELS

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The ability of gravel bedded streams to establish and maintain riffle-pool sequences are essential to the physical and ecological health of the ecosystem they support. Stream restoration design has focused on restoring stable cross-sectional, profile and plan form geometry to create and maintain riffle-pool spacing and sequencing, often disregarding the effect of bed resistance on channel morphology. This presentation discusses the application of riffle grade control/rock ramp structures to several restored stream channels and the effect of the structures on adjacent channel morphology. Rock ramp structures are defined as stone structures installed within the bed of a stream channel intended to emulate the physical attributes of natural riffles within a stream system. These structures can be designed to function simply as grade control structures such as in White Marsh Run in Baltimore County, MD or nature-like fishways such as the rock ramps constructed in the Northwest Branch of the Anacostia River in Hyattsville, MD. This presentation compares the predicted and actual (short-term within 2 years of construction) impacts of these structures on adjacent channel morphology. The effects of these structures on improving flow diversity may indicate the ability of rock ramp structures to stabilize and mimic natural riffle-pool sequences in urban stream systems, while allowing for the migration of native and anadromous fish species. The processes that perform the maintenance of the features are a deeply researched topic in the geomorphic and hydraulic sciences. The presentation will also focus on describing the hydraulic properties of the structures and how they relate to channel morphology maintenance theories such as the velocity reversal hypothesis (Keller 1970) and sediment transport discussions through riffle-pool sequences (Carling, 1991). The armoring of riffle features by constructing rock ramps increases the resistance of the bed and further influences the structure of the riffle pool sequences, potentially improving the ecological health and habitat diversity of the effected stream channel.

Keywords: *morphology, riffle grade control structures, rock ramps, stream restoration, natural fish passage*

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*About the speaker:*

**Scott Lowe** is an Associate and Environmental Scientist for the Environmental Design and Construction Management Division of KCI Technologies, Inc. in Hunt Valley, Maryland. In his eight years of environmental research, construction and consulting work he has contributed to twelve stream restoration projects totaling over 35,000 linear feet. He recently served as the principal designer for the SR 220 project in Centre County, PA restoring over 21,000 linear feet of channel in the North Bald Eagle Creek watershed. Scott now is serving as the Design Specialist for the Woodrow Wilson Bridge Fish Passage Improvements Project addressing 21 blockages in the Washington Metro Area, which is currently under construction.

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## STREAM CHANNEL RESTORATION AT BRIDGE SITES

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There is a growing amount of work and research in the stream restoration area, but relatively little has been done with regard to restoration at bridge sites. The complex flow patterns, high velocities and scour potential make stream restoration at bridge sites more challenging. Stream channel stability and habitat maintenance at bridge crossings are important, and restoration of channel geometry and habitat is a growing need in Georgia, as well as other southeastern states.

At many bridge sites in Georgia there is an occurrence, channel widening or blowouts, which has affected the mussel habitat according to aquatic biologists. These over-widened channels are the result of live-bed and clear-water contraction scour. Pier scour and debris accumulation increase the problem in many cases. Application of stream restoration techniques in combination with hydraulic modeling, sediment transport computations and pre- and post project monitoring will be utilized at selected bridge sites with the goal of restoring channel geometry and mussel habitats in South Georgia streams. The restored channel geometry may also allow shorter bridge channel spans where the bridges are replaced, providing some economy in these cases.

Previous papers published in the area of stream restoration at bridges include “Stream Restoration in the vicinity of bridges” by Johnson, Hey, Brown and Rosgen. That paper describes the use of how vanes, cross vanes and w-weirs “may provide adequate flow transition at bridges”. The use of these structures as well as others such as permeable spurs and Longitudinal Peaked Stone Toe Protection (LPSTP) applications will be modeled, constructed and monitored. The modeling will include sediment transport computations, as previously noted, along with 1-D and 2-D hydraulic models to evaluate the placement and predict the performance of these structures.

It is important to understand and change the conditions that caused the severe contraction scour. It is also important to develop methods for quickly and effectively restoring the channels.

*About the speakers:*

**Mr. Robbie Frizzell**, P.E. in Georgia and South Carolina, is a Senior Engineer and Member, ASCE, with over 15 years of hydraulic modeling and design experience, having been responsible for the bridge hydraulic design, scour analysis and stream stability evaluation of over 150 sites in Georgia. BCE/Georgia Institute of Technology, 1984.

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**FEMA, FLOOD HAZZARD MITIGATION AND THE ELUSIVE  
“NO-RISE” CERTIFICATION  
MECKLENBURG COUNTY’S FLOODPLAIN ORDINANCE AND FIRM’S**

Andrew A. Burg, PE, RLS

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Floodplain management is a delicate balance of hazard mitigation and environmental stewardship. While most restoration practitioners are mainly interested in leaving the world in a bit better shape than they received it, we must realize that the built environment, for better or worse, and created by man must be considered in the restoration design.

Among other things, our built environment includes such constraints as utilities, property lines, conflicting laws, various “rights” and other physical infrastructure. This presentation explains the impacts that a restoration project must consider and mitigate against on properties in the floodplain, structures on those properties and public safety.

Mecklenburg County has jurisdictional responsibility for the FEMA-regulated floodplains (those streams draining more than one square mile of drainage area) and administers both the local floodplain ordinance and NFIP regulations promulgated under the Code of Federal Regulations (44-CFR, 59-78). Any number of floodplain activities can trigger one or the other or both. Some floodplain activities trigger additional rules such as zoning hearings and building variances.

Additionally, there exist two sets of regulatory criteria within one set of Flood Insurance Rate Maps (FIRM’s). Charlotte and Mecklenburg County regulate to the ultimate “build-out” condition for all “development” activities in the floodplain, while FEMA regulates only to the existing condition for flood insurance purposes.

This presentation provides an overview of permitting requirements in Charlotte and Mecklenburg County, which are very atypical from the rest of the country. Furthermore, it explains the need for a thorough hydraulic analysis and a thorough on-site investigation to ground-truth existing field conditions. The need for a professional engineer becomes evident when one considers that a typical stream restoration project may not only change a stream’s geometric cross section, it will more than likely change the water surface elevation (100-year or other event), it will probably also affect the stream’s length (and stationing) and it will most likely alter the width of the floodway and floodplain. This maze of regulation must be navigated just as skillfully as the federal 404 and state 401 programs. Proper planning at the front end by a skilled project manager can provide a balanced project that meets all of the regulatory requirements while leaving the world a little nicer place.

Keywords: *FEMA, FIRM, NFIP, no-rise, flood, hazard, mitigation, floodplain*

*About the speaker:*

**Mr. Burg** currently works as a project engineer for his own firm and was formerly with Mecklenburg County Storm Water Services, a division of the Water and Land Resources Division of the Land Use and Environmental Services Agency. As a water resources engineer, flood control and environmental restoration efforts come together under his direction in the form of stream and wetland restoration projects. Having re-engineered his career during the last several years, Mr. Burg, has integrated his civil engineering skills with “green” techniques to construct “living, breathing, evolving” projects

rather those of his past training. Rather than working with architects, planners and other “traditional” allies, he now finds himself working with geomorphologists, biologists, fisheries experts, botanists, floodplain managers and a host of other disciplines as a “project developer” to bring restoration concepts to life.

Mr. Burg is a licensed civil engineer in six states and a licensed land surveyor in California. He received his undergraduate degree in civil engineering from Lehigh University in Bethlehem, Pennsylvania in 1981. After graduation, he became a staff engineer for the Los Angeles County Department of Public Works in the mountain road design section. Mr. Burg also spent some time as a field engineer constructing high rise structures before working as a consultant in Southern California and Florida, designing both subdivisions and various municipal projects until 1993. Since 1994, Mr. Burg and his wife reside in Charlotte, North Carolina.

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## RESTORATION BASED ON A WATERSHED APPROACH

Callie Dobson

*Hiwassee River Watershed Coalition, Murphy, NC.*

Individual stream stabilization or restoration projects can effectively stop bank erosion and improve instream and riparian habitat in a localized area. However, evaluating an entire watershed prior to beginning stream restoration work can help prioritize localized problems such that an entire watershed might be restored. The Hiwassee River Watershed Coalition (Coalition) conducts stream restoration work based on a watershed approach. In 1999, the Coalition received a \$2,100,000 4-year grant for restoration work in the Brasstown Creek watershed. At the grants completion on December 31, 2003, 12 stream restoration projects involving nearly 30,000 linear feet of stream had been completed. In addition, seven critical bare area projects restored more than 160 acres of eroding pastureland and 42 acres of riparian buffer were established and protected.

Natural channel design principles and bioengineering are the basis for all Coalition restoration projects. Although the vast majority of projects are classified as stabilization, four of the projects (12,000 linear feet) involved significant restoration to correct severe (historic) channelization problems. Although very little water quality monitoring was conducted in the watershed before restoration activities began, sites were prioritized and chosen so as to achieve the maximum benefit to the entire watershed.

In the Little Brasstown Creek watershed, about 75% of the stream's total length was impacted and streambank erosion was particularly severe. To date, the Coalition has restored the stream's natural channel and riparian vegetation to 38% (7,895 feet) of the stream's entire length (20,703.4 feet). In 2004, the Coalition received additional funding to complete two more projects in this small watershed bringing the total to 54% (11,165 feet).

In 2002, the Coalition also began to focus on restoration of the Valley River watershed. This time, the Coalition collected extensive biological and habitat data prior to beginning restoration work. Two projects are currently in various stages of construction; one stabilization project is on the Valley River mainstem and one restoration project involves a 1,000-foot reach of Town Branch in the Town of Andrews. The whole watershed is being evaluated and sites are again being prioritized based on benefit of restoration to the entire watershed.

The Coalition works closely with local agency personnel of the Natural Resources Conservation Service as well as local Soil & Water Conservation District staff. These professionals have already established good relationships with local landowners. By getting their buy-in on projects, the Coalition makes strong headway more quickly when an area is targeted for restoration. Strong partnerships are essential for successful watershed restoration and long-term protection of water quality.

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## SLIGO CREEK – FIFTEEN YEARS LATER

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Sligo Creek is a highly impervious (30%) 8.6 square mile urbanized watershed located in southern Montgomery County, Maryland. It is a tributary of the Potomac River, via Northwest Branch and the Anacostia River. The Sligo Creek watershed was largely developed before stormwater controls were implemented. In the 1980's Sligo Creek was identified as the most seriously degraded stream in Montgomery County.

Sligo Creek suffers from many urban runoff related problems, including poor water quality, severe stream channel erosion, bank instability, and degraded fish and benthic communities. The watershed is characterized by high-density commercial and residential areas, and much of the natural stream system was piped during development of the last 70 years.

In 1989, the Montgomery County Department of Environmental Protection, the Maryland-National Capital Park and Planning Commission and other agencies started construction of restoration projects to improve stormwater management controls and restore aquatic habitat. Over the past 15 years, two older stormwater management ponds were retrofitted to state of the art technology and four new stormwater management ponds were constructed, which provide improved stormwater controls to over two square miles of the watershed. In addition, erosion repair and aquatic habitat restoration was performed on over four miles of stream channel.

In 1988, before restoration work began, there were only two native fish species (plus goldfish) found in Sligo Creek and its tributaries. The presence of blockages to upstream fish movement prevented fish from recolonising the creek after water quality and habitat conditions had improved. After the completion of the first stormwater management pond retrofit and the first phase of stream restoration, in 1991, fish were collected from Northwest Branch, the stream into which Sligo Creek flows, and stocked into Sligo Creek. As other projects were completed, additional areas of Sligo Creek were restocked with native fish species. As a result of these efforts, several have established breeding populations, and there are currently eleven species that appear to have stable populations. Since both water quality and habitat quality have continued to improve since the initial stockings, the stocking of additional species is planned for 2004.

It has taken 15 years and over \$2.5 million to improve conditions in Sligo Creek. This presentation discusses the planning of the restoration, watershed improvements implemented, and the biological responses to those improvements.

Sligo Creek served as the pilot watershed for a restoration program that is now countywide. Biological monitoring was conducted in all streams in Montgomery County. The results of this monitoring, when compared to reference conditions, were used to categorize the biological conditions of the streams. The biological data was a significant factor used in setting watershed priorities through the Countywide Stream Protection Strategy. Watershed studies identify and prioritise specific watershed restoration projects. Areas that are scheduled for restoration are subjected to biological monitoring before and after construction, and when necessary native species are reintroduced into restored areas.

Keywords: *Stormwater management, stream restoration, native fish species*

*About the speakers:*

**Doug Redmond** is a Principal Natural Resources Specialist/Aquatic Ecologist with the Maryland-National Capital Park and Planning Commission's Park Planning and Resource Analysis Unit. He has a Master of Science degree in Marine, Estuarine, and Environmental Sciences from the University of Maryland at College Park.

