


Stream Restoration as a Water Quality BMP

Presented at the Florida Stormwater Association Conference | June 13, 2024




Agenda

1. Causes of Stream Impairment
2. Stream Morphology and Channel Evolution
3. Restoration Benefits (including Nutrient Reduction!)
4. Quantifying Annual Sediment Loss and Nutrient Load
5. Case Studies
6. Restoration Strategies

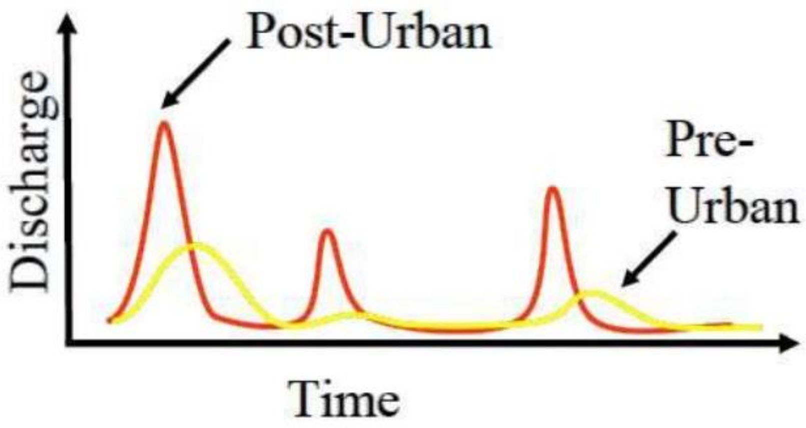
Stream Restoration

Stream Restoration is often defined as:

- The act or process of returning the stream corridor, including the floodplain and riparian corridor, to its original condition by removing the impact in support of biodiversity, recreation, water quality, flood management and landscape development.

Causes of Impairment

Increased Peak Discharges



Causes of Impairment

Floodplain Encroachment

1957

Today

Causes of Impairment

Floodplain Encroachment

Causes of Impairment

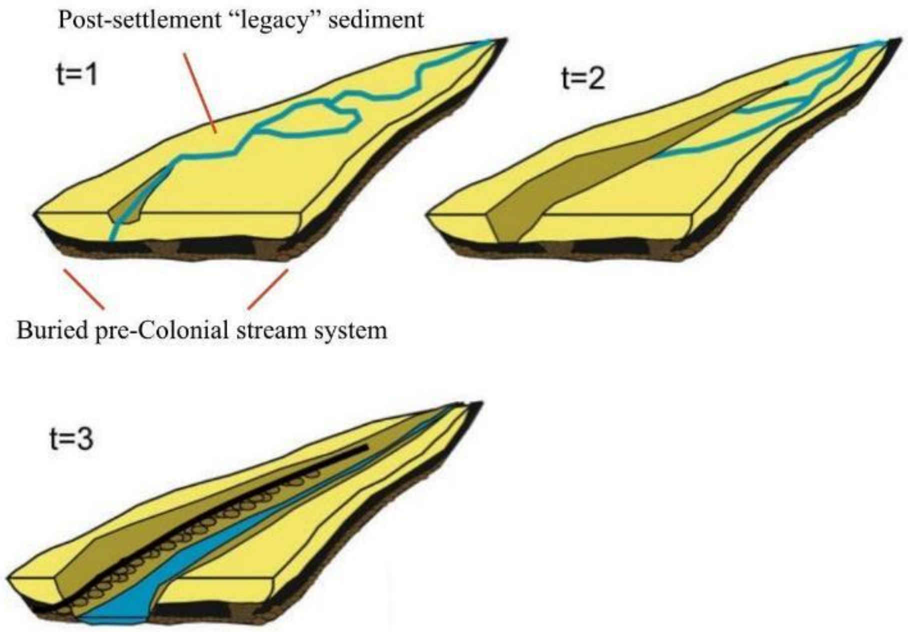
Removal of Natural Bank and Bed Controls or Erosion through Them

