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Stream Functions Pyramid

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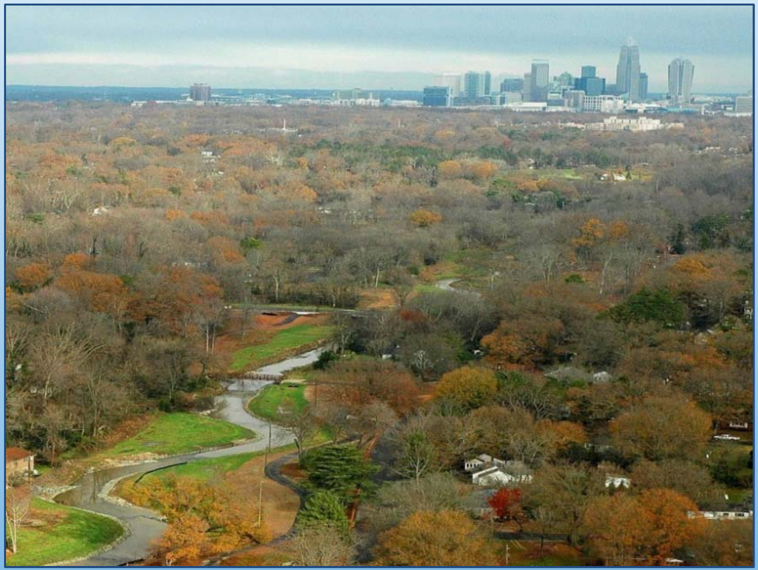
www.stream-mechanics.com

We are at a 2nd Crossroad

Crossroad # 1

Traditional Channel Design

Transport water quickly; Bed and banks don’t move



Natural Channel Design

Create a dimension, pattern, and profile that transports water and sediment.

Crossroad # 2

Restoration of Dimension, Pattern, and Profile → Restoration of **Functions**

What is a Stream Function?

“The physical, chemical, and biological processes that occur in ecosystems,” Clean Water Act (33 CFR 332.2; 40 CFR 230.92)

“ The processes that create and support a stream system.“ EPA Region 10

Stream Function and Structure

- Structural measures evaluate stream condition at a point in time
  - Channel Form, Habitat Features, Number of Species
  - Describes "How the System Is."
- Functional Attributes describe processes and **rates (per unit time)**
  - Describes how the system is performing

Source: Palmer and Bernhardt, 2009

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A Guide for Assessing & Restoring Stream Functions » OVERVIEW

5 **BIOLOGY** » *Biodiversity and the life histories of aquatic and riparian life*

4 **PHYSIOCHEMICAL** » *Temperature and oxygen regulation; processing of organic matter and nutrients*

3 **GEOMORPHOLOGY** » *Transport of wood and sediment to create diverse bed forms and dynamic equilibrium*

2 **HYDRAULIC** » *Transport of water in the channel, on the floodplain, and through sediments*

1 **HYDROLOGY** » *Transport of water from the watershed to the channel*

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A Guide for Assessing & Restoring Stream Functions » FUNCTIONS & PARAMETERS

5 BIOLOGY »
FUNCTION: *Biodiversity and the life histories of aquatic and riparian life*
PARAMETERS: ***Primary and Secondary Production,*** *Macroinvertebrate Communities, Fish Communities, Riparian Communities, Landscape Pathways*

4 PHYSIOCHEMICAL »
FUNCTION: *Temperature and oxygen regulation; processing of organic matter and nutrients*
PARAMETERS: *Dissolved Oxygen,* ***Temperature Regulation,*** *pH, Conductivity,* ***Nutrient Processing, Organic Processing,*** *Turbidity*

3 GEOMORPHOLOGY »
FUNCTION: *Transport of wood and sediment to create diverse bed forms and dynamic equilibrium*
PARAMETERS: ***Sediment Transport Capacity*** *and Competency, Channel Evolution,* ***Streambank Erosion Rates,*** *Percent Riffle and Pool, Depth Variability, Substrate Distributions,* ***Large Woody Debris Transport and Storage,*** *Riparian Vegetation density and composition*

2 HYDRAULIC »
FUNCTION: *Transport of water in the channel, on the floodplain, and through sediments*
PARAMETERS: *Velocity, Shear Stress, Stream Power, Bank Height Ratio, Entrenchment Ratio, Rating Curves (****discharge*** *vs. stage),* ***Groundwater/Surface Water Exchange***

1 HYDROLOGY »
FUNCTION: *Transport of water from the watershed to the channel*
PARAMETERS: *Precipitation/****runoff*** *relationship, Channel Forming Discharge, Flood Frequency,* ***Flow Duration***

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3

GEOMORPHOLOGY »

FUNCTION: *Transport of wood and sediment to create diverse bed forms and dynamic equilibrium*

PARAMETERS: ***Sediment Transport Capacity*** *and Competency, Channel Evolution,* ***Streambank Erosion Rates****, Percent Riffle and Pool, Depth Variability, Substrate Distributions,* ***Large Woody Debris Transport and Storage****, Riparian Vegetation density and composition*

2

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HYDROLOGY »

FUNCTION: *Transport of water from the watershed to the channel*

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Parameters in ***bold*** *are also functions*

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5

BIOLOGY »

FUNCTION: *Biodiversity and the life histories of aquatic and riparian life*

PARAMETERS: ***Primary and Secondary Production***, *Macroinvertebrate Communities, Fish Communities, Riparian Communities, Landscape Pathways*

4

PHYSIOCHEMICAL »

FUNCTION: *Temperature and oxygen regulation; processing of organic matter and nutrients*

PARAMETERS: *Dissolved Oxygen*, ***Temperature Regulation***, *pH, Conductivity*, ***Nutrient Processing***, ***Organic Processing***, *Turbidity*

*Parameters in **bold** are also functions*

Why do we need the Pyramid?

- So we don’t incentivize this result and we think about what we’re trying to achieve.

- So we don't miss key functions and processes during the design process.

- So we don’t do this!

Why are we struggling with success?

- We don’t ask **why.**
  - We don’t link functional lift to functional loss.
- Because we don’t focus on **what** functions can be improved and **how** to restore those functions.
- We don’t align the site selection with the functional goals.
  - We’re not going to fully restore biological functions with severely degraded watersheds and patchwork restoration.

So, what do we do?
How can we use the Pyramid to help?

To Create Better:

- **Goals and Objectives**
- **Function-Based Assessment Protocols**
- **SOP's**
  - **Debit and Credit Determination Methods**
  - **Success Criteria**
  - **Performance Standards**

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To Create Better Goals and Objectives

- **Common Goal**
  - Create a stable dimension, pattern and profile so that the channel doesn't aggrade or degrade
- **Better Goal**
  - Reduce sediment supply to improve native fish populations:
    - Restore floodplain connectivity,
    - Reduce streambank erosion,
    - Improve bedform diversity, and
    - Establish a riparian buffer.

Objectives

Functional Drivers for C and E Stream Types

- Floodplain Connectivity
- Bedform Diversity
- Streambank Erosion (Lateral Stability)
- Riparian Buffer
- Site Selection

Requires

Appropriate Watershed Condition.
Adequate hydrology functions.
Reach scale versus watershed scale understanding.

Quantitative Objectives

- Floodplain Connectivity
  - Reduce bank height ratios from 2.0 to 1.0.
  - Increase entrenchment ratio from 1.2 to 3.0.
- Bedform Diversity
  - Convert riffle dominated bedform (95% riffle) to riffle-pool sequence (70/30).
- Streambank erosion
  - Reduce erosion rates by 95%.
  - Reduce erosion rates to reference reach condition.
- Riparian Buffer
  - Increase buffer width from 0 feet to 50 feet.