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## **GWYNNS FALLS WATER QUALITY MANAGEMENT PLAN: A CASE STUDY IN STREAM ASSESSMENT**

Kelly Brennan, P.E.<sup>1\*</sup> and Chin Lien, P.E.<sup>2</sup>

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Parsons Brinckerhoff (PB) lead a team of water resource engineers and environmental scientists to develop a comprehensive water quality management plan for the Gwynns Falls Watershed. The headwaters of the Gwynns Falls begin in Baltimore County and drains through Baltimore City, into the Middle Branch of the Patapsco River and ultimately into the Chesapeake Bay. This project was a joint effort between Baltimore County Department of Environmental Protection and Resource Management (DEPRM) and Baltimore City Department of Public Works (DPW) as a first inter-jurisdictional, regional cooperative restoration effort and initiative. The goals of the water quality management plan were:

1. Identify and evaluate non-point source stormwater pollution and stream degradation,
2. Determine management measures for the reduction of nonpoint source pollution and reestablishment of stream stability, and
3. Provide a watershed restoration framework for Baltimore City and Baltimore County.

While the water quality management plan had many individual components, one of the major components of the study was the stream assessment. The team assessed more than 133 miles of stream within the watershed. Field crews walked, collected data and photographed every mile of stream in the Gwynns Falls. The streams were divided into approximately 900 individual reaches averaging 750 linear feet each. The large number of reaches and data to be collected presented a unique challenge for the assessment team. A systematic approach was developed and implemented in collecting geomorphic data and subsequent analysis.

Handheld Pocket PC's were used to collect channel morphology, channel disturbance and habitat information for each reach. The use of the Pocket PC's allowed for the standardization of data and saved time by reducing the hours needed to process field data sheets. GIS mapping and Access databases were developed to manage the large quantities of field data. The results of the stream assessment were then used in conjunction with the other study components to make recommendations for improving water quality in the Gwynns Falls.

Keywords: *watershed management plan, stream assessment*

*About the author:*

**Kelly Brennan** is a senior water resource engineer with PB Water in Baltimore. She has worked on several watershed assessment studies in the Baltimore area. Kelly has her B.S. and M.S. degrees from the Pennsylvania State University in Civil Engineering with an emphasis in water resources.

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# **WILMORE WALK**

## **A MULTI-FAMILY LID AND CHARLOTTE STORM WATER PILOT PROJECT**

Christopher J. Estes

*Estes Design Inc., Charlotte NC*

As design professionals continue with reactive efforts to restore our streams and rivers, development continues to accelerate their degradation. Now, with an increased understanding of the affects of urbanization on our streams, we are able to begin pro-active efforts to preserve these resources through development policy and innovative planning and development tools. This presentation discusses an example of a Low Impact Development design in down town Charlotte that significantly reduces storm water impacts to receiving waters. The low impact design was retrofitted to an existing traditional site design by implementing a few minor revisions in the grading plan while maintaining the original site layout. This project is the first of it's kind in Charlotte and was achieved with minimal compromise in dwelling units and landscaping.

Wilmore Walk is an urban redevelopment project designed for multi-family use. A portion of the property was previously developed as an apartment complex prior to 1987. The plan consists of demolishing the existing apartment building and incorporating the property into the overall design. The storm water run-off from 93% of the new proposed on-site impervious area is treated by bio-retention and pervious concrete. Additional offsite drainage is also treated making the total drainage area treated or infiltrated equal to 98% of the proposed impervious surfaces. The design consists of eight bio-retention areas and 0.14 acres of permeable concrete. The bio-retention areas are designed to blend into the landscape and pose as natural planting beds. All of the bio-retention areas accept and treat a minimum of one inch of runoff from their respective drainage areas. The pervious concrete area serves as a parking area while retaining and infiltrating the two-year storm for it's respective drainage area. The paving design consists of 6241 square feet of pervious concrete formed on a gravel base with an underlying sub-grade of sandy clay. The total cost of the projects BMPS compared favourably to traditional site design that include typical landscaped areas, parking and storm water infrastructure.

Keywords: *LID, storm water, bio-retention, permeable concrete, infiltration, development, BMP*

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*About the speaker:*

**Christopher J. Estes** is president of Estes Design Inc. an environmental design and consulting company that specializes in LID design, stream & wetland restoration and regulatory services. Mr. Estes received a B.A. in Landscape Architecture from the School of Environmental Design at the University of Georgia in 1988. Before starting Estes Design Inc. Mr. Estes worked for the City of Charlotte Engineering Department for eleven years where he initiated and managed Charlotte's

stream restoration and bioengineering program for 8 years with over 60 stream projects and 15,000 feet of urban stream enhancement & restoration. Certifications and training include; Registered Landscape Architect, N.C. & S.C., Soil Bioengineering for Stream Banks, Rutgers University, 1993 Level IV Rosgen Training, Pagosa Springs, CO 1997, USACE Wetland Delineation Certification, Waterloo Stream Course, Ontario, Canada 2000 N.C. Aquatic Insect Collection Protocols for Stream Mitigation and Restoration, 2001, Trout Water Reclamation, Danish Ministry of the Environment, Denmark 2002.

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## CASE STUDIES AND LESSONS LEARNED IN THE RESTORATION OF SAND BED CHANNELS

Kevin Tweedy

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Many of the natural channel design methodologies which are commonly used for stream restoration projects were developed from studies and projects performed on gravel bed streams. When the same methodologies are applied to sand bed channels without proper consideration for the inherent differences between gravel and sand bed systems, the end result has often been an unstable stream system, or a system which lacks appropriate instream habitat.

This presentation will focus on the differences in gravel and sand bed systems which must be considered from a natural channel design standpoint. Points of discussion will include sediment transport, instream habitats, selection of structures, grade control, and flow regimes. Case study examples will focus primarily on the Westbrook Lowgrounds and Marston Stream Restoration Projects in the Coastal Plain of North Carolina, however, specific examples from other on-the-ground projects will be incorporated.

The Westbrook Lowgrounds Wetland and Stream Mitigation Project involved the restoration of approximately 60 acres of wetland and 5,500 feet of sand bed stream channel in Johnston County. Construction was completed in March 2003. The Marston Wetland and Stream Restoration Project included the restoration of approximately 38 acres of wetlands and 6,300 feet of sand bed stream channel in Jones County. Construction was completed in February 2004. Monitoring data from both projects will be presented.

*Keywords: wetland restoration, stream restoration, sand bed channels*

*About the speaker:*

**Mr. Tweedy** is a Water Resources Engineer for Buck Engineering. He has seven years experience specializing in the restoration of stream and wetland systems. He has a BS degree from Virginia Tech in Agricultural Engineering, and a MS degree from NC State University, also in Agricultural Engineering.

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## Evaluation of Stream and Riparian Wetlands Restoration in Chowan River Basin

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Previous studies have documented wetlands and riparian vegetation to be effective in reducing nonpoint source pollution leaving developed areas from entering surface water streams. A monitoring study was undertaken to evaluate the effect of a stream and riparian wetland restoration and creation project. The construction portion of the project was funded by the Clean Water Management Trust Fund and granted to Chowan County to restore a portion of the regional airport stream system that was channelized some sixty years ago. In addition to restoring a 1000' reach of the lower floodplain, constructed wetland cells and a 1000' stream reach were created to pre-treat runoff prior to it being discharged to the Albemarle Sound. The monitoring portion of the study was funded by 319(h) non point source grant obtained by North Carolina State.

Water quality treatment effectiveness of the three wetland systems (pre-treatment wetland cells, constructed stream/riparian floodplain, and restored stream/riparian floodplain) were monitored and evaluated based on flow measurements and chemical analyses of flow samples. Stream samples were analyzed for TKN, ammonium-N, nitrate-N, total-P, ortho-P, and sediment.

Both total nitrogen and total phosphorus concentrations were observed to decrease thru the created stream reach. It is believed that wetland processes are the primarily cause of this water quality improvement. Additionally sediment concentrations were lower at the created stream reach than at upstream sampling locations. It appears that the constructed wetland cell in the downstream extent of the created stream/floodplain reach was effectively reducing both the nutrients and sediment transport.

Keywords: *stream restoration, stormwater, wetlands*

*About the speaker:*

**Mr. Smith** is an Extension Engineer in the Department of Biological and Agricultural Engineering at NCSU. A 1995 graduate of his current employer he currently works in the arena of stormwater quality and environmental restoration.

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## Purlear Creek Stream/Wetland Restoration — A Case Study

Will Wilhelm, P.E.<sup>1\*</sup> and Chad Evenhouse, PWS<sup>1</sup>

*1 Kimley-Horn and Associates, Inc., Raleigh, NC*

The Purlear Creek stream restoration was the focal point of an overall watershed management plan in Wilkes County, North Carolina. Key components of this rural stream restoration project included 14,000 feet of stream/buffer restoration, 4 acres of wetland restoration/enhancement, and agricultural BMPs (watering, fencing, culvert crossings, and low water crossings). The involvement of multiple stakeholders — the landowner, a cattle farmer leasing the property, NRCS, EEP, designers, and contractors — required an extensive coordination effort. This presentation will focus on the “lessons learned” with respect to communication, contractual obligations, and maintaining flexibility during planning/design, construction, and post construction monitoring.

Keywords: *stream/wetland restoration, BMPs*

References: None

*About the speaker:*

As one of Kimley-Horn’s leading water resource engineers, **Will Wilhelm** manages numerous watershed restoration projects such as natural channel designs, stream restorations, and best management practices for water quality and quantity. Mr. Wilhelm has been involved in all aspects of urban and rural watershed projects, including feasibility and planning, permitting, public involvement, modeling, design, and construction management. He received Bachelor of Science degrees in both environmental and civil engineering from North Carolina State University.

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## **Yates Millpond Stream Restoration**

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The Yates Millpond Stream Restoration Project is a collaborative effort between Wake County Parks and Recreation and North Carolina State University (NCSU). Initiated on January 1, 2000 the project is funded by the NC Clean Water Management Trust Fund (CWMTF). The Yates Millpond watershed in southern Wake County is part of the Neuse River Basin and drains into the 42,300-acre Swift Creek watershed in the central Piedmont region of North Carolina. Yates Millpond was constructed around 1754 by the damming of Steep Hill Creek and its tributaries. Recently restored after a dam breach during Hurricane Fran, the millpond has 3,289 acres drainage basin.

The Yates Millpond Stream Restoration Project goal is to restore natural hydrology and forested buffers of degraded stream channels and riparian areas within the Yates Millpond watershed. Specific objectives of the project include:

- Reduce sediment loading to Yates Millpond by reducing the amount of streambank erosion.
- Reduce non-point source pollution to Yates Millpond by creating and/or enhancing buffers along riparian corridors.
- Improve aquatic and riparian habitats.
- Provide environmental education opportunities.
- Provide demonstration sites for stream and riparian area restoration.

### **Tributary 1a Restoration**

#### ***Existing Condition:***

Tributary 1a is a small intermittent stream, which flows primarily through agricultural and forested land owned by NC State University and the NC Department of Agriculture. The stream begins as the discharge from a small private pond, which is not shown on a USGS quadrangle map. Below the pond, the stream is an incised and eroded gully. Bank height ratios decrease and the stream is stable and meanders through a wooded area approximately 1000 feet downstream of the pond. Below the wooded area, the stream passes through a culvert and then through a pasture for approximately 1500 feet. Buffer widths are less than 10 feet on either side of the stream, and the stream transitions from a stable meandering channel with moderate bank stability into a severely eroded gully with unstable and eroding streambanks. The stream then re-enters the woods, where it widens significantly from erosion and has unstable streambanks for a distance of approximately 900 feet. The channel then narrows for a distance of approximately 400 feet before returning to a stable channel with fairly stable streambanks. Approximately 500 feet upstream of its confluence with Steep Hill Creek, the valley slope decreases and Tributary 1a alternates between a braided channel and wetland system.

The incised and unstable sections of stream found within the middle reaches of Tributary 1a were most likely the result of channel straightening and changes in land use. Although there is not documentation, channel straightening was a common practice during the late 1800s and early 1900s. The channel in the pasture area is very linear. Straightening of the channel likely increased the

velocity and shear stress in the channel, beginning the process of downcutting. At the same time, an increase in land clearing and agricultural production would have increased the amount of runoff reaching the stream during storm events, increasing the volume and frequency of storm flows in the channel. The wetland and braided section of the stream near the downstream end were likely formed by aggradation of sediments eroded from the upstream reaches. These sediments have deposited as stream slope and velocities decrease.

### ***Restoration Design:***

Two phases of restoration have been implemented on Tributary 1a. The first Phase included replacement of 750 feet of degraded channel in the pasture area with 1000 feet of a stable meandering channel. In the upper part of the reach, the channel sinuosity was restricted due to the available floodplain width. Therefore, a step-pool channel with several log weirs that serve as grade control was constructed. Floodplain widths and channel sinuosity increased in the lower portion of the reach. Fewer grade control structures were necessary as meander pools provided energy dissipation. Log-vanes were used to protect outside meander bends and to create scour pools. Several log weirs and rock cross-vanes were installed for grade control. A culverted stream crossing was constructed at the downstream end of the Phase I reach, to allow cattle crossing. At discharges above bankfull, flows spread out on the floodplain and flow around the culvert.

For Phase II, 1750 feet of a deep eroding gully were filled in and replaced by 2675 feet of a very sinuous meandering channel, utilizing all the historic wooded floodplain. Numerous boulder cross-vanes, several log sills and a log cross vane were installed in the new meandering channel. Riffle substrate was harvested from the existing stream and incorporated into the newly constructed riffles to rapidly provide habitat. A large boulder drop structure was created at the downstream end of the meandering channel to tie the new channel into the existing channel, which was approximately 2 feet lower. In addition, boulder cross-vane and single arm vane structures to enhance stability and habitat were added to the downstream 375' of stream channel.