Dense baldcypress roots

Densely compacted organic material exposed from downcutting

Causes of Impairment

Legacy Sediment



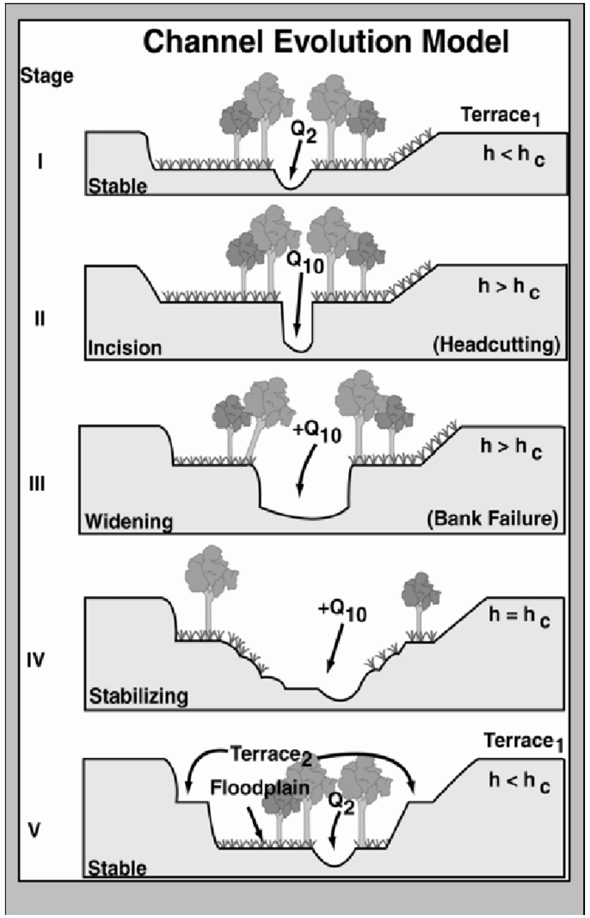
- Time 1: Perched Stream (disconnected from floodplain)
- Time 2: Channel Incision and Bank Widening (after dam breach or increased peak discharge)
- Time 3: Channel incises to depth of original base control

Causes of Impairment

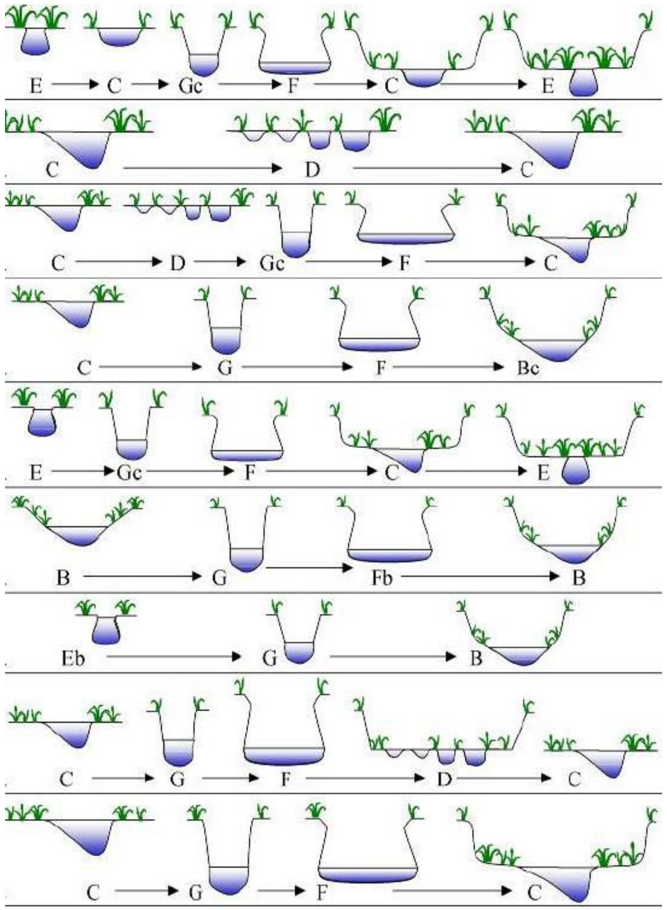
Sediment Imbalance / Land Use Change

Channel Evolution

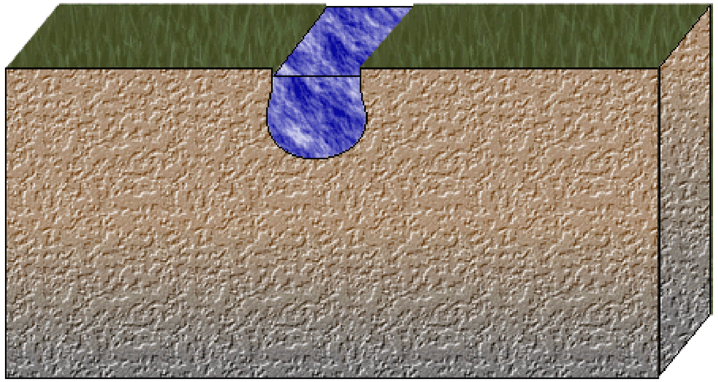
After channelization/canalization, a channel within an inset floodplain is the natural succession endpoint



(Zaimes and Emanuel, 2006)