Framework for Function-Based Assessments

- Functional Assessments
  - Focus on parameters listed in pyramid
  - Acknowledge the hierarchy
  - Tailor to different regions

Assessments for Different Reasons

- Mitigation Related
- Departure from Stability and Restoration Potential
- Watershed Management and Planning

Assessments for Different Reasons

- Mitigation Related
  - Assess lost functions at permitted impact site
  - Assess functional lift at mitigation site
  - Basis for credit determination and performance

Assessments for Different Reasons

- Departure from Stability and Restoration Potential
  - Hydrologic Changes
  - Geomorphic Assessments
  - Physiochemical and Biological Health
  - Restoration Potential
- Watershed Management and Planning

Assessments for Different Reasons

- Watershed Management and Planning
  - Watershed scale
  - ID healthy sub-watersheds
  - ID unhealthy sub-watersheds / reaches and the stressor
  - Develop management plan to restore functions
    - Use all appropriate tools, like restoration, BMPs, preservation, etc.

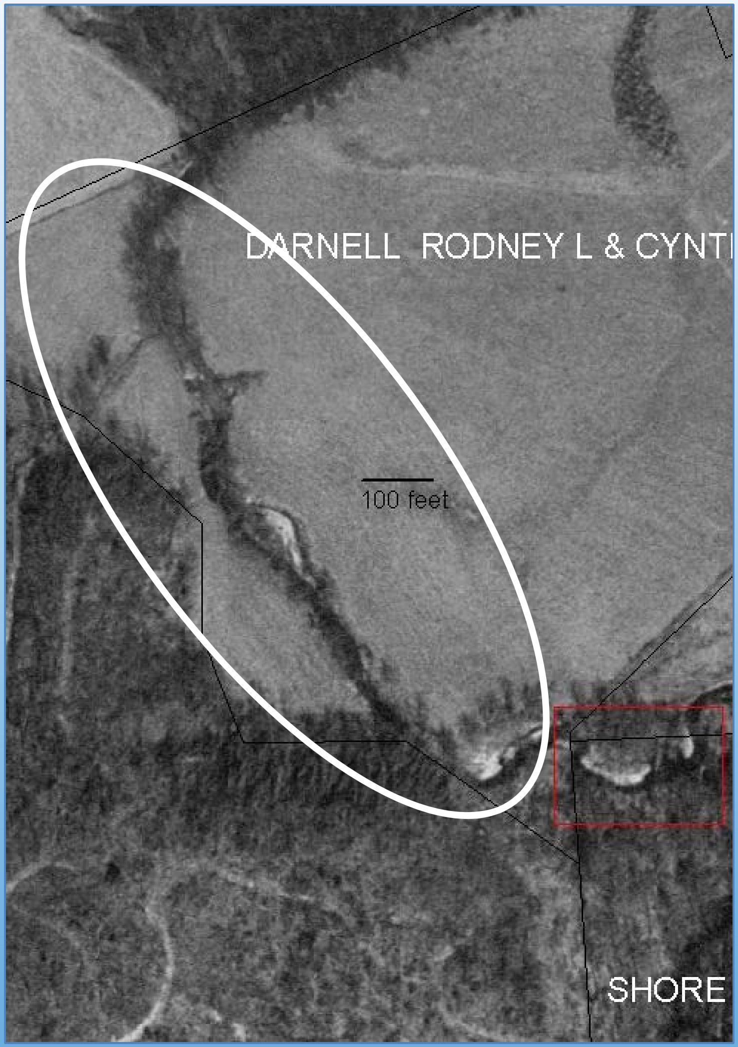
Framework for Mitigation SOPs

- SOPs
  - Move from restoration of dimension, pattern, and profile to functions.
  - Better link between impact site and mitigation site.
  - Applies to:
    - Debit and Credit Determination Methods
    - Functional Assessment
    - Performance Standards

Rural Piedmont: South Fork Mitchell River Darnell / Harman Reach

- Not a mitigation project
- Funded by the NC Clean Water Management Trust Fund
- Mitchell River Watershed Coalition and Surry Soil and Water Conservation District
- Watershed scale effort
- Design by Michael Baker Corporation

Pre-Restoration Condition



Widespread bank erosion
Channel is re-adjusting pattern

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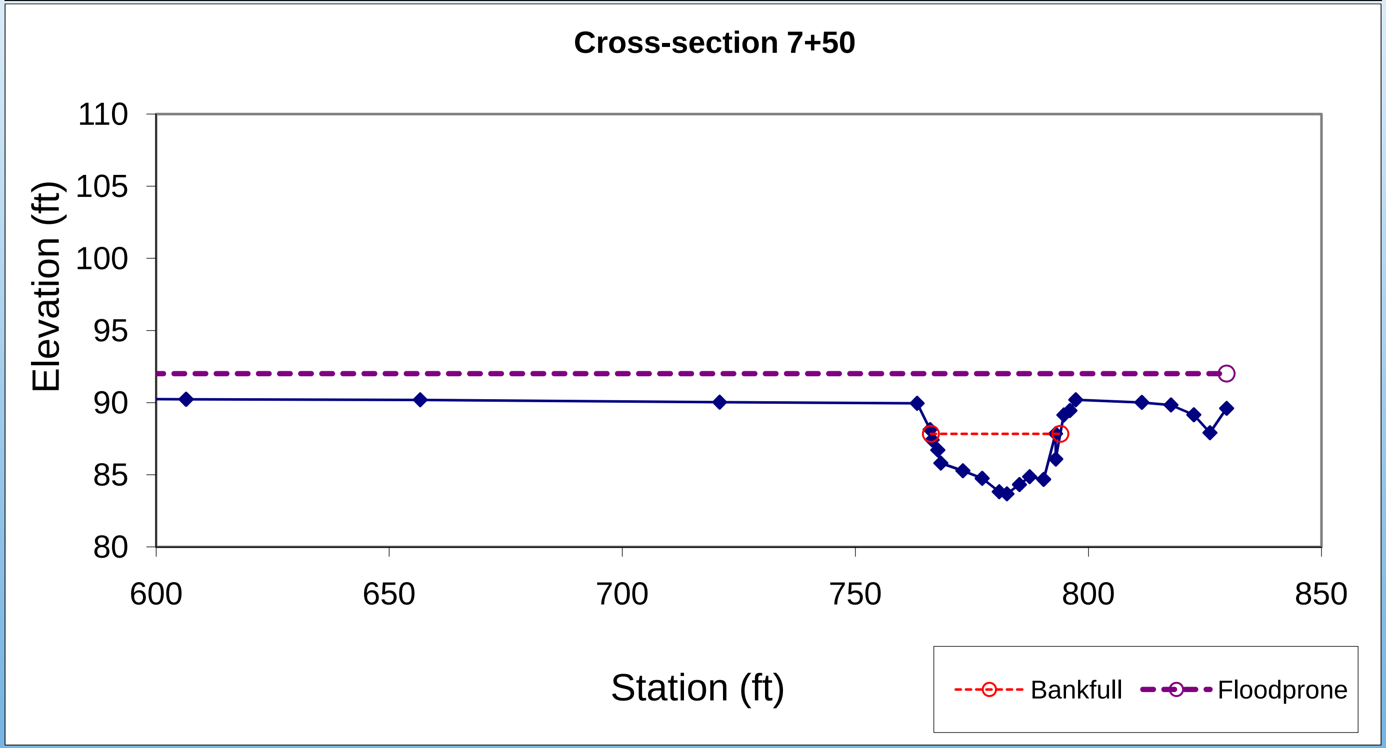
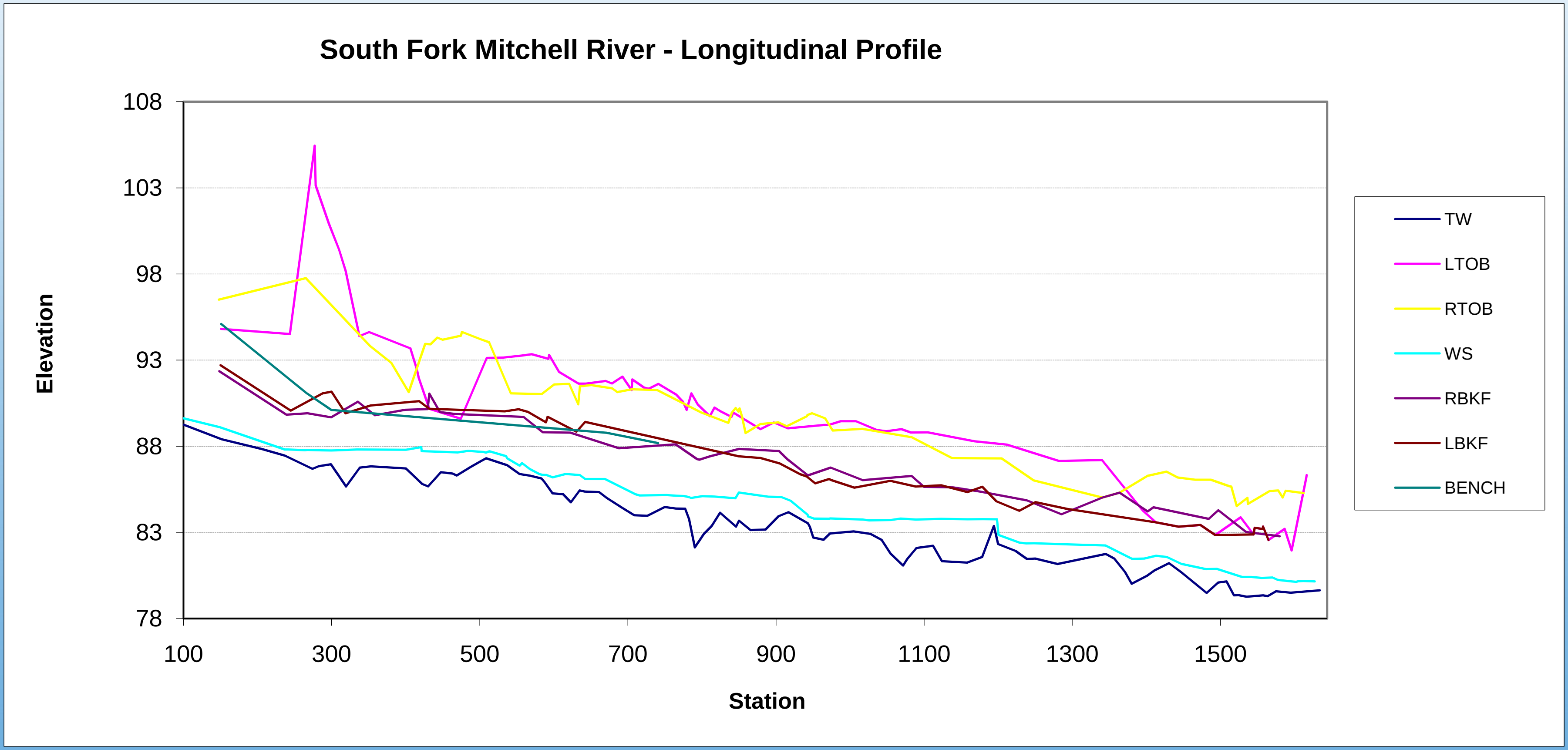
Pre-Restoration Condition

Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Riffle		76	27.77	2.74	4.16	10.15	1.5	>357.20	87.84	89.95



Moderately Incised. BHR = 1.5

Pre-Restoration Profile



Functional Lift

- Hydrology
- Hydraulic
- Geomorphic
- Physiochemical
- Biological

Hydrology

- No lift
  - No change in rainfall / runoff relationship
  - No change in design discharge (bankfull)
  - No change in flow duration

Hydraulics

- Floodplain Connectivity
  - Bank Height Ratio reduced from **1.5 to 1.0**
  - Entrenchment ratio did not change
- Flow Dynamics
  - Reduced average channel velocities
  - Reduced shear stress from 0.85 to 0.67 lbs/sqft
  - Reduced stream power

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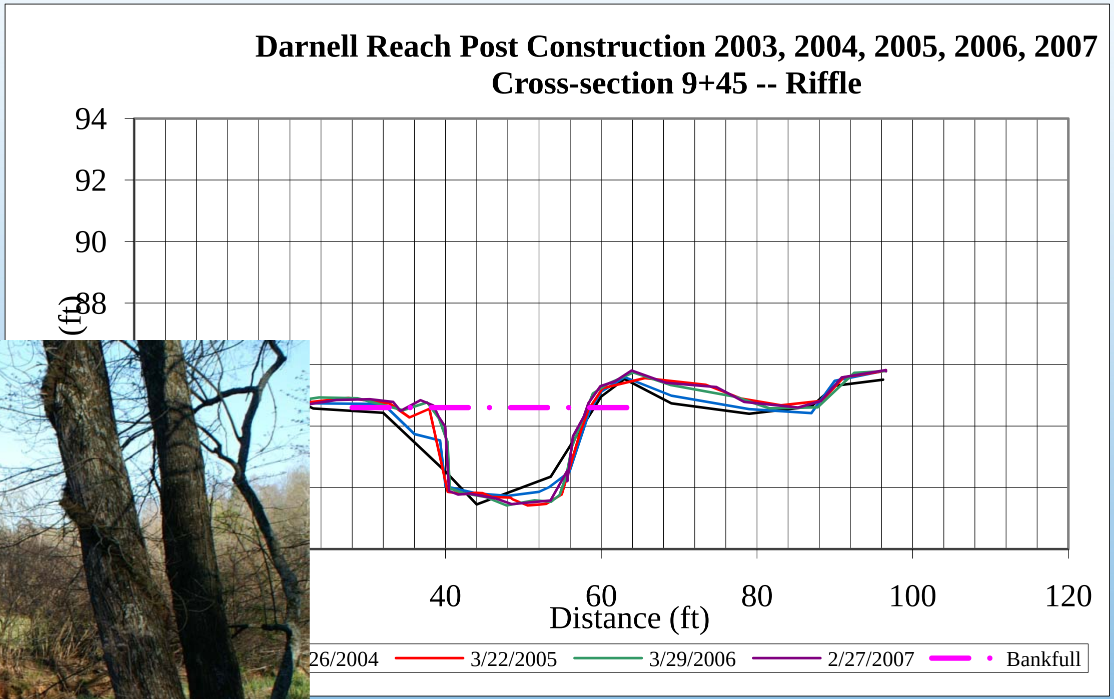
Floodplain Connectivity

Before

After

Floodplain Connectivity



Geomorphic

- Sediment Transport Competency
  - Reduced average depth from 3.4 to 2.5
  - As-built depth matches required depth
- Sediment Transport Capacity
  - Not quantitatively assessed