### ***Monitoring:***

Morphologic survey monitoring of both the Phase I and Phase II reaches include annual longitudinal profile, cross-section and pebble count surveys. In addition, photopoints are collected quarterly to capture vegetation establishment as well as physical changes in the stream. Ground water levels are monitored for both reaches. Samples are collected weekly from seven manual wells and data is downloaded monthly from only one automated samplers for Phase I. These wells have been collecting data prior to construction. An increase in the groundwater level as a result of the restoration was therefore documented through the Phase I groundwater monitoring. Six new wells were recently installed over three transects throughout the Phase II reach. One wells was installed near the downstream end of the project to extend an existing NCSU research well transect across the new channel and opposing floodplain. This well is being monitored for nutrients in addition to groundwater level. Information from all three Phase II transects will be used to evaluate the movement of water from the buffer across the old channel, that has been filled in, and into the new channel.

### ***Riparian Buffer Enhancement and Invasive Plant Control:***

For Phase I, the former pasture area was planted with several tree species, including sycamore (*Platanus occidentalis*), water oak (*Quercus nigra*), willow oak (*Quercus phellos*), and persimmon (*Diospyros virginiana*) to reestablish a floodplain forest community. On-site native plant materials

were salvaged during construction and transplanted along the channel including giant cane (*Arundinaria gigantea*), elderberry (*Sambucus canadensis*), black cherry (*Prunus serotina*), oaks (*Quercus* spp.) and others. In addition, prolific stands of invasive exotic Chinese privet (*Ligustrum sinense*) have been cut and treated with herbicide to reduce competition on the newly planted native tree community. For Phase II an extensive effort to preserve the existing forest community was implemented. Large specimen trees, including oaks and pines (*Pinus* spp.), were identified in the pre-construction survey and were avoided to the greatest extent possible during the design and construction process. Native floodplain tree species such as sycamore, water oak, willow oak, cherrybark oak (*Quercus falcata* var. *pagodifolia*), and sugarberry (*Celtis laevigata*) were planted along the new channel construction corridor. Extensive livestock stakes of elderberry and silky dogwood (*Cornus amomum*) were installed along the high scour areas of the newly constructed channel, including the outside of meander bends and adjacent to the boulder cross-vane structures. Exotics are extremely prevalent in the Phase II reach. Extensive herbicide treatments have been implemented to control and eradicate Chinese privet at the downstream end of the project. Japanese stilt grass (*Microstegium vimineum*) has become a troublesome invasive plant in all areas where construction occurred. Although no specific treatment is underway currently, this exotic pest will need to be addressed if a healthy riparian buffer is to flourish.

*About the Speaker:*

**Barbara Doll** is water quality specialist for N.C. Sea Grant, which is a federal/state program that promotes the wise use of coastal resources. Based at NC State University, Barbara provides information to the public and local governments about water quality status, research and regulations. Much of Barbara's current work is focused on repairing degraded stream systems and reducing the impacts of stormwater runoff and nonpoint source pollution. With grant funding from both state and federal agencies, she has implemented several stream restoration projects, including a small tributary of Hewlett's Creek on Pine Valley Golf Course in Wilmington and a tributary of Yates Millpond in Raleigh. She is currently spearheading the \$5 million overhaul of a highly degraded urban stream corridor located on the NC State University campus.

Barbara has bachelor's and master's degrees in civil engineering from N.C. State University. Before joining Sea Grant in 1992, she specialized in water resources and surface water quality in consulting work and graduate school.

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# USING FOREST REFERENCE STREAMS TO AID OUR UNDERSTANDING OF NATURAL CHANNEL GEOMORPHOLOGY AND WATER QUALITY

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Forest streams found in protected landscapes in the southeastern United States exhibit some of the most stable channels and best water quality conditions we can reasonably expect to find. Long-term continuous monitoring of such streams can document characteristics over the range of channel forming water-flows, indicating a normal variation in chemical and physical conditions.

Complimentary measurements describing stream channel geomorphology provide a necessary context for interpreting these data. The Rosgen stream channel classification method allows effective characterization, organization, and communication of measurements using channel geomorphology.

Geomorphology, hydraulic geometry, and time-series turbidity measurements are presented for two unique Rosgen stream channel classes found in protected, forested settings in Virginia. Turbidity reference curves and non-linear statistical models expressing turbidity as a function of the fraction of bankfull discharge are presented for each of two Rosgen stream types.

These relationships document a range of conditions describing the natural tendencies of undisturbed forest streams. Classification using the Rosgen method provides appropriate context. Understanding natural variation is essential to informed management decision-making in areas such as BMP implementation, stream and watershed restoration, and TMDL allocation.

Keywords: *reference, monitoring, geomorphology, classification, turbidity*

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## *About the speaker:*

**Samuel Austin** is Forest Hydrologist with the Virginia Department of Forestry. His interests include forest ecosystem dynamics, watersheds, fluvial geomorphology, and programming system dynamics computer models that describe forest, hydrologic and ecosystem processes, and effects of forest management and forest water policy decisions. He received a Bachelor of Science degree in Environmental Management with minors in Economics and Computer Science from Warren Wilson College near Asheville, North Carolina, and a Master of Forestry degree from the Duke University School of the Environment.

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## DEVELOPMENT OF SOUTH CAROLINA RURAL PIEDMONT REGIONAL CURVES FOR THE SC DEPARTMENT OF TRANSPORTATION

Adam V. McIntyre

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Bankfull hydraulic geometry relationships, or regional curves, represent the correlation between stream channel geometric measurements at the bankfull stage and the watershed drainage area. This presentation is for the first regional curve relationships developed using regression analysis for the rural South Carolina Piedmont hydrophysiographic province. Regional curve relationships were created for bankfull cross-sectional area, mean depth, width, and discharge. Eight stream channels at gage sites maintained by the United States Geological Survey (USGS) and two ungaged stream channels were selected based on the following criteria: 10-year minimum of annual peak-flow data; watershed drainage area with less than 10% impervious surface; no record or evidence of impoundments, diversions, or structures that would alter the natural bankfull stage; and no record of significant malfunction of gage or recording apparatus.

Cross-sectional and longitudinal profile surveys from selected gaged and ungaged streams were used to compute channel information. The bankfull return interval for each study reach was estimated using the log-Pearson Type III distribution variables. The return interval of the bankfull discharge for the gaged, rural Piedmont streams ranged from 1.01 to 1.35 years, with a mean of 1.14 years. The coefficients of determination ranged from 0.83 for the relationship of bankfull mean depth versus drainage area to 0.95 for the relationship of cross-sectional area versus drainage area. The addition of more data points to the relationships is recommended to increase the accuracy of the regression equations.

*Keywords: bankfull, regional curve, bankfull hydraulic geometry relationships, log-Pearson Type III distribution*

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## **STREAM REGIME AND RESTORATION CHALLENGES IN URBANIZING AREAS OF THE PIEDMONT OF NORTH CAROLINA**

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Considerable debate continues regarding “regime” morphologic conditions for urban streams in the SE US Piedmont. Do streams in urbanizing areas redefine themselves to accommodate higher dominant discharges, essentially arguing for a Constant Return Interval (CRI) model? Or do the bankfull events merely occur more frequently (a Constant Bankfull Discharge (CBD) model)? Design of restoration projects in urban settings produce dramatically different visions depending on which model one adopts. If the CBD model is adopted and wrong, the restored pattern and dimension will both promote continued instability. If the CRI model is adopted and wrong, an aggradational channel will likely evolve with unstable inner channel lateral bars and meanders.

Background research conducted for urban restoration projects in the metro area near Charlotte, North Carolina, on approximately 12 watersheds ranging from .2 to 30 square miles, indicates that the rural regime curves grossly underestimate bankfull cross section areas and discharges within the Piedmont. For example, a rating curve has been calibrated for a section with bankfull indicators within the Irwin Creek NCEEP restoration area using the nearby Irwin WWTP USGS gage station. The observed bankfull area ( $A_{\text{bkf}}$ ) and discharges ( $Q_{\text{bkf}}$ ) are twice that for a rural watershed of similar size, but the return intervals remain between 1 and 1.5 years. Similar  $A_{\text{bkf}}$  and  $Q_{\text{bkf}}$  results have been obtained for Little Sugar Creek, Little Hope Creek, Caldwell St. Creek, West Reeds Fork, Gar, McMullin, Long, and several un-named tributaries to Paw Creek and the South Fork Catawba River. These include watersheds ranging from 20 to 60% impervious cover. In contrast, watersheds with up to 15% impervious cover have stream dimensions and discharges remaining consistent with rural regime relationships. Overall, the data support a continuum of channel adjustments that occur in response to increases in impervious cover. There is some indication of a threshold or “trigger” level of impervious cover that is needed to induce systemic adjustments near 15%; and a ceiling to these adjustments perhaps near 60% beyond which changes in channel hydraulics are sufficiently buffered by over-bank flow. Enlargement of channel dimension occurs with or without bedrock resistance to incision. Grade control merely influences the direction, but not the extent of accommodations to be made. Antecedent or relic rural morphologic channel features are occasionally left within these enlarged channels in the inner meander bends and yield  $A_{\text{bkf}}$  and discharges  $Q_{\text{bkf}}$  values consistent with pre-urbanized conditions. Also common in the urbanized watershed are channels with adjusted dimensions but antecedent planforms. Channel bends with radii of curvature  $\ll 2$  times bankfull widths are common in these altered watersheds, and are believed to represent a lag between the channel dimension and channel pattern responses to changing storm flow conditions.

Restoration of creek dimensions within fully built out watersheds can be diligently approached if one can identify a well ‘adjusted’ urban reference reach channel within similar natural and urban settings. Few changes in profile should be necessary providing there has been consistent grade control over time. However, pattern characteristics must be scaled by application of the appropriate dimensionless ratios. We advocate W/D consistency in the election of a scaling rule, but only for streams that remain of the same basic morphologic class before and after adjustments. Then meander radii and belt width

can be scaled by the adjustment factor:  $(W_{\text{bkf-rural}})/(W_{\text{bkf-urban}})$ . In this manner the scale invariance for channel factors (e.g. wetted perimeter, slope, sinuosity) in discharge are maintained, and one can then establish the same riffle to pool ratios. Sediment transport dynamics is one area where one cannot always predict the end result. While theoretically a constant W/D ratio and slope would yield increases in the stream median grain size ( $D_{50}$ ), thoroughly, or deeply, weathered soil and rock profiles may not allow for increases. There is some indication that urban streams in the SE US Piedmont have grain size populations biased by the rapid chemical disaggregation of rock to relic mineral grain dimensions, in lieu of the gradual mechanical fracturing and wear of rock into smaller and smaller fragments within the colluvial to alluvial landscapes common to youthful terranes of the western US and colder climatic regimes of the northern US. The primary factor in predicting bed material characteristics is host lithology, then followed by channel hydraulics, or bed shear stresses. To obtain appropriate reference data for channel restoration, it is important to find reference watersheds with geologic formations of comparable weathering histories. Wolman pebble counts or other quantitative attempts to fix a design bed grain size population are fraught with large uncertainties that are not function of the restoration channel hydraulics, per se.

Restoration within watersheds undergoing development to greater extents of impervious cover is the most problematic. These channels are under constant adjustment, and a stable morphologic state can not be predicted until one has some a priori knowledge on the extent of impervious cover at 'build out'. While stream restoration in the urbanizing fringes to the larger metropolitan areas is environmentally and politically expedient, it is very difficult to accomplish with assurances of long-term stability. If one restores to current conditions, say 25% impervious cover, a stable channel may exist for a 5-year period following the restoration, and thus successfully complete a 5-year program of monitoring. However, in 20 years-time when the impervious cover has climbed to 40% the channel could again be undersized by 1/2, with unstable meanders, areas of entrenchment and lateral bank undercutting that eventually topples trees and produces debris jams. The opposite is also fraught with problems. If one designs for 40% build out, the over-dimensioned channel will become a sediment trap and have a constantly shifting pattern of lateral bars that act to destabilize banks and lower aquatic habitat.

The solution to stream restoration in urbanizing watershed is to partner stream restoration initiatives with storm water flow control programs. Low Impact Development (LID) strategies are one way to accomplish this goal. Local and regional upstream detention may also serve this end, as long as they are engineered for maintaining storm flows for predevelopment conditions down to the 1-year storm.

*Keywords: Stream Restoration, Urbanization, Regime Relationships, Piedmont, Charlotte, Impervious landcover*

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## SEDIMENT IN OUR STREAMS: UPLAND AND STREAM BANK EROSION IN NORTH CAROLINA

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For many years, the revised universal soil loss equation RUSLE2 and its predecessor, the USLE have been successfully used by USDA-NRCS and other professionals to estimate sediment production by sheet and rill erosion on overland flow areas. Soil erosion was recognized as a major threat to continued productivity of the land in the 1930's. Initially USLE and later RUSLE2 calculations have served as excellent guides for resource managers and planners in the choice of conservation practices needed to control erosion to a desired "soil loss tolerance" level, T. Soil loss tolerance is the average erosion rate that can occur with little or no long term degradation of the soil. T values have been assigned by NRCS to all major soil types in the United States. T values range from 1 to 5 tons/acre/year with normal values in the 3 to 5 tons/ac/yr range. RUSLE2 can be used to estimate sediment production within the watershed, but not sediment yield to the stream since much of the sediment produced within the watershed is also deposited in the watershed before reaching the stream.