Rosgen stream succession scenarios for low-lying coastal areas

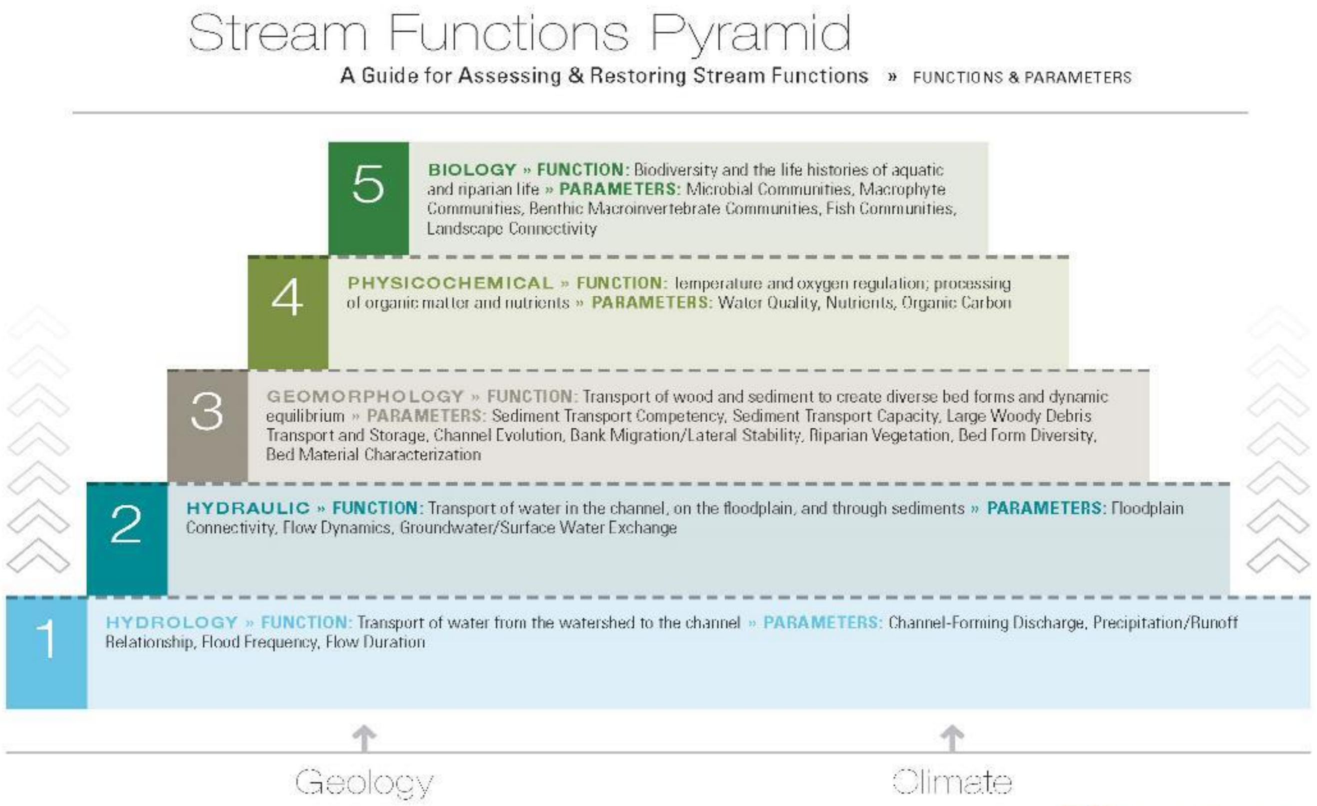


(Endreny, SUNY)