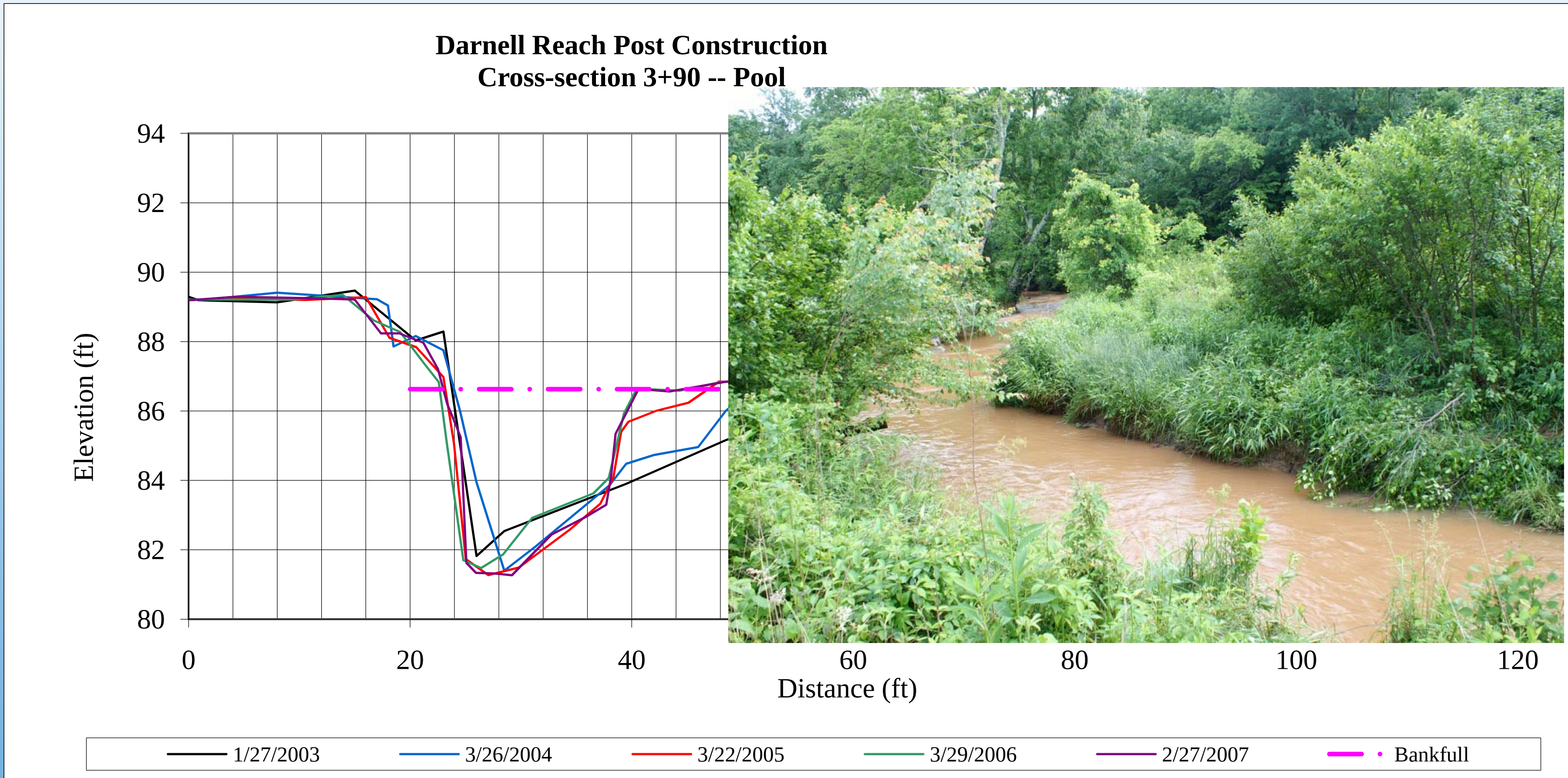
Geomorphic

- Channel Evolution
  - Pre-restoration condition
    - E moving towards a Gc – F – C –E
  - Restored to a C/E

Geomorphic

- Lateral Stability
  - Did not do before and after BEHI assessments, which could be used for functional lift
  - Used cross section surveys to show lateral stability after restoration construction.