In recent years, sediment has been identified as the leading pollutant in streams in the United States. Stream bank erosion is a major contributor to total sediment yields in many stream systems. Erosion hazard rating procedures were developed in 1990 that allow the rating of stream bank conditions with a bank erodibility hazard index (BEHI) that predicts the potential of the bank to erode. The procedure relates the physical characteristics of the bank and the distribution of stream flow in the near-bank region to predict the annual rate of stream bank erosion. Data from established monitoring sites in the piedmont and mountain regions have been used to develop stream bank erodibility curves for North Carolina. Data was collected from sites that were delivering sediment directly to the streams. Measured stream bank erosion rates range from 0.004 ft/yr to over 11 ft/yr. Data will be presented describing upland erosion rates and stream bank erosion rates in the piedmont and mountain geographic regions of North Carolina. The North Carolina Stream Bank Erodibility curves will contain data from 1997 through 2003. This study is in the process of being expanded to include the evaluation of stable stream banks as well as the collection of additional data from eroding stream banks. This data will presented at a future time.

Keywords: *RUSLE, soil loss, BEHI, stream bank erosion rates*

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*About the speaker:*

**Angela Jessup** is a registered Professional Engineer in NC. She has worked as a Civil Engineer with NRCS for over 23 years. She has design and construction experience on watershed projects, animal waste management, and other soil and water conservation systems planned for the protection of our natural resources. For the past 10 years of her career, she has specialized in stream assessment, stabilization and restoration using natural channel design methodologies.

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## RESTORING STREAMBANK VEGETATION

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Restoring appropriate vegetation is critical to the success of all stream restoration projects. In addition to stabilizing banks, modulating water temperature, and providing woody debris, the right plants can support non-aquatic wildlife and improve a project's beauty to human eyes. Before they can perform all of these wonderful functions, though, the plants we install must survive.

In this session we look at the special challenges of stream restoration sites from a plant's perspective, and learn what we can do help the plants we install thrive. We will review the advantages and disadvantages of seed, live stakes, bare root and containerized material. Finally, we will view a palette of plants perfectly adapted for revegetation of restored or degraded streams in the southeastern USA.

Keywords: riparian, streambank, vegetation, plant, stocktype

*About the speaker:*

**Ellen Colodney** is the owner of Coastal Plain Conservation Nursery, in Edenton, North Carolina. She was a practicing physician for many years before leaving the field pursue her true love, helping to restore the magnificent wetlands and waterways of North Carolina by propagating the native plants needed for ecological restoration and conservation projects.

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# TREES AND SHRUBS FOR RIPARIAN AREAS IN THE PIEDMONT: A GROWER'S PERSPECTIVE

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A wide variety of trees and shrubs must be produced for plantings to meet the stream buffer requirements now mandated in an increasing number of river basins. Many of these species are not generally available in the nursery trade or in the sizes or numbers needed. We will briefly describe some of the more common trees and shrubs of the bottomlands of the Southern Piedmont, where they occur, how they are propagated and some of the problems encountered in production. Special emphasis will be given to plant sizes and the times required to produce saleable plants.

Keywords: *riparian plants, native vegetation, restoration plants*

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## NCSU CENTENNIAL CAMPUS OUTDOOR FIELD LABORATORY: CONTROL OF INVASIVE PLANTS ON NORTH CREEK

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North Creek, a severely degraded stream on North Carolina State University's campus, is a focus of NC State University's Centennial Campus, a growing research and advanced technology community of university, corporate and government R&D facilities. The North Creek restoration project, partially funded by a USDA-CSREES Water Quality grant, is an opportunity to educate youth, policy makers, and the public and campus community about protecting and improving surface water quality, riparian corridor health, storm water runoff control, and watershed management. Restoration of sections of the degraded stream and its associated wetlands and riparian areas are being done to reduce downstream flooding and pollutant movement, and improve aquatic and wildlife habitat.

One major component of the restoration efforts has been exotic and invasive plant control. Kudzu (*Pueraria lobata*) has severely infested the entire riparian corridor. Controlling this invasive exotic vine was a priority before beginning stream restoration activities and installing native vegetation. Much of Centennial Campus had formerly been planted in kudzu to control erosion. However, as part of the channel assessment prior to restoration, the Bank Erodability Hazard Index (BEHI) assessment index measurements rated the stream 'High' to 'Very High' when accounting for the kudzu root coverage on the stream banks: BEHI ratings were 'Very High' to 'Extreme' discounting kudzu.

Two methods of control and eradication of invasive exotic plants are currently being employed. Biological controls using goats and chemical control using selective herbicides are being compared in their effectiveness for removing the exotic species.

NC State Meat Goats and Forage Systems unit oversaw the biological control utilizing goats starting in May 2003. Invasive Plant Control, Inc. applied mechanical and herbicide controls in July 2003. These controls are being repeated in 2004 and planned for 2005. In addition to kudzu, other treated species included Chinese privet (*Ligustrum sinense*), Japanese honeysuckle (*Lonicera japonica*), and multiflora rose (*Rosa multiflora*).

Areas treated by goats in 2003 showed some regrowth of kudzu in 2004, but not nearly to the extent present pre-2003. Japanese stilt grass (*Microstegium vimineum*) regrowth occurred in a few open areas occupied formerly by kudzu. In the treated areas, early successional plants as well as some riparian plants were dominant in the spring of 2003. These species included fescue (*Festuca* spp.), dog fennel (*Eupatorium capillifolium*), daisy fleabane (*Erigeron annuus*), fireweed (*Erechtites hieracifolia*), sorrel (*Rumex crispus*), soft rush (*Juncus effusus*), deer tongue (*Panicum clandestinum*) and seedlings of elderberry (*Sambucus canadensis*) and sweetgum (*Liquidambar styraciflua*).

After the 1<sup>st</sup> year of treatment, herbicide treated areas have shown vigorous kudzu regrowth in selected places, greater than the goat-treated areas, but less than the non-treated areas. The reduced treatment by the herbicide application may be due to a large rainfall event following application in 2003. In the chemically treated areas where kudzu control was most effective, other invasive exotic species such as Japanese honeysuckle, multiflora rose, Chinese privet, and Japanese stilt grass have flourished in the newly exposed areas. Native species such as black berry (*Rubus* spp.) and elderberry are also growing in these areas.

Keywords: *Invasive, goats, kudzu*

*About the speaker:*

**Jean Spooner, Director**, Soil & Water Environmental Technology Center (SWETC), Group Leader of the NCSU Water Quality Group, Professor, Water Quality Extension Specialist, Department of Biological and Agricultural Engineering, North Carolina State University. Dr. Spooner is a Soil Scientist and Applied Statistician. She performs statistical analyses to evaluate changes in water quality associated with non-point source (NPS) pollution controls, and provides technical assistance to NPS projects on water quality and land treatment monitoring designs and data analysis. Dr. Spooner holds a Ph.D. in Soil Science (minor in Statistics) from North Carolina State University, a M.S. in Soil Science (minor in Statistics) from North Carolina State University, a M.S. in Applied Statistics from Utah State University, and a B.S. in Agronomy from Cornell University.

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## MEASURING SUCCESS OF VEGETATION ESTABLISHMENT

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In North Carolina, stream mitigation requirements are resulting in a steady increase in stream restoration projects. Currently, vegetation requirements are 320 stems/trees per acre at the end of 5 growing seasons. With numerous projects having been in place for several years now, North Carolina State University and the NC Stream Restoration Institute has been able to monitor the success, partial success, and/or failure of riparian plantings along newly restored or enhanced streams.

Photo points taken during the growing season each year reveal changes in vegetation cover over time. These pictures are an invaluable tool when disseminating project results to stakeholders or the general public. However, photos alone cannot tell the whole story. Vegetation surveys must be performed each year during the growing season to determine actual mortality numbers, diversity, and whether or not natural regeneration is occurring. These surveys can take the forms of plots or transects appropriate to the size of the project. Currently, NCSU is evaluating several different monitoring protocols to determine overall effectiveness of each one. In addition to surveys and photos, knowing the project's background can help the vegetation evaluator in assessing the success or lack of for individual projects. Reading the initial design plan gives valuable information regarding the types of plants that were planted, quantity of planted vegetation, soil test results, and special features of the project. Further, general field reconnaissance can help the evaluator determine potential problems that may prevent the project from being successfully vegetated. Some of the issues may include improper installation of plants, deer browse, and droughty soils among others.

NCSU plans to continue research in riparian vegetation monitoring and success criteria. Vegetation plays a significant role in the restoration of streams and better understanding and practice of its application will hopefully lead to more successful projects.

Keywords: *riparian vegetation, vegetation monitoring*

*About the speaker:*

**Karen Hall** serves as an Extension Associate in the Biological and Agricultural Engineering Department at NCSU. She specializes in riparian vegetation for stream and buffer restoration projects. She holds an MS degree in Forestry from North Carolina State University and a BS degree in Biology from the University of North Carolina at Chapel Hill.

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# EVALUATING BENTHIC RESPONSE TO LOCAL AND WATERSHED CONDITIONS: MAKING THE CASE FOR A WATERSHED-BASED APPROACH TO STREAM RESTORATION.

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Although benthic macroinvertebrates are often used to qualify the success of stream restoration projects, it is still largely unclear to which changes in the stream function the insects are responding. To investigate which components of stream ecosystems are critical for structuring benthic communities, fifteen environmental variables are evaluated for their effect on variations in community composition. These variables, describing watershed activities, local geomorphology, and riparian condition, were measured in association with macroinvertebrate collections for thirty-two restored and upstream reaches across the western Piedmont of North Carolina in rural, urban, and agricultural landscapes. Detrended Correspondence Analysis (DCA) and Canonical Correspondence Analysis (CCA) ordination methods were applied to the datasets to elucidate variables responsible for variation in the community structures. Analysis results indicate different processes controlling upstream and restored benthos; communities in restored reaches were mostly dominated by variables characterizing watershed activities, such as SCS-CN, d90, and % sand or finer. In contrast, upstream reaches were controlled by a mix of local and watershed conditions, described in this analysis by variables such as SCS-CN, Bank Height Ratio (BHR), and detrital biomass. These differences may be interpreted as a function of channel stability. While restored reaches attempt to regain a stable system following construction, geomorphological processes governed by watershed activities, such as sediment transport, habitat embedding and disturbance, and flow regime are responsible for structuring benthic communities. However in more stable stream reaches, the benthos respond as much to local conditions, such as floodplain access and energy processing, and as they do to watershed conditions. These results suggest that including activities, such as Stormwater Best Management Practices (BMPs), to diminish the degrading impacts of construction and impervious surfaces within the watershed may improve benthic recovery until restored streams reach stability. Further, results indicate that habitat quality is as critical to benthos as water quality in both restored and upstream reaches. This confirms the value of using benthic macroinvertebrates in describing the function of stream ecosystems, as they respond to a range of sediment, flow, and water quality conditions.

*Keywords: Restoration, Macroinvertebrates, Best Management Practices (BMPs), Benthos, Ordination.*

*About the speaker:*

**Desiree Tullos** is a PhD candidate at NCSU in Biological Engineering and expects to complete her program in May of 2005. She has earned both her Bachelor's and Master's degrees in Civil Engineering; current research interests include watershed hydrology, stormwater management, and stream ecology.

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# INITIAL BIOLOGICAL AND PHYSICAL ASSESSMENT OF A SOUTH CAROLINA PIEDMONT RESTORATION PROJECT

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Little Garvin Creek, an entrenched (G5c Rosgen-type) stream impacted by cattle grazing was restored to a more stable (E5 Rosgen-type) stream October, 2002, using a natural channel design. The objective of this study was to determine if stream restoration improved the quality of macroinvertebrate community structure and the physical function of Little Garvin Creek. Benthic samples were collected quarterly prior and monthly after construction by habitats (leaf pack, pool, roots, cobble and gravel substrate, sand substrate and large woody debris). Bank height ratios (BHR), entrenchment ratios (ER), width to depth ratios (W/D), median particle size (d50), substrate percent composition and total suspended sediments were assessed before and after restoration. Within the restored reach, rock and leaf pack habitats contained greater numbers for total abundance, EPT richness, and taxa richness compared to pool, sand, root and large woody debris habitats. High variability was found between winter and spring benthic samples due to extensive rain fall events following restoration. Taxa richness within the restored reach was lower than above the restored reach, but increased over time. The designed channel maintained its dimension, pattern and profile with the exception of the upstream 10 meters. The suspended sediment in transport through the restored reach improved following restoration. Substrate composition within Little Garvin Creek varied, but showed an increase from a mixture of clay and fine sand to a mixture of medium sand and small gravel. This study successfully showed the effectiveness of a natural channel design to establish a naturally stable channel and improve floodplain function of Little Garvin Creek. This study has shown that the initial responses of the macroinvertebrate community within Little Garvin Creek's were very dynamic. It is still premature to assess whether restoration practices improved or restored the benthic biodiversity and function of Little Garvin Creek.