Stream Restoration Benefits

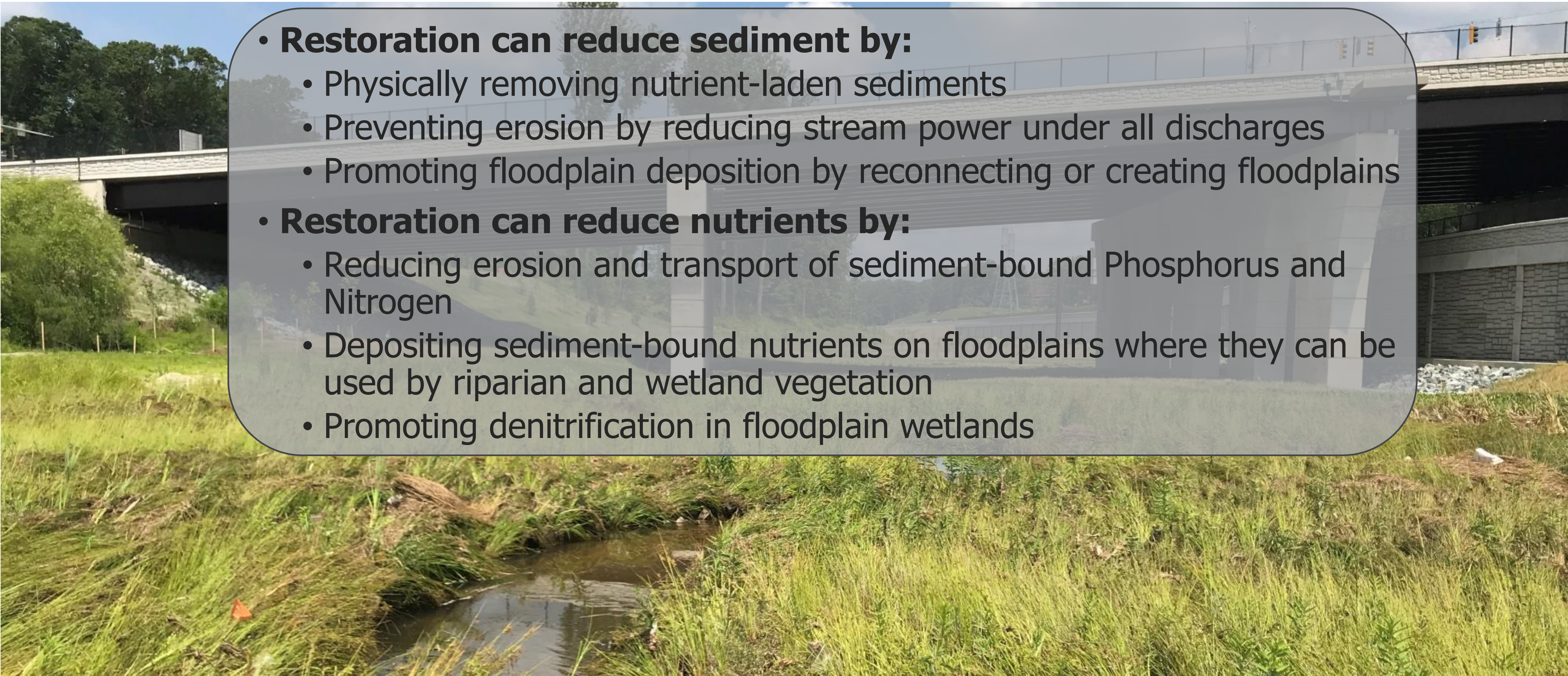
Why should we restore fluvial systems?

- Long-term Stability and Infrastructure Protection
- Flood Control
- Reduced Maintenance
- Habitat Improvements
- Floodplain Wetland Establishment
- Ecological Uplift (Fish, Reptiles, Amphibians, Invertebrates, Macrophytes, Landscape Connectivity)
- Unavoidable Impacts / Mitigation
- **Nutrient Reduction**



StreamMechanics

How can stream restoration reduce nutrients?



- **Restoration can reduce sediment by:**
  - Physically removing nutrient-laden sediments
  - Preventing erosion by reducing stream power under all discharges
  - Promoting floodplain deposition by reconnecting or creating floodplains
- **Restoration can reduce nutrients by:**
  - Reducing erosion and transport of sediment-bound Phosphorus and Nitrogen
  - Depositing sediment-bound nutrients on floodplains where they can be used by riparian and wetland vegetation
  - Promoting denitrification in floodplain wetlands

Florida Nutrient TMDLs

Final TMDL Report

Nutrient TMDL

and Documentation in Support of Development of Site Specific Numeric Interpretations of the Narrative Nutrient Criteria

DEPARTMENT OF ENVIRONMENTAL PROTECTION
FLORIDA

TMDLs in Florida consider a variety of nutrient sources, but they often do not explicitly account for the sediment-bound nutrients that enter systems from streambank erosion.

How Do We Quantify These Nutrients?

First Quantify Annual Sediment Loss

- Streambank Assessment
- Repeated Cross Section Surveys
- Capitalize on Historic Data
- Dendrochronology

Quantify Annual Sediment Loss – Rapid Assessment

Use Rapid Characterization Methods

- BANCS (Bank Assessment for Non-point source Consequences of Sediment)
- NBS (Near Bank Stress)

BEHI Score (Fig. 3-7)

Study Bank Height / Bankfull Height (C)

Study Bank Height (ft) =	(A)	Bankfull Height (ft) =	(B)	(A) / (B) =	(C)	BEHI Score

Root Depth / Study Bank Height (E)

Root Depth (ft) =	(D)	Study Bank Height (ft) =	(A)	(D) / (A) =	