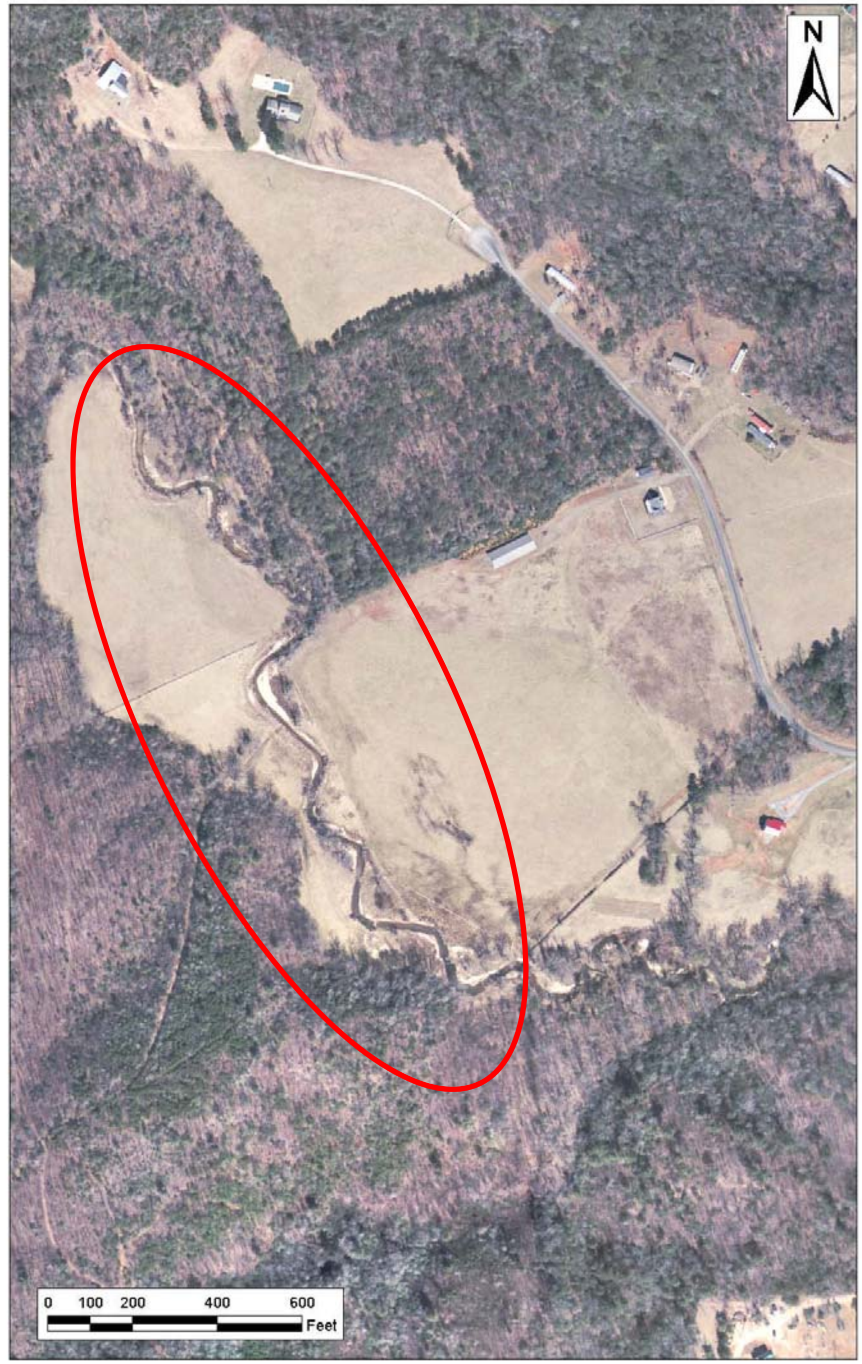
Lateral Stability



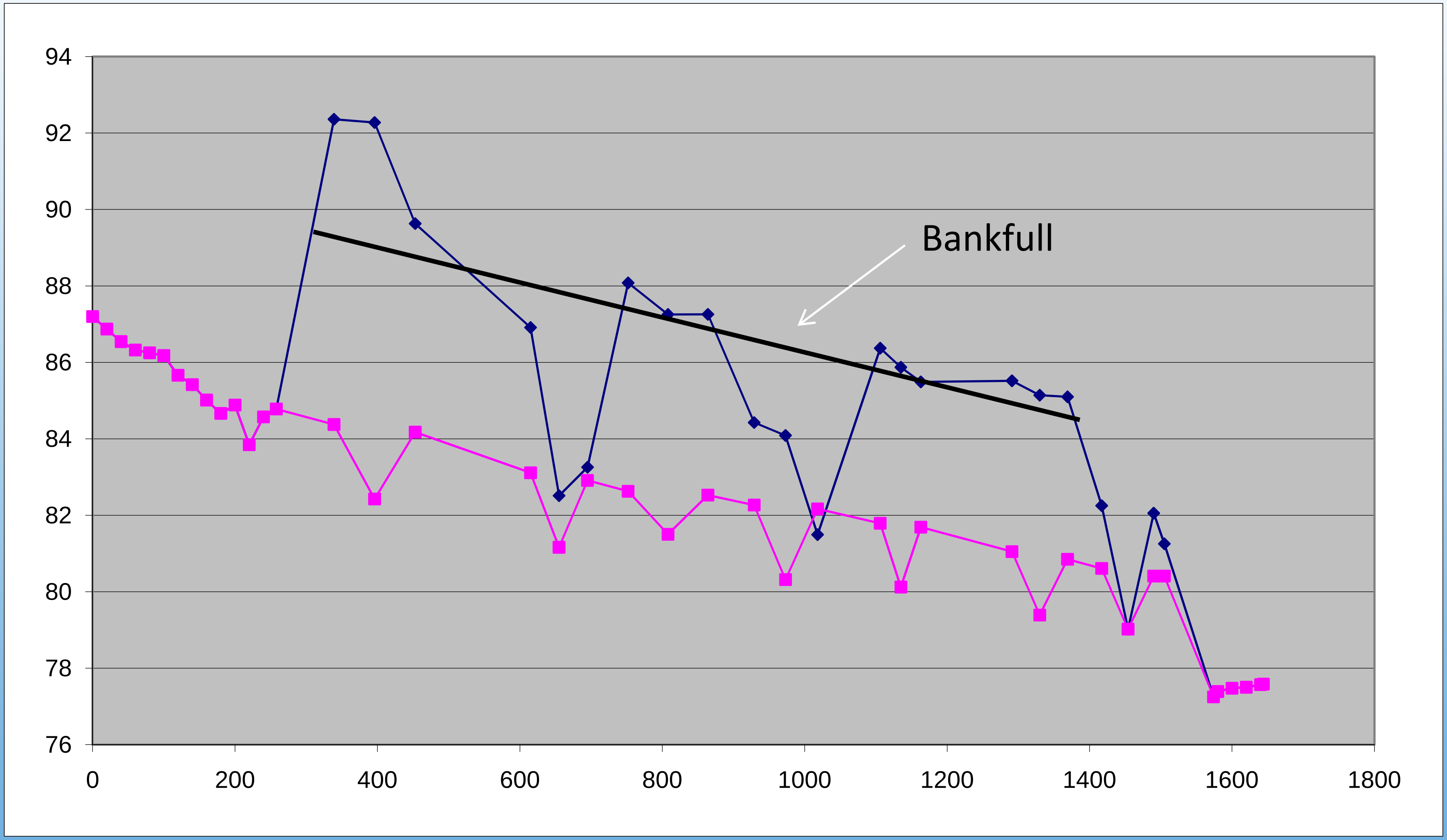
Bed Form Diversity

- Percent Riffle and Pool
- Pool Depth Variability
- Substrate Distributions

Rosgen Priority 1



Profile Design



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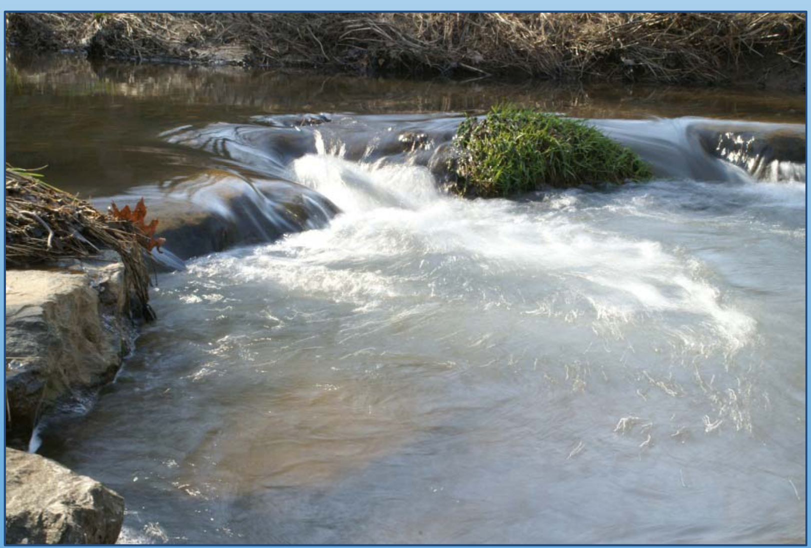
Profile After Restoration



Percent Riffle and Pool

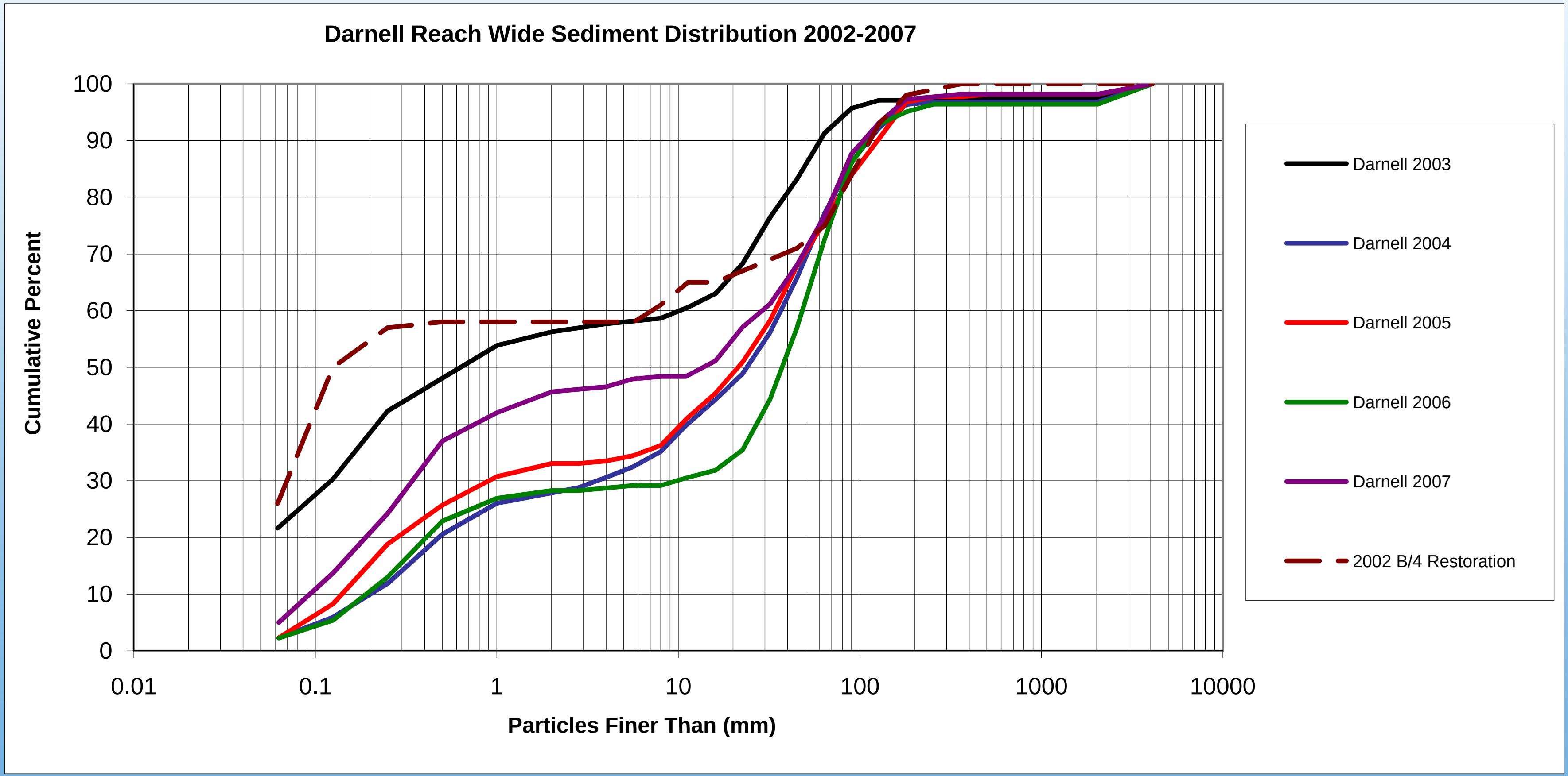
Bed Form	Before Restoration Percentage	Year 5 Restoration Percentage
Riffle	51	46
Pool	49	54