Keywords: *morphological monitoring, biological monitoring*

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## **The RE-ESTABLISHMENT OF A BENTHIC COMMUNITY WITHIN A UNIQUE RESTORED STREAM**

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In the early 1970's, a 10-acre pond was created by the construction of an earth dam on a second order unnamed tributary to Marks Creek in Wake County, NC. The pond flooded the tributary as well as three first order tributaries. The pond was drained in August of 2001 and wetland and stream restoration commenced in December 2002. The purpose of the Marks Creek stream and wetland restoration project was to provide on-site mitigation for the Knightdale Bypass by restoring more than 3,200 feet of stream and 6 acres of wetlands.

The restoration of the stream channels on the floor of the former pond represented an ideal opportunity to document the restoration of ecological function following stream restoration. As part of evaluating the success of the stream restoration project, benthic macroinvertebrate sampling was conducted prior to stream restoration. Sampling was carried out in the unstable channels forming on the floor of the drained pond and in an upstream reference site. Benthic macroinvertebrates were collected using the North Carolina Division of Water Quality's Qual-4 sampling technique. This type of collection is intended to quickly assess between-station differences in diversity and community composition. Biotic assemblages were evaluated utilizing the biotic indices outlined by NCDENR.

In general, pre-construction sampling results revealed that the macroinvertebrate fauna at the reference reach had organisms with longer life spans, coarse substrate habitat preferences and good water quality requirements. The stations located in the new channels on the old pond floor were dominated by organisms such as black flies and Chironomids that could tolerate fine sediment, organic enrichment, higher water temperatures, degraded water quality and less streamside vegetative cover. Additionally, the feeding guilds shifted from predominantly scrapers, shredders and collector/gatherers at the reference site to more predatory functional feeding groups at the stations located in the newly forming channels.

Post-construction monitoring of these sites will be carried out in April 2004. This sampling should provide interesting insight into the reestablishment of ecological function of the unique stream that was created when the pond was drained in the fall of 2001. The stream went through a period of extreme instability as the new channels formed on the floor of the pond. The stream was then completely reconstructed in the winter of 2002/03. Annual sampling will document the benthic recolonization of the restored stream channels and the restoration of ecological function.

Keywords: *benthic, restoration, stream, sampling, macroinvertebrate, EPT, indices*

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# ECOLOGICAL EFFECTS OF BIOENGINEERED STREAMBANK STABILIZATION IN URBAN STREAMS

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The National River Restoration Science Synthesis (NRRSS) is a multi-year, interdisciplinary working group with three main goals: 1) to compile a representative database of stream restoration projects nationwide, 2) to answer questions about the current state of scientific knowledge and its role in stream restoration practice, and 3) to provide a foundation for guidance of future research in the science of stream restoration ecology. Preliminary results show many differences in the amount, cost, and types of restoration done in different regions of the country. Some of these differences may be due to regional differences in definitions and goals of restoration and levels of coordination between different agencies. These initial results also suggest that the amount of monitoring and evaluation of restoration projects varies widely due to differences in governmental mandates and availability of funding and expertise. This research project is one of the first efforts utilizing the background knowledge provided by NRRSS to study the ecological effects of a stream restoration practice.

Non-structural streambank stabilization, or bioengineering, is a stream restoration practice commonly done to remedy eroding streambanks. While it is frequently done as a stand-alone practice, it is also a common part of other, larger stream restoration projects. Little research has been done assessing its ecological effects. We surveyed bank habitat and sampled bank macroinvertebrates at four bioengineering sites, an unrestored site, and a reference site in the urban Peachtree-Nancy Creek catchment in Atlanta, GA. Macroinvertebrates are useful to study following stream restoration because they have short life cycles and therefore respond quickly to changes in their environment. In addition, macroinvertebrates are an important food resource for fish and amphibians and, therefore, restoration of the macroinvertebrate community can be a first step towards restoring larger animals to urban streams.

The amount of organic bank habitat, wood and roots, was much higher at the reference site and three of the bioengineering sites than at the unrestored site or the other bioengineering site. At all sites we saw high abundance of tolerant invertebrate taxa, particularly chironomids (midge larvae), and low richness and diversity of the bank macroinvertebrate community; these properties are typical of urban streams in Atlanta. Total biomass, insect biomass, and non-chironomid insect biomass were highest at the reference site and two of the bioengineering sites. Across all sites, higher total biomass and insect biomass were found on organic habitats versus inorganic habitats (mud, sand, and rock). Percent organic bank habitat at each site proved to be strongly positively correlated with many factors, including taxon richness, total biomass, insect biomass, and shredder abundance, and negatively correlated with percent chironomid biomass. These results suggest that, although it cannot mitigate many effects of urbanization, when bioengineered bank stabilization increases organic bank habitat it can have positive effects on macroinvertebrate communities in urban streams. However, some practices commonly considered bioengineering, in this case “joint planting”, may not increase available organic bank habitat and so they may not be the best techniques for use in ecological stream restoration.

Keywords: *monitoring, bioengineering, bank stabilization, macroinvertebrates, urban streams*

*About the speaker:*

**Elizabeth Sudduth** is a graduate student at the Institute of Ecology at the University of Georgia where she has focused on the ecology of urban streams and stream restoration, including coursework in ecology, entomology, hydrology, geomorphology, and engineering. She is a member of the National River Restoration Science Synthesis Working Group at the National Center for Ecological Analysis and Synthesis in Santa Barbara, CA.

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## **SALEM CREEK AT CIVITAN PARK: A COMPREHENSIVE APPROACH TO STREAM RESTORATION**

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Historically stream restoration projects in urban watersheds have utilized traditional engineering approaches to channel stabilization. Although the last decade has seen many restoration projects designed and implemented utilizing geomorphic principles and a natural channel design approach, the focus has still been on stabilizing the stream channel. However, the Salem Creek at Civitan Park Restoration Project in Winston Salem, NC is an example of a comprehensive approach to restoration that involves channel restoration, wetland creation/restoration, storm water management retrofits, riparian reforestation, and construction of a pedestrian bridge and boardwalk/trail system that improves public access and opportunities for passive recreation.

Salem Creek is part of the Muddy Creek/Yadkin River system. The main sources of drinking water for residents of the City of Winston Salem and Forsyth County are the Yadkin River and Salem Lake. The hydrologic regime of Salem Creek watershed has been historically altered by development in and around the City of Winston Salem. The channels of Salem Creek and its tributaries have adjusted in response to the alterations in watershed hydrology by incising, widening, and eroding laterally. These channel adjustments, in addition to historic channel maintenance work and floodplain fill decreased flood storage/detention capacity and increased flood conveyance to downstream reaches contributing to flooding problems throughout the City. The stream bank erosion and sedimentation problems also represent a long-term maintenance issue as lateral erosion impacts trails, parking lots, recreational facilities, sanitary sewer lines, culverts, and power lines within the park.

The City of Winston Salem, working with assistance from Pilot View RC&D and funding provided by the Division of Water Resources and Clean Water Management Trust Fund, implemented the Salem Creek Restoration Project to correct the stream channel instability problems, improve water quality, enhance and/or restore natural floodplain characteristics, protect infrastructure, and reduce the loss of public land.

The general restoration approach for Salem Creek involved reconstructing the upper reach as a stable C4 channel with a more regular plan form and improved floodplain access, reconstructing the straight, incised middle reach as a stable meandering E4 channel routed through the adjacent floodplain, and maintaining the existing meander geometry but a narrower cross-section and improved floodplain access for the lower reach. All banks were graded or reconstructed to create a more stable angle of repose and stabilized with biodegradable fabric and staking/planting of native trees and shrubs. Flow diverting structures were installed to keep storm flows away from newly constructed banks. Riffles were constructed to provide grade control and in-stream habitat.

Multiple sanitary sewer lines, a water main, numerous power transmission towers and distribution poles, the existing storm drain systems, parking lots and athletic fields presented design constraints for the entire project. However, an old bridge abutment situated beneath the ML King, Jr. Drive Bridge presented a particular challenge for the restoration of the upper reach. Working with NCDOT the old abutment was removed and the bridge reach restored. An elevated 18-inch sanitary sewer line crossing and steep unstable slopes also presented a challenge for the restoration of the lower reach. The sewer line was protected by a staggered installation of flow diverting structures. The unstable slopes were reconstructed utilizing rock toe benches, soil fabric lifts with live branch layering, and erosion control matting.

The old channel along the middle reach of Salem Creek was backfilled to create a wetland/water quality pond to manage storm water runoff from Winston Salem State University. In addition, a rubble landfill was removed from the left floodplain to create a forested wetland in its place. The straight, incised lower reach of Stadium Branch Tributary was rerouted through the wetland as a stable meandering E4 channel. The deeply incised lower section of an Unnamed Tributary was reconstructed as a stable B4 channel with log/boulder steps and pools. A deep gully that carried storm water runoff from the adjacent University parking lot was stabilized and rerouted through a second wetland/water quality pond constructed in the floodplain along the lower reach of Salem Creek.

A pedestrian bridge and boardwalk were constructed to provide access from the University to Civitan Park. An asphalt walking trail and wetland loop trail with timber bridges were constructed to provide opportunities for passive recreation and public education.

As a result of this project 5240 feet of unstable stream channel was restored, 5.2 acres of forested wetlands was created, 17.5 acres of riparian forest and native meadow buffer was created, the natural stream/floodplain interaction was restored, in-stream habitat was improved, and sediment and nutrient loadings to Salem Creek from eroding banks and upland storm water runoff have been significantly reduced. The City of Winston Salem worked closely with Winston Salem State University to establish a conservation easement that will permanently protect the riparian corridor along this reach of Salem Creek.

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## LITTLE SUGAR CREEK ENVIRONMENTAL RESTORATION INITIATIVE PHASE 2 FREEDOM PARK STREAM RESTORATION AND GREENWAY TRAIL (4,400 LF)

Chris Matthews

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Phase 2 of the Little Sugar Creek Environmental Restoration Initiative is a joint effort between Mecklenburg County and the NC Ecosystem Enhancement Program (NCEEP), placing four (4) new meanders on Little Sugar Creek in Freedom Park. Little Sugar Creek, straightened many years ago, drains almost 9 square miles of basin at this point and drains the eastern half of the Charlotte uptown area. This NCEEP project is one of the largest of its kind in the State, placing over 1,500 linear feet of stream on a new alignment as much as 150-feet from its current location. The stream has 15-foot bank heights and 30-foot bottom widths and is being constructed economically, in spite of moving over 50,000 cubic yards of earthwork; over 3,000 tons of boulders, river cobble and cross vanes; and installing over 40,000 trees and shrubs. This project was constructed “in the wet.”

Some of the natural design elements implemented in the project include rock vanes, boulder clusters, natural stone storm water outfall structures, floodplain benches, root wads and boulder walls which used to cut off the old stream channel. Of special interest is the implementation of constructed riffles that are designed to provide stability and habitat using a combination of stone and boulder materials. As part of the restoration, over twenty shrub and tree species were used to stabilize the banks and to reforest the upland areas. Additionally, a diverse seed mix was used to provide herbaceous cover to quickly stabilize the banks.

An important component to this project was the effort to involve the community during the planning and construction phases of the project. Public meetings for input and review were held during the course of the project to make sure that project information was shared with the community and several special interest groups. Prior to and during construction, signs indicating schedule and project team members were posted. Additionally, images showing the final conceptual design and some of the rationale behind the design elements were posted in kiosks along the stream.

This is the first project in a series of four adjoining segments of Little Sugar Creek that are under-going restoration and greenway trail development. The four segments are part of a much larger watershed-wide environmental initiative that includes demolition of concrete liners, dam removal and “daylighting” (removing parking decks from above the stream).

Project Specifics: Design bankfull height is ~6.5 feet. From the time construction started on March 10, 2003 and ended on September 2, 2003 there were 41 rain-day delays and the creek peaked in excess of 8-feet in water depth 9 times. Bankfull design depth has been reached 18 times and there was a major flood event (8 year storm) during construction. Based on actual USGS gauge data at the upstream end of the project, a bankfull return period of 3.5 days was obtained during construction.

Keywords: *Urban Stream Restoration Park Constructed Riffle Public Involvement*

*About the speaker:*

**Chris Matthews** is the Environmental and Water Resources Section Manager for the HDR Engineering Carolinas operations. He has been performing stream restoration activities since the early 1990's. Chris has a BA in Biology from the University of North Carolina at Charlotte and an MS in Applied Ecology and Conservation Biology from Frostburg State University, Frostburg MD.

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# ANATOMY OF A SUCCESSFUL URBAN STREAM RESTORATION

Vincent Sortman

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More and more urban/suburban streams are being restored/rehabilitated using natural channel design techniques. Urban streams present an array of problems and constraints not encountered with rural stream restoration projects. Urban hydrologic regimes with frequent, flashy discharges make it extremely difficult to determine bankfull discharge. Site constraints such as roads, utilities, and private property often do not allow for proper planform and profile geometry. Impervious surfaces and vast storm drainage systems have removed first order channels from the watershed and eliminated sediment supply to the stream. These pitfalls have sabotaged many well-intentioned stream restoration projects. The purpose of this presentation is to dissect a stable stream restoration and thereby glean the basis of its success.