Cross Vane Too High

Downstream Cross Vane

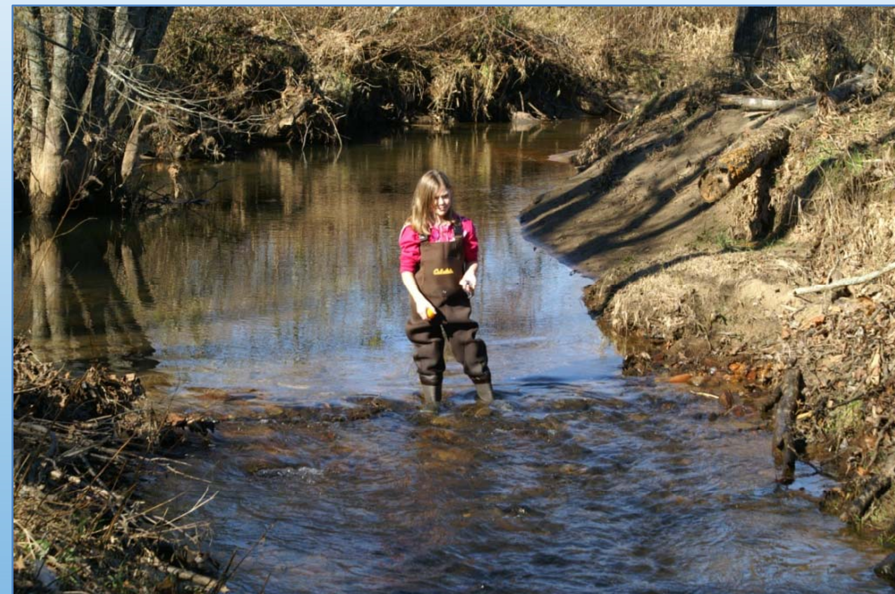
Upstream Riffle

Substrate Variability



Pre and Post Beaver Dam

Summer 2008



Winter 2008

Physiochemical Functional Lift

- Not measured
  - DO
  - Temperature
  - pH
  - Conductivity
  - Nutrients
- Discussion

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Biological Functional Lift

- Primary Production – not measured
- Macroinvertebrate Communities
  - Ken Bridle, Ecologic
- Fish Communities
  - Stamper Aquatics
- Riparian Communities

Macroinvertebrate Communities

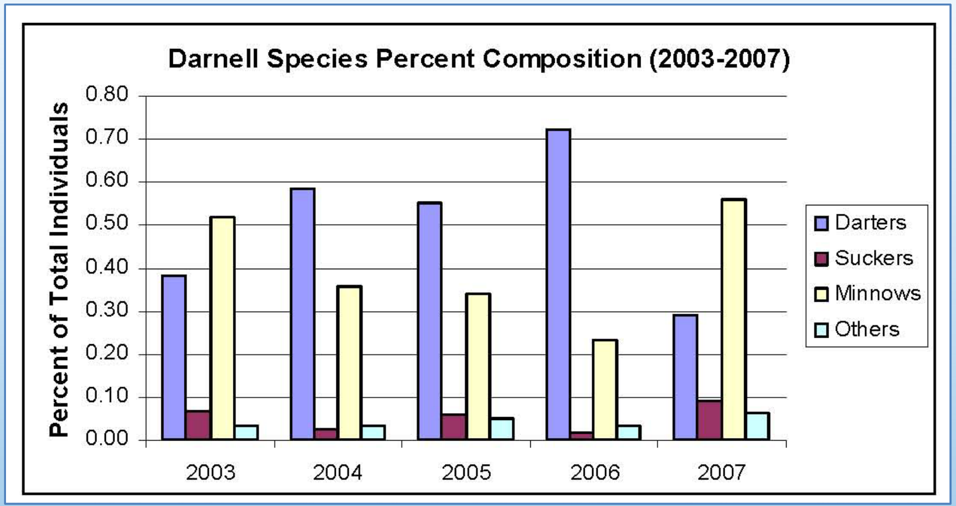
Total Number of Taxa

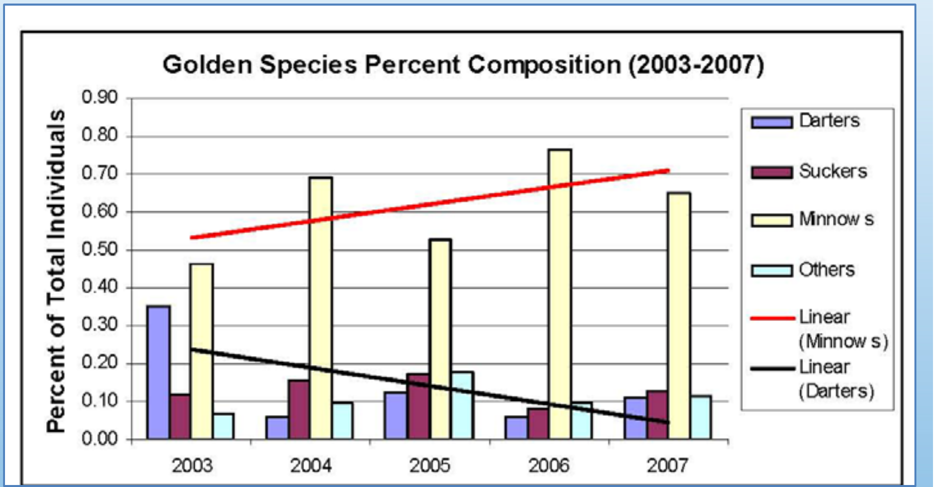
Station	2003	2004	2005	2006	2007
Project	35	54	46	31	51
Downstream	39		48		35

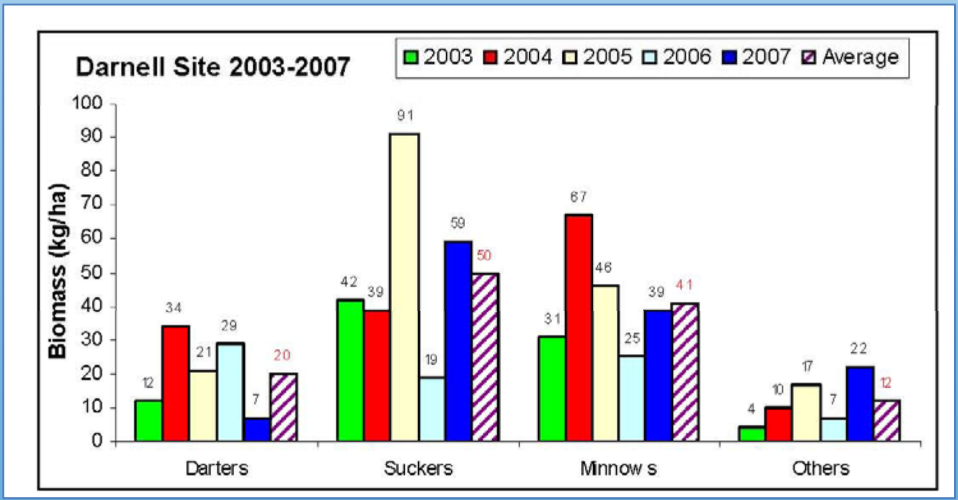
Total Number of Organisms

Station	2003	2004	2005	2006	2007
Project	135	294	278	149	286
Downstream	186		362		184

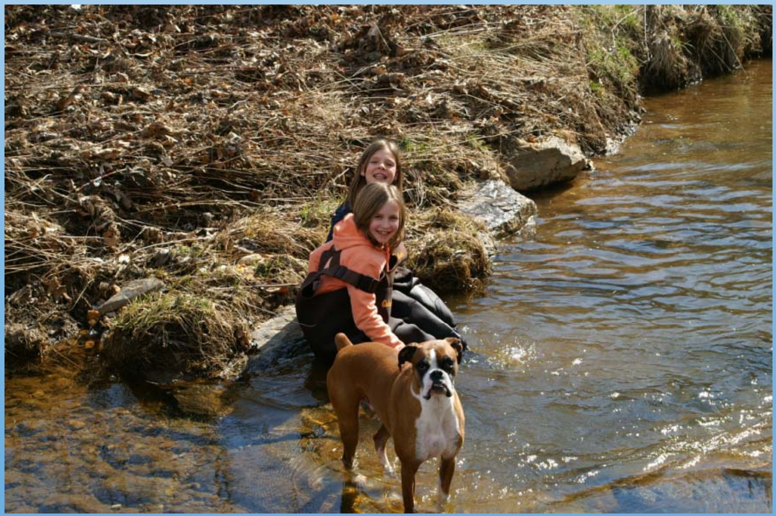
Fish Communities







Volunteer Monitoring 2007-8



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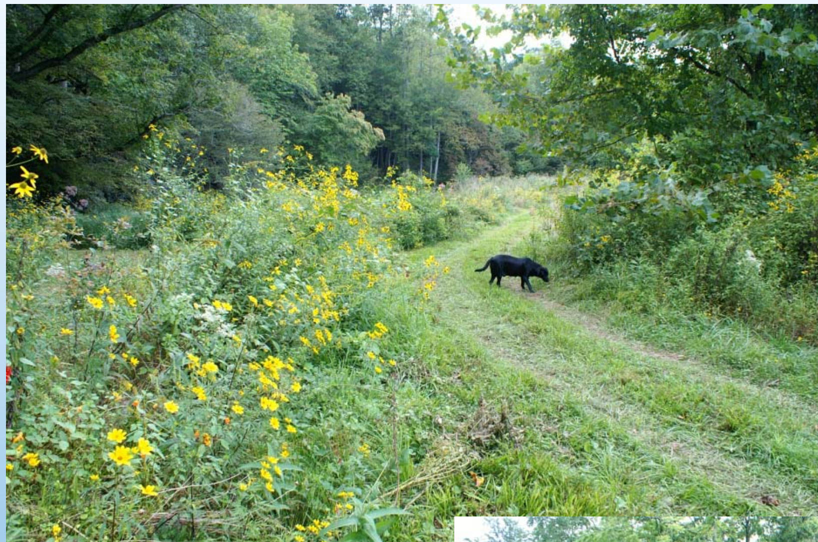
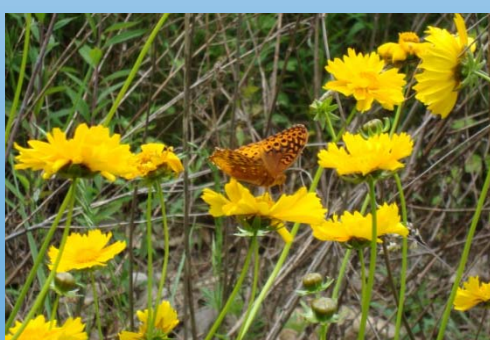
Riparian Communities

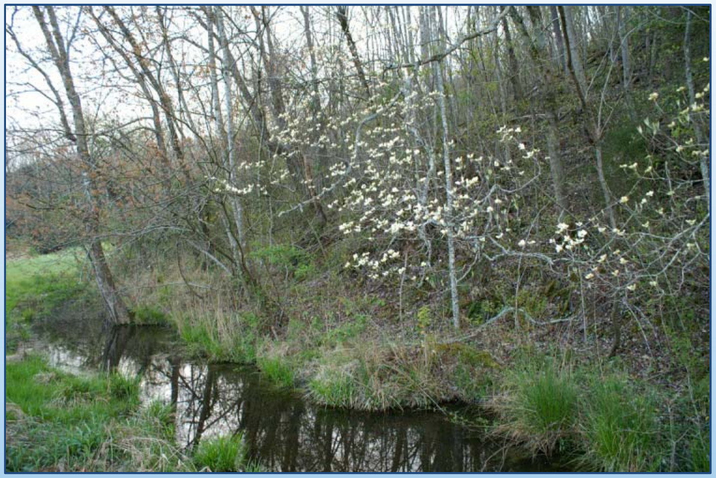


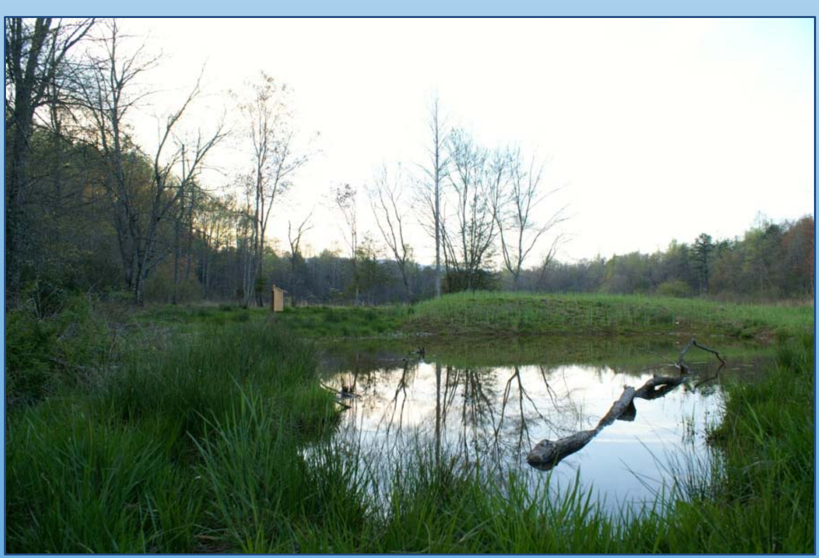


Riparian Communities

Table 4.9. Darnell Reach Vegetation Monitoring Plot Stem Count			
Tree Species	**2004 Stem Count**	**2005 Stem Count**	**2006 Stem Count**
Prunus serotina, Black cherry	0	6	8
Diospyros virginiana, Persimmon	3	3	3
Platanus occidentalis, Sycamore	9	11	10
Acer rubrum, Red maple	2	10	3
Liriodendron tulipifera, Tulip poplar	3	8	7
Juglans nigra, Black walnut	1	1	1
Fraxinus pennsylvanica, Green ash	0	1	0
Nyssa sylvatica, Black gum	3	0	0
Total Stems	**21**	**40**	**32**
Stems/Acre	**378**	**720**	**576**

Wetland Communities





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Volunteer Wetland Monitoring

Fun for the whole family …

Mountain Stream Example
Mitchell River, Mickey Reach

- Drainage Area = 0.45 square miles
- Channel Slope = 3.5%
- Bankfull Discharge = 55 cfs
- Bankfull Cross Sectional Area = 14 ft^2
- D50 = 31 mm (Coarse gravel)
- Rosgen Stream Type = B4
- Design by Michael Baker Corporation