The Spring Branch stream restoration project in Baltimore County, Maryland was completed in March 1996. Over the past eight years it has withstood record rainfall and record drought without any remedial construction. The design was the first “major” restoration for the consultant, the contractor, and the client so it could be expected that many mistakes would be made; yet, the restored stream is one of the most stable stream restoration projects in the region.

Spring Branch was so severely degraded that no bankfull indicators were found in the channel. In 1995 no regional curves were available for this area. The bankfull discharges were based entirely on hydrology modeling of the watershed. This produced a slightly larger cross section than the now-apparent bankfull discharge which provided a stable channel for the urban discharges experienced by Spring Branch.

Also in 1995 the use of reference reaches as models for the restoration design was not widespread and thus reference reaches were not measured for this project. Empirical ranges for plan, profile, and cross section were utilized and modified for the design based on the constraints of each reach. This approach worked surprisingly well for the narrow right-of-way.

While the narrow right-of-way constrained the planform design, it unexpectedly provided a stabilization technique that was not accounted for in the design. Construction access was accomplished in the existing channel by first installing cobble material for the equipment to run on. This cobble then became the channel bed material for the proposed stream. It provided a stable riffle substrate that would not have been available naturally in an urban stream.

These are just a few examples of the various design and construction techniques that allowed the Spring Branch stream restoration to be so successful. Because urban stream restorations are becoming more common it is imperative that we learn from successful and unsuccessful restoration projects.

Keywords: *stream restoration, natural channel design, soil bioengineering*

*About the speaker:*

**Mr. Sortman** is the senior stream restoration designer at Biohabitats, Inc. He is a fluvial geomorphologist with over 10 years of experience in natural channel design and construction. The majority of his stream restorations are on urban streams in the mid-Atlantic region and range in size from a couple hundred feet to a couple miles.

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## **ADDING SOME GREEN TO BROWN BRANCH: STREAM RESTORATION IN THE RURAL PIEDMONT**

Ellen McClure

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Under its mandate to improve water quality and habitat by implementing large-scale restoration projects, the North Carolina Ecosystem Enhancement Program (formerly the Wetland Restoration Program) sought to restore 6,000 feet of Brown Branch in rural Caldwell County. The goal was to establish a stable channel cross section, profile and planform pattern to reduce bank erosion, enhance in-stream habitat, and improve the function and aesthetics of the riparian corridor. First-year monitoring results from Brown Branch suggest design successes (e.g., preservation of stable reaches, stability in realigned reaches, creation of diverse ecological niches), as well as shortcomings that serve as lessons learned (e.g., poor survival rates of bare root stock and herbaceous cover, localized erosion).

Historically, Brown Branch was ditched along one side of a narrow alluvial valley to maximize adjacent farmable land. The straightened channel subsequently incised into its floodplain, leading to severe bank erosion, filling of pools, and poor aquatic refugia. Persistent grazing further restricted natural reforestation of the channel banks and valley floor. Since the early 1900s, the Pisgah National Forest has managed the land upstream of the project area. Despite a century of generally consistent sediment supply and hydrology, Brown Branch had not recovered its former channel pattern.

Measurements from three reference reaches within the North Carolina Piedmont and Mountain physiographic provinces were used to establish typical design parameters such as radius of curvature, meander wavelength, and pool depth and spacing. In addition, surveys at Brown Branch helped estimate bankfull discharge, which was corroborated with available regional curves and results from hydrologic modeling. Observations of successful native plant communities were made in the forested reach upstream of the project to help inform revegetation plans.

The channel design included the grading of a predominantly pool-riffle, meandering channel, periodically interrupted by straighter, steeper sections. The channel was sized to convey the bankfull flow, with floodflows inundating a broad excavated floodplain. Structural elements in the channel, such as rootwads, J hooks, and log vanes, were used locally to provide grade control, deflect flow from banks, and promote pool scour. To create complexity along relocated portions of the channel, floodplain grading was irregular, with significant microtopography. Portions of the abandoned channel were preserved as deeper, larger depressions to form emergent wetlands.

Native plantings included trees, shrubs, and herbaceous species adapted to the upper and lower forested floodplain and emergent wetlands. Planting densities were doubled along erosion-prone zones in anticipation of poor survival rates. Care was taken to plant species that would attract pollinators and provide habitat and/or nutritive value to terrestrial and avian species throughout the year. Permanent fencing was installed to exclude livestock from revegetated areas. Additional creative habitat elements included the placement of constructed brush piles, snags, and downed logs to provide ecological niches for terrestrial species.

The design also emphasized preserving and exploiting existing site characteristics to maximize habitat quality and diversity. For example, some segments (approximately 500 feet total) of the

existing channel were left undisturbed, since they already offered beneficial riparian or aquatic habitat. In addition, the channel location was maintained at several bedrock outcrops to exploit the natural grade control. Similarly, the outer banks of meander bends were relocated against known bedrock outcrops to promote pool scour without the use of engineered bank stabilization. Finally, the grading plan and channel alignment spared the largest trees to help maintain root cohesion, streamside shading, and leaf litter inputs, plus promote natural colonization of the floodplain with dropped seeds.

Available funding was limited to \$100 per linear foot, so keeping construction costs low was a major concern during the design process. To minimize costs, cut and fill were balanced on-site, and log and rootwad structures were built exclusively from cleared trees. Upon completion in September 2003, design (including construction observation) and construction costs averaged \$36 and \$51 per linear foot, respectively.

The five-year monitoring plan includes annual surveys of the channel profile and monumented cross sections, pebble counts, vegetation plots, and photodocumentation. Results from the first year of monitoring suggest that the successful elements of the project include overall channel stability, as indicated by persistent cross-sectional dimension, channel planform pattern, and longitudinal profile. Log toe protection and rock cross vanes have been more effective in aiding this channel stability than log vanes. Anecdotal observations of benthic macroinvertebrates and wildlife use are promising and suggest the rapid return of many species. Benthic macroinvertebrates noted in riffles were both numerous and diverse. Frogs were observed along the channel and amphibian eggs were noted in wetland depressions.

The most significant problems encountered to date include poor survival rates of bare root species, delayed and spotty growth of herbaceous cover, and associated rilling along the floodplain. Recommended contingency measures include filling rills and replanting and reseeding some areas before the next round of monitoring. The use of containerized plants and soil bioengineering, and prompt reseeding of barren areas would have greatly improved vegetative survival rates and prevented surface erosion.

*Keywords: stream restoration, applied geomorphology, case study, monitoring, habitat*

*About the speaker:*

**Ms. McClure** is a fluvial geomorphologist with five years of consulting experience in the field of stream restoration and an additional four years of experience in the geomorphic research of pristine and anthropogenically impacted channel networks. She obtained a B.S. with Distinction in Geological Sciences from the University of Washington and an M.S. in Geosciences and Civil Engineering from Oregon State University. Ms. McClure integrates principles of natural channel processes with more conventional river engineering techniques to design stable, naturally functioning restored channels.

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## **DESIGN, CONSTRUCTION, AND POST-CONSTRUCTION MONITORING FOR RELOCATION OF 5,288 FT OF STREAM CHANNEL IN NEW HARTFORD, NEW YORK**

Rostyslaw Caryk

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Stantec designed and constructed a total of 5,288 ft of new stream channel in 2000 to relocate a regulated New York State trout stream. The impacted stream supported a cool/warmwater fish community including a small population of juvenile brown trout. Extensive pre-design biological, morphological, and hydrologic studies were conducted in order to devise a natural channel relocation plan acceptable to the two major regulatory agencies, the New York State Department of Conservation (NYSDEC) and the U.S. Army Corps of Engineers, Buffalo District (USACOE). Impacts of the project included 4,700 feet of stream and 5 acres of wetland. A full half of the stream was channelized (paralleled railroad) or cut through a construction debris fill area.

Natural channel design and bioengineering techniques were used to relocate the entire stream and integrate it with existing and new wetland areas. Extensive use of stream bank and bed protection methods such as concealed grade control structures, coconut fiber coir logs, native stone bed materials, erosion control matting, and native plant materials were used in the design. The new channel incorporated several design reaches including a meandering Rosgen “E” channel with several floodplain wetlands in the upper reach; a cascade/pool reach to stabilize a steep grade section; a meandering Rosgen “C” channel through a sensitive woodlot/wetland; and a downstream “E” section where project storm water runoff was incorporated. A total of 9 acres of adjacent wetlands were constructed as part of this mitigation project.

The project was started in mid summer at the most downstream end when site conditions were most favorable for movement of construction equipment, a major concern due to numerous seeps present in the area. As a result the project was not completed until late fall. The last constructed reach was the most upstream reach. Differences in the upper and lower reaches related to the establishment of bank and floodplain vegetation became evident the following spring when floodwaters overtopped the stream banks as designed. Floodplain and bank erosion was noted in upper reaches, although most control materials functioned as intended. No erosion was observed in the middle and lower reaches where the vegetation was more fully established.

Post-construction monitoring in 2001 and 2002 indicates that overall the new stream-channel is stable. Banks are fully vegetated and stable, with considerable streamside shrub growth providing overhanging cover and a source of woody debris. The 2001 monitoring study found that fish had repopulated the new stream and that the fish community included a new species not found in the original stream surveys, a brook trout. The benthic community is still in the process of recovering as sampling still shows a less diverse community. It is anticipated that this re-location will be considered successful by the regulating agencies.

Keywords: *re-location, restoration, trout habitat, bioengineering, biology*

*About the speaker:*

**Mr. Caryk** is a Senior Ecologist at Stantec Consulting Services Inc. responsible for managerial, supervisory and technical coordination responsibilities for projects involving ecological impacts and mitigation, especially related to wetland and stream permitting. He has considerable experience in wetland mitigation, stream restoration, preparation of erosion and sedimentation control plans and environmental construction oversight. Mr. Caryk has a B.Sc. degree in Biology and a M.A. degree in Natural Sciences and Mathematics from the State University of New York at Buffalo, New York.

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## **ESTIMATING CHANNEL DEGRADATION RATES IN A RAPIDLY DEVELOPING WATERSHED**

Melanie Carter

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North Creek is a small stream (drainage area 0.5 sq mi.) that flows through the center of Centennial Campus, NCSU. The campus has experienced considerable development over the past few years, with negative impacts on the receiving stream. Excessive sediment loads and increased stormwater runoff are contributing to channel instability. Two large in-stream culverts are currently controlling the grade of the channel. Their presence establishes three subreaches that are experiencing different stages of channel evolution. The upstream reach is deeply incised, receiving runoff from a previously developed watershed. The middle reach is surrounded by the most active development and has moderate channel incision. The downstream reach has little incision, and is composed of a steep riprapped section that flattens out to a low gradient channel.

In this study, bank erosion rates were measured for 1.5yrs along North Creek using permanent cross-sections and toe-pins. Bank erosion hazard index (BEHI) assessments were performed and near bank shear stress (NBS) was calculated along the entire reach, in order to compare predicted bank erosion rates with actual measured values. Longitudinal profiles were also surveyed along the stream, in order to determine the rate of vertical incision within reaches.

The results of this study show that the channel is progressively degrading, in this case, as you move downstream. The upstream reach is incised but relatively stable, with some evidence of channel widening. The middle reach is actively incising as you move downstream, with increasing signs of instability. The downstream reach has changed the most dramatically over the study period. In an effort to reach equilibrium, the stream has removed the riprap in the steep gradient portion, and placed it in the lower gradient sections just downstream in order to balance the gradient over the reach. This reach has experienced bank erosion rates greater than 5 lateral ft/yr in the lower gradient, downstream areas. These rates are much higher than those predicted using BEHI assessments and NBS categories. The results of the longitudinal profile surveys in this reach show that vertical incision rates have exceeded 2.5ft/yr in the steeper gradient sections. For North Creek, channel degradation patterns are predominantly controlled by the in-stream culverts, even though the degradation itself is caused by the watershed development.

The results of this research are important to demonstrate that urban stream degradation rates can be much higher than predicted for other stream types. Predictive bank erosion rate curves need to be generated for urban streams, for better estimates of bank erosion. Urban streams can have in-stream structures that alter both bank erosion and channel degradation rates, by altering typical grade forming processes. In North Creek, the typical headcut migration patterns were not observed due to the interruption of the channel by the over-widened culverts. From the results of this study, it is evident that more research is needed on bank erosion and channel degradation rates in urban streams. Documenting these rates and formulating better predictive tools would help improve watershed planning and management decisions.

*About the speaker:*

**Melanie Carter** is a PhD Student at North Carolina State University in the Biological and Agricultural Engineering Department. She received her Bachelor's Degree from Virginia Tech in Biology and her Master's Degree from the University of Alabama in Aquatic Biology. Her research interests include the evaluation and incorporation of biological habitats into constructed wetland and natural channel design.