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Existing Condition

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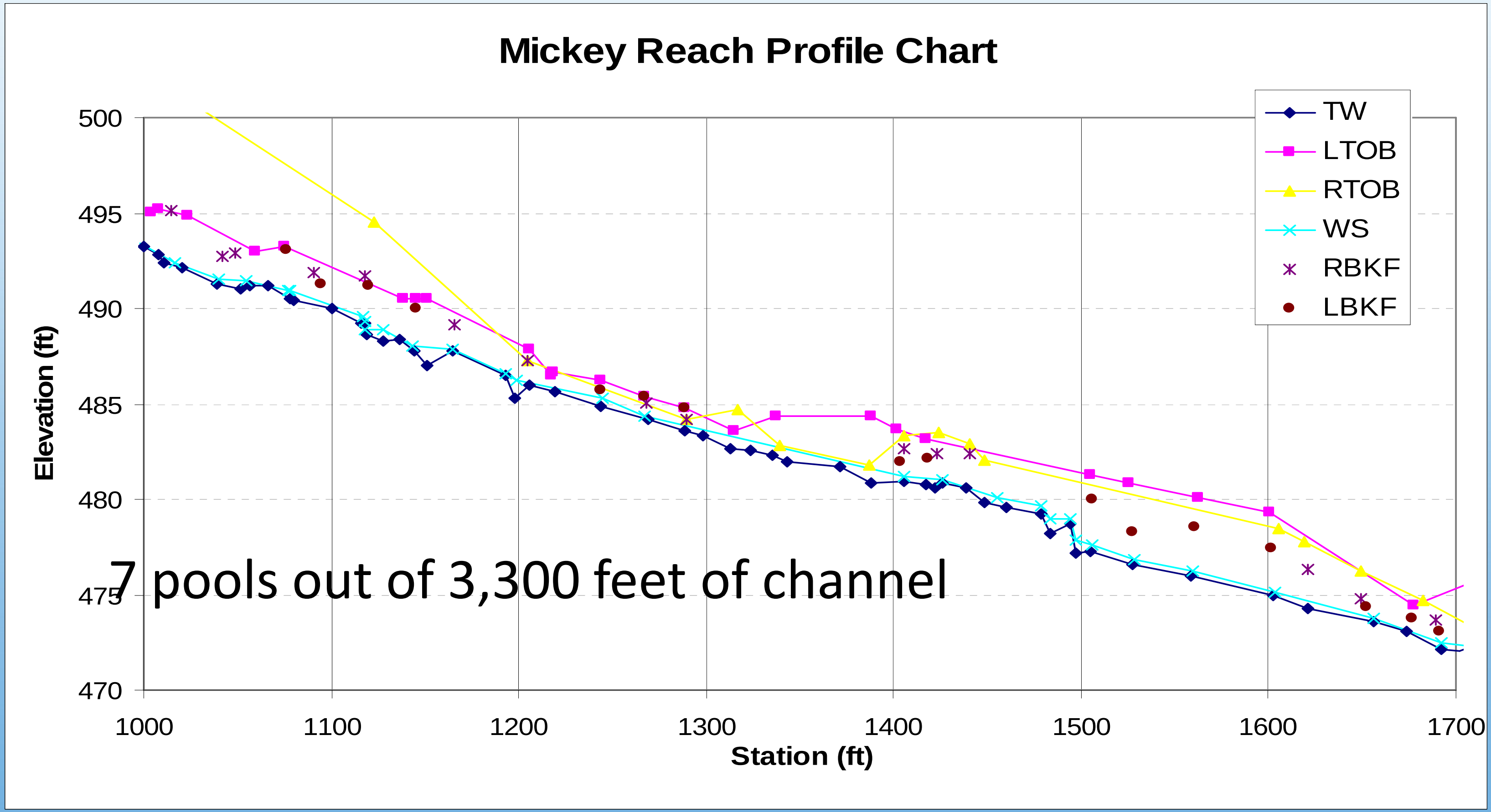
Before Restoration Profile




Before


2005


2004

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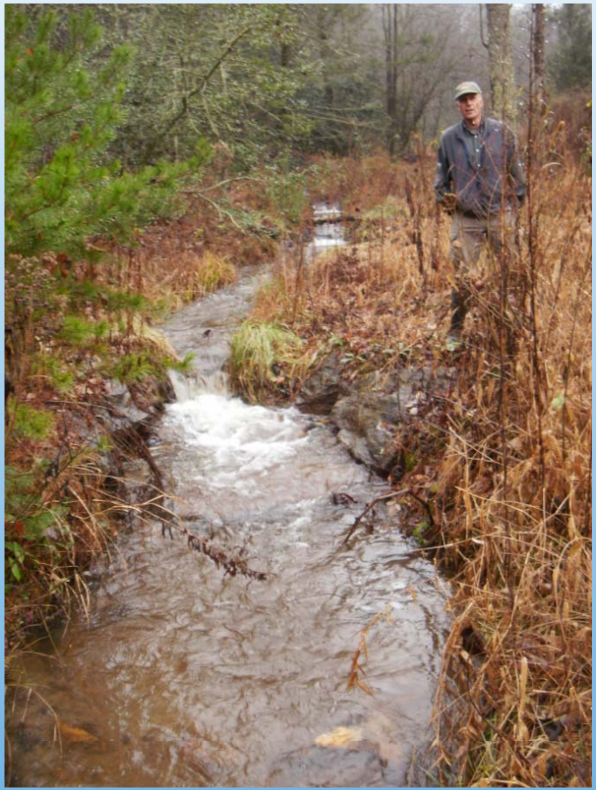
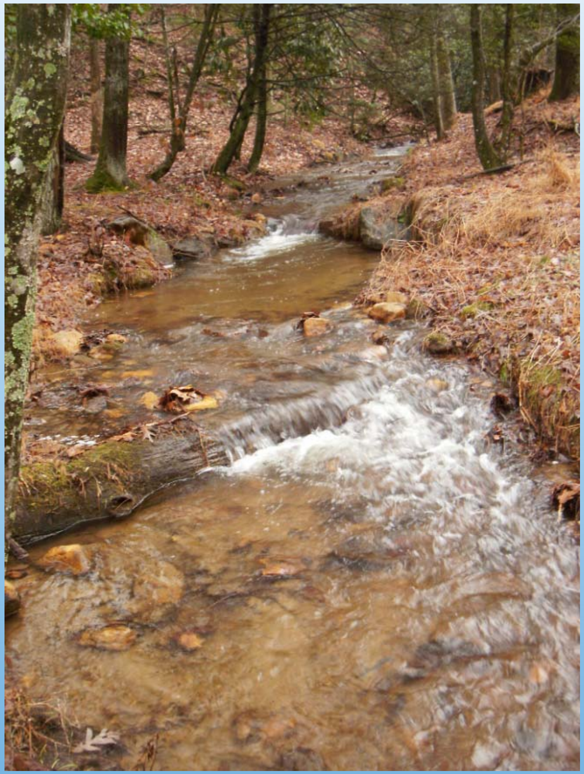
2009 Photos





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Pool to Pool Spacing / Bankfull Width and Total Number of Pools

Year	Min	Max	Total #	
2002	1	>100	7	Existing Condition
2003	2	16	29	As-built Condition
2005	0.5	9	53	
2006	0.5	9	50	
2007	0.6	8	48	

Lower end of project

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Riparian Buffer

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Functional Summary

- Improved floodprone area connection in lower reach.
  - Converted G to B
- Improved bed form diversity
  - 7 pools to ~50 pools
  - Maintained pool to pool spacing
- Improved wetland / bog
- Created riparian buffer

Thank You