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## IT WASN'T SUPPOSED TO DO THAT: ANALYSIS OF PLANFORM ADJUSTMENTS AFTER STREAM RESTORATION

Conor Shea<sup>1\*</sup>, Rachel Shea<sup>2\*</sup>, Chuck Weinkam<sup>3</sup>, and Robert Shreve<sup>4</sup>

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The Maryland State Highway Administration (MSHA) restored 1,200 linear feet of Deep Run in August 1995 using natural channel design principles. Soon after completion of construction, the restored reach became unstable as bank stabilization measures failed. Large-scale lateral adjustments in stream channel planform occurred as well as significant bank erosion. Remedial stream restoration efforts were undertaken in 1997 to reconstruct the original restoration plan. The remedial work failed soon after construction and the stream continued to destabilize.

Starting in 2000, MSHA initiated an intensive monitoring program of the restored reach as part of a study to identify future trends in channel evolution; and to determine what, if any, remedial actions were required to stabilize the stream restoration. This paper reports on long-term observations of planform adjustments, analysis of geomorphic processes responsible for major stream instabilities, and conclusions regarding the need for further remedial actions.

Monitoring and analysis of planform changes since completion of construction showed the following changes:

- Migration/rotation of the apexes of meander bends in the downstream direction; typically moving through the location of the as-built channel banks on the downstream-outside bend of meander bends.
- Migration of channel thalweg on the upstream portion of meander bends from the outside of the bend to the inside of the bend. Flow concentrated at the inner bends causing bank erosion.
- Formation of cut-off channels that reduced channel length and sinuosity.
- Abandoned channels filled with sediment forming bars composed of sands, gravels, cobbles, and river-carried debris.
- Bankfull cross section width generally doubled.

Hydraulic modeling showed that prior to planform and cross section adjustments, stream power was high on the downstream, outside bends of meanders. Channel adjustments have worked to lower stream power by reducing meander curve length, increasing riffle length, and increasing meander radius of curvature. Stream power along meander bends was greatly reduced and peaked only in mid-channel areas at the head of riffles.

The study concluded that the initial failure and the subsequent rapid rates of lateral channel migration were caused by several factors. Meander radii of curvature were too low and individual meander lengths were too long in the original design. This created extremely high shear stress on the convex bank at the downstream ends of meander bends. Rootwad revetments did not withstand erosive forces and were quickly bypassed in areas of high stream power. Areas of fill used to create channel banks offered little erosive resistance due to the lack of mature rooting material.

The study concluded that the rate of change in channel planform is now slowing as the channel achieves a stable planform. Meander bend geometry adjustments and formation of cut-off channels reduced bend length and thereby reduced the stress on channel banks and forces causing bend migration. Channel substrate became armoured, decreasing the amount of sediment movement within the channel. Channel width widened reducing stream power and increasing channel resistance. Because the rates of adjustments are decreasing and a stable planform is being developed, the study recommended to not undertake any further remedial actions to “repair” the restoration.

Keywords: *post construction monitoring; hydraulic modelling; meander migration.*

*About the speakers:*

**Conor Shea**, Ph.D., P.E. is a hydrologist with the U.S. Fish and Wildlife Service’s Chesapeake Bay Field Office in Annapolis, MD. He is a member of the Stream Habitat Assessment and Restoration Program. Conor prepares stream restoration designs and provides technical assistance with natural channel design and fish passage restoration to federal, state, and local agencies. Conor earned his doctorate in Fluvial Geomorphology at The Johns Hopkins University. This work was prepared while Conor was the practice area leader for watershed management for Parsons Brinckerhoff Quade and Douglas, Inc.

**Rachel Shea**, P.E. is engineering geomorphologist with Greenman-Pedersen, Inc. where she directs design and construction of stream restoration projects. Rachel has prepared numerous stream restoration projects for state and local agencies. Her design approach emphasizes the use of hydraulic, geomorphic, and sediment transport analyses to ensure stable channel designs. Rachel earned a Master of Science degree in Geomorphology at The Johns Hopkins University.

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## **Stream Restoration Monitoring in North Carolina**

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North Carolina State University is monitoring 20 stream restoration projects completed by the North Carolina Ecosystem Enhancement Program (NCEEP) since 2000. All projects are being monitored to evaluate success using NCDWQ and ACOE criteria for dimension, pattern, profile, substrate, and vegetation assessment. Additional monitoring includes soils analysis, bank hazard erosion index (BEHI), and near bank stress assessments. Some projects were selected for intensive monitoring which includes hydrologic stage recorders, monthly water quality samples, storm flow sediment samples, macroinvertebrate assessment and groundwater samples within the buffer area.

Web based monitoring reports are generated for each project. Reports include project background information, results, analysis and documentation of problem areas. Analysis procedures include annual comparisons of cross section, channel bed, feature slopes and channel substrate. A web accessible database of channel characteristics will be generated for continued study.

*About the speaker:*

**Dan Clinton** received his undergraduate and master's degrees at NC State University in Biological and Agricultural Engineering. His master's thesis focused on the development of reference reach relationships from stable stream reaches in the Mountain and Piedmont regions of North Carolina. Dan worked for Earth Tech as a stream restoration engineer, focusing on stream restoration design. He has been heavily involved in the design, permitting, construction, and monitoring of numerous stream restoration projects along the east coast from Pennsylvania to Georgia. At NC State, Dan's focus is on stream restoration monitoring along with sediment and erosion control.

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## EVALUATING MONITORING REQUIREMENTS FOR STREAM RESTORATION PROJECTS

Dani Wise Johnson

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As more streams are restored utilizing Natural Channel Design, an important questions looms. What are appropriate monitoring methods and analyses of the data that is collected? In North Carolina, the NC Department of Transportation, Ecological Enhancement Program, and others have implemented numerous restoration projects and are currently monitoring these projects. The results of the physical monitoring efforts include measurements of permanent cross sections, longitudinal profiles, and substrate analyses. Interpreting the data that is collected has proven to be a challenge for regulatory personnel, especially for these mitigation projects. The existing Guidelines for Stream Mitigation in North Carolina provides a broad overview of which data must be collected. An engineer, biologist, and hydrologist may view success of a restoration project differently. Marrying these disciplines and effectively providing a stable dimension, pattern, and profile for an unstable channel is at the heart of stream restoration. This presentation details the existing monitoring requirements by federal and state regulatory agencies and offers alternative methods of analyses for the physical and biological monitoring for these projects.

*About the Speaker:*

**Dani Wise Johnson**, Water Quality Extension Associate, Department of Biological and Agricultural Engineering, North Carolina State University. Ms. Johnson holds a Masters in Hydrology from the Department of Forestry at North Carolina State University. Her responsibilities include working with research and extension faculty to demonstrate and evaluate watershed management and stream restoration systems for protecting water quality across the state.

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## **An Analysis of Stream Restoration Costs in the North Carolina Ecosystem Enhancement Program**

J. S. Jurek<sup>1</sup> and D. M. Haupt<sup>2</sup>

*1 Jeff Jurek, EEP, Raleigh, NC.*

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The North Carolina Ecosystem Enhancement Program (EEP) is an innovative program charged with assessment of watersheds in each of the seventeen river basins in the state, and then addressing the needs with the functional restoration of wetlands, streams, and riparian buffers. Payment to the EEP is an option for applicants who must provide compensatory mitigation as a condition to receive a Section 404 Permit or 401 Water Quality Certification for impacts to streams, wetlands, and riparian buffers. Currently, applicants pay the EEP \$200 (raised from \$125 in April 2003) per linear foot for stream impacts. The Program is responsible for using this money to implement stream restoration projects that are both ecologically functional and cost efficient. The purpose of this study is to track costs of natural stream restoration and to determine whether the \$200 per linear foot fee is adequate to meet EEP goals.

In 2004, EEP analyzed forty-five stream restoration projects (182,000 total linear feet) that are either under construction or constructed. The stream restoration projects were divided into urban and rural groupings. The restoration costs were divided into categories: site identification, site acquisition, project assessment, project design, construction management, site restoration, monitoring, and long-term management. Costs analyses were performed on a per linear foot basis and a percentage of total cost for each of the categories.

The twenty-five urban stream projects averaged \$190.00 per linear foot for restoration while the twenty rural stream projects averaged \$131.06 per linear foot. The average for all twenty-five stream projects was \$163.80 per linear foot, \$39 more than the \$125 per linear foot fee charged for mitigation and \$20 more per linear foot one year ago.

The eight project categories were analyzed for cost per linear foot of restoration and percentage of total project cost. Project assessment, which includes watershed assessment, data collection and assimilation, averaged \$24.98 per linear foot and was 15.25% of the total project cost. Design averaged \$12.32 per linear foot and 7.52% of total cost, while Construction Management was \$12.09 and 7.38%, respectively. Finally, Site restoration, which includes all construction, planting, and fencing, averaged \$90.52 per linear foot and 55.26% of total project cost. Site Identification, Site acquisition, monitoring, and long-term maintenance combined to average \$23.90 per linear foot and the final 14.59% of total stream restoration project cost.

Certain trends have become more evident as these restoration projects are completed. One trend is the increase in construction management cost due to several factors in 2003. Wet weather combined with inexperience of contractors led to unexpected construction overruns, which caused management prices to increase. Also, maintenance cost has risen over the projected cost due to failures in design and construction.

The solution to cost/benefit in these stream restoration projects is through researching the data collected during the monitoring of the stream projects. As more and more stream projects have completed construction, opportunity to collect needed data will increase.

Keywords: *Stream Restoration Cost Design Construction Monitoring*

References: None

*About the speaker:*

**Jeff Jurek** is the Supervisor of the Design/Construction section of the NC Ecosystem Enhancement Program. He has been with this program since its inception as the NC Wetlands Restoration Program seven years ago. His degrees include a B.S. in Ecosystem Assessment and a M.S. in Natural Resources-Hydrology from NC State University.

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# MAINTENANCE COSTS FOR STREAM RESTORATION PROJECTS IN THE ECOSYSTEM ENHANCEMENT PROGRAM

Mac Haupt<sup>1\*</sup>, Jeff Jurek<sup>2</sup> and Jason Guidry<sup>3</sup>

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The North Carolina Wetlands Restoration Program (NCWRP), now the Ecosystem Enhancement Program (EEP), has constructed 25 stream restoration projects. Over the last three years of constructing stream restoration projects, maintenance costs have become an important component to consider in the life of a project. This paper will examine the costs of maintenance for the 25 NCWRP/EEP stream restoration projects, provide explanations as to why the maintenance was needed and offer solutions for each problem. Stream restoration project maintenance will be examined on two levels: one level is the maintenance needed for channel alterations (typically dimension and profile), and the second level involves riparian planting methods and survival.

Projected maintenance costs for stream restoration projects were estimated at 1-3% of the total project cost. The results of the 25 completed stream projects yielded maintenance costs to average approximately 4.5% of the total project cost. Stream restoration maintenance costs are separated into two major areas; geomorphic

modifications and riparian planting. These two areas were further subdivided into the level of maintenance required: minimal, moderate, and extensive.

Minimal channel maintenance is defined as repair to only 1-3 structures and no bank or slope repair. Moderate channel modification can be defined as repair to 3-5 structures and some stream bank repair needed. Extensive channel maintenance is defined as whole short reaches (typically 500- 1,000 linear feet) of a stream project needing repair with over 5 structures being completely rebuilt and areas of stream bank requiring significant grading and excavation. Of the 25 completed stream restoration projects, 4 required extensive channel modifications, 6 required moderate channel work, 7 required minimal channel maintenance, and 8 did not require channel/structure maintenance.

Minimal riparian planting is defined as less than 20% of the site required replanting. Moderate riparian planting involves the replanting of 20-40% of the site. Any replanting over 40% of the site was classified as extensive riparian maintenance. Of the 15 sites that have had at least one growing season, 9 required extensive riparian

replanting maintenance, 1 required moderate riparian replanting, and 5 did not require planting maintenance.

When stream restoration channel and structure maintenance is required, it is usually based on one or a combination of four major areas: 1) faulty design and/or poor design review, 2) poor construction methods coupled with a lack of experienced oversight, 3) poor weather conditions, and 4) vulnerability of the project in the early stages due to lack of vegetation. The survival of riparian plantings has been poor on the completed stream restoration projects. There are three major areas which contribute to the poor survival success of riparian plantings: 1) poor seedling characteristics, 2) poor planting techniques, and 3) harsh substrate conditions (in terms of soil condition and excessive flow on the floodplain).

The Ecosystem Enhancement Program staff have implemented various strategies to reduce the amount of stream channel maintenance and repair on stream restoration projects. The strategies for reducing stream channel maintenance are summarized below by category:

1. faulty design and/or poor design review
  - a. closer review of project designs by design and EEP staff
  - b. analysis of projects in their first and second year of monitoring to determine which techniques work the best
2. poor construction methods and oversight
  - a. the EEP will fund a more experienced construction manager to be on sight during critical construction sequences
  - b. the EEP will sponsor a contractor training/certification workshop to improve the methods and number of experienced construction contractors/operators
3. poor weather conditions
  - a. do not schedule construction of projects during wet season
  - b. reduce the amount of time on site when conditions are wet
4. vulnerability of project in early stages
  - a. take a closer look at natural channel design methods especially in coastal plain and consider alternative strategies/methods
  - b. initiate flume studies in coordination with field studies to determine the effectiveness of various structures in different substrate types
  - c. consider alternative matting and/or vegetation strategies

The Ecosystem Enhancement Program staff have implemented various strategies to improve the success of riparian plantings for stream restoration projects. The strategies for improving vegetation success are summarized below by category:

1. poor seedling characteristics
  - a. the EEP staff have initiated more stringent bare root seedling and live stake specifications
2. poor planting techniques
  - a. the EEP staff require a licensed forester or landscape technician to monitor the planting
  - b. the EEP staff have altered the planting methods and payment to increase the success of the newly planted species
3. harsh substrate conditions
  - a. require soil testing and/or fertilization for floodplain and/or streambank species

Keywords: *stream restoration, maintenance costs, channel repair, riparian planting*

*About the speaker:*

**Mac Haupt** is currently the Monitoring Supervisor for the Ecosystem Enhancement Program. Previously, he was the Implementation Coordinator for the NC Wetlands Restoration Program. His undergraduate degree is in Biology from Wake Forest University and he has masters degrees from Appalachian State University (biology) and Duke University (environmental management). His areas of expertise includes wetland ecology with special emphasis in coastal wetland ecosystems, wetland hydrology, soil science, and stream restoration techniques.

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## **STREAM IMPACTS AND MITIGATION: A REGULATORY PERSPECTIVE**

McLendon, Scott

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Section 404 of the Clean Water Act through the 404(b)(1) Guidelines requires appropriate and practicable mitigation to compensate for the unavoidable impacts to streams and wetlands resulting from permitted activities. Although the practice of wetland mitigation has been conducted for many years in North Carolina, the restoration and enhancement of streams and adjacent riparian areas is less understood from both a design and success perspective, especially for projects implemented in urban watersheds. Several hundred thousand feet of streams have been restored or enhanced over the past several years in North Carolina to compensate for permitted impacts, and as monitoring of these projects continues, many questions regarding the success of these efforts will be generated. Currently, stream mitigation requirements will vary depending on the quality of the stream being impacted as well as the type and quality of the mitigation project that is proposed to compensate for these impacts. Many stream restoration projects are undertaken in urban areas however it has not been determined that these generally higher cost projects are accomplishing their stated goals. There is a need to adopt a watershed approach that provides incentives to control storm water quality and quantity in addition to traditional stream channel restoration. Finally, outside of some watershed planning efforts, there is no accepted process or procedure that identifies “good” stream restoration projects. Current monitoring requirements are weighted towards measures of structure or stability of the restored stream but fall short of providing information relative to the biological components of the restored channel. With the implementation of a large number of stream projects over a relatively short timeframe, there is also a need to develop a standard monitoring protocol that documents channel condition, information on growth and survival of riparian vegetation, and improvements in biological activity. As stream restoration efforts continue we must ensure that there is a continuing dialogue between stream designers, resource and regulatory agencies, and the public to ensure that these projects are designed, built and monitored according to the best and latest information to ensure that these efforts are adequately compensating for permanent stream losses.

*Keywords: stream restoration, watershed planning, mitigation, Clean Water Act*

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## **POSTER EXHIBIT**

### **THE FRENCH BROAD RIVER WATERSHED EDUCATION TRAINING CENTER**

Jon Calabria, L.A.

*NC State University Water Quality Group, Asheville, NC.*

Water quality is generally high in the French Broad River Basin, supporting state designations for trout waters, outstanding resource waters and high quality waters. During the development of the French Broad River Basinwide Management Plan, however, several water quality issues were identified and targeted for improvement. These issues included sedimentation, nutrients, toxic substances and oxygen-consuming wastes. Each one is related to nonpoint source pollution. The French Broad training center offers educational programs that address nonpoint source pollution and is emerging as a regional leader for effectively dealing with such water quality concerns.

Established in spring of 2001 as a partnership between North Carolina State University and The North Carolina Arboretum, the center is home to North Carolina State University scientists and field faculty who target water quality and quantity issues in Western North Carolina. In coordination with North Carolina State University's Soil and Water Environmental Technology Center, the French Broad River Training Center provides comprehensive nonpoint source educational programming to landowners, concerned citizens, natural resource managers and public officials. Educational programs offered through the center include environmental planning, conservation easements, agricultural and urban stormwater runoff management and erosion control.

The center is located at The North Carolina Arboretum in Asheville, NC. The Arboretum is a 426-acre public garden located within the Bent Creek Research and Demonstration Forest of the Pisgah National Forest. It is a place for education, research, conservation and garden demonstration. The Arboretum offers a wide range of activities for visitors of all ages and integrates both education and research as it elevates the aesthetic, cultural and economic quality of life in Western North Carolina. For additional information on this North Carolina treasure, visit [www.ncsu.edu/waterquality/](http://www.ncsu.edu/waterquality/).

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## POSTER EXHIBIT

### DEFINING AND IMPROVING STANDARDS IN ECOLOGICAL RESTORATION

Mark A. Taylor

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In the emerging field of ecological restoration, many of the standards needed to measure success and define quality designs and constructed projects have yet to developed. The problem is exacerbated not only by the relative infancy of the industry, but also by the fact that we are dealing with natural systems that are chaotic, dynamic, and subject to largely unpredictable man-made and natural processes and events.

Natural design methods developed in the arid western U.S. are being applied to the humid eastern states with uncertainty about what can be expected. Experts don't always agree on the degree of application of natural methods versus more conventional engineering approaches to riverine systems. These collective uncertainties lead to inconsistent approaches to project design and implementation, unmet expectations, and sometimes excessive or repetitive expenditures of limited resources, both fiscal and human, in a time of economic frugality.

The quality of any design or constructed project is typically measured against *standards*. Standards used to establish the minimum acceptable quality of design work products and constructed projects include: industry standard of care, regulatory standards (local, state, and federal), professional standards, client and contract-mandated standards, and industry standards (ANSI, ASTM, etc.). Standards must also rely on consistent and industry-specific definitions of terms. Examples of some important ecological restoration terms needing refinement or clarification include: "ecologically functional", "natural", "stable", "success" and "failure".

The author will endeavor to identify some of the most urgent needs for standardization in an effort to stimulate discussion, research and experimentation regarding the protocols for and measure of success of ecological restoration projects. The goal is to accelerate progress, ensure vitality and maximize cost-effectiveness in an industry that will determine whether or not real progress is made toward preventing and/or mitigating the negative impacts of human activity on our ecosystem.

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## POSTER EXHIBIT

### Urban Stream Restoration Using a Natural Channel Design Approach

Barbara A. Doll<sup>1</sup>, Daniel R. Clinton<sup>2</sup> James W. Jenkins, Jr.<sup>3</sup>, Jan M. Patterson<sup>3</sup>, N. Jill Coleman<sup>4</sup>

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Urban development takes a heavy toll on creeks, streams, and rivers throughout the nation. A broadening landscape of impervious surfaces - parking lots, roads, and rooftops - causes excess stormwater to course through stream channels. Urban development also frequently consumes floodplain area, severely restricting space for stream channels. Increased impervious surfaces combined with channel constriction can result in streambank erosion with each rain event.

Thousands of miles of streams in North Carolina are unstable and eroding, contributing large volumes of sediment to many stream systems. Traditionally, culverts, concrete, and riprap have been used to armor eroding urban streams. However, these approaches are costly and can destroy aquatic habitats along with the natural beauty of the stream. In contrast, natural channel design, a more recent technology, works to establish a stable dimension, pattern and profile based on fluvial geomorphology principles.

This presentation will feature a natural channel design restoration project on a highly urbanized stream in North Carolina. Rocky Branch is a highly degraded stream located on the North Carolina State University campus in Raleigh, N.C. Phase I of this project involves restoring 3,300 feet of creek using natural channel design concepts. In addition, the project includes 16-innovative stormwater controls and a wet detention basin to improve water quality. Two of the three culverts within the project were replaced and floodplain culverts were added to provide a more hydraulically efficient passage for storm flows. An existing sewer line was relocated to allow for greater belt-width of the restored channel. Riparian buffers were restored, a greenway path constructed, and access paths to the stream were installed for educational purposes. The design addressed adjustments to morphologic features, including riffle-pool sequence, bankfull channel dimension, floodplain width, meander geometry, sinuosity, and slope. Construction of this phase was completed in May 2002.

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## POSTER EXHIBIT

### THE “GREENER” GENERATION OF THE U.S. ARMY CORPS OF ENGINEERS: STREAM RESTORATION IN THE NATION’S CAPITAL

Mary Pittek<sup>1</sup>, Carey Nagoda<sup>1</sup> and Stacey Sloan Blersch<sup>1</sup>

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Under Section 206 of the Water Resources Development Act, the U.S. Army Corps of Engineers (USACE), Baltimore District is proposing to enhance habitat and improve environmental conditions of several streams in the Washington, D.C. area. This authority allows the USACE to study, design and construct aquatic ecosystem restoration and protection projects if the project will improve the quality of the environment, is in the public interest, and is cost effective. Each project is limited to a Federal cost of not more than \$5 million, which includes project-related costs for feasibility studies, planning, engineering design and construction. The Federal government will share these costs with a non-Federal partner at 65% Federal and 35% Non-Federal.

The District of Columbia, our national’s capital, is a heavily urbanized metropolitan center with a long history of ecological problems. Increasing population, changes in land use and land cover, continual losses of forest and wetland habitat, alterations of streamflow, sewage system leaks and non-point source pollution have all contributed to the degradation of streams in the D.C. area. Because the problems are so complex, successful restoration efforts require the cooperation and collaboration of many stakeholders, including resource agencies (Federal, state and local), landowners, and the public.

The Baltimore District is active in several collaborations, which include the Watts Branch, Pope Branch and Fort Dupont Aquatic Ecosystem Restoration Projects. Watts Branch, a stream with erosion and debris problems, is severely degraded and lacks valuable in-stream habitat. Public interest is high in restoring Watts Branch, as 60,000 residents live within one mile of the narrow park that surrounds the stream. The USACE is planning to enhance the riparian buffer and restore the stream’s geomorphology using natural stream channel design. Pope Branch, another degraded tributary of the Anacostia River, contains major fish blockages, inadequate stormwater management, poorly maintained culverts and infrastructures, and reaches that are piped underground. The Pope Branch restoration effort includes improving in-stream habitat, possible development of wetlands for treatment of nearby railroad runoff, and environmental education. Fort Dupont, located in the highly urbanized SE quadrant of Washington D.C., is also a degraded stream system containing many fish blockages. Just upstream of the Anacostia River, it is piped underground, limiting anadromous fish migration. The USACE restoration design for Fort Dupont includes daylighting the lower portion of the stream to restore tidal influence and wetland/ tidal gut creation. Upstream improvements include natural stream channel design, bank stabilization, and bioretention/filtration of stormwater.

While the science and engineering of stream restoration is still evolving, it is important to share lessons learned during the process. Do adequate research to understand the problem and determine the causes. Take a holistic watershed approach. Assess project limitations, such as utilities or future

development, early on in the feasibility study process. Practice open communication with all stakeholders throughout the entire restoration effort. Understand the customer's expectations and priorities.

Keywords: *stream, restoration, urban, erosion, fish blockages*

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## POSTER EXHIBIT

### ASSESSMENT AND RESTORATION OF AN URBANIZED CREEK SYSTEM IN THE GEORGIA PIEDMONT

Jason D. Evert<sup>1\*</sup>, David Pizzi<sup>2</sup>, and Gregory D. Sousa<sup>3</sup>

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The U.S. Army Corps of Engineers, Mobile District initiated a study of the Shoal Creek watershed (Spalding County, Georgia) to investigate the feasibility of restoring instream aquatic habitat. The project was funded under the authority of Section 206 of the Water Resources Development Act of 1996. Shoal Creek lies within the Flint River basin, and the upper portion of the Shoal Creek watershed exists within the city limits of Griffin, Georgia (population 23,451). Growth and development of the city and surrounding areas, due in part to the southward expansion of the Atlanta metropolitan area, has affected stream morphology as demonstrated by substantial streambank erosion, deeply incised channels, and excessive instream deposition. Hydrologic impacts of stormwater runoff from the urbanized portion of the watershed have destabilized considerable reaches of Shoal Creek. Sediment generated from the unstable channel morphologies has led to embedded substrates, limited velocity/depth combinations, and reduced epifaunal substrate and in-stream cover. These factors effectively homogenized and degraded in-stream habitats, and seriously impaired the ecological integrity of the stream. Based on biomonitoring protocols developed by the Georgia Department of Natural Resources for fishes and macroinvertebrates, Shoal Creek's biological integrity was categorized as "poor" and "very poor," respectively. Because measurements of various water quality parameters were within state standards, it appears that degraded in-stream habitat, rather than impaired water quality, was responsible for the presence of communities with poor biological integrity. Therefore, restoration of ecological integrity in Shoal Creek would occur as a result of improving the quality of instream and riparian habitats. The ecological benefits associated with various restoration measures (e.g., flow detention facilities, sediment traps, stream bank protection, and stream restoration) on parameters indicative of habitat quality can be projected and compared to most effectively target restoration efforts.

Keywords: *Georgia, Section 206, assessment, restoration, stream, sedimentation, habitat, biomonitoring*

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International Paper  
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Kimley-Horn and Associates  
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Mellow Marsh Farm  
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RIVERMorph, LLC  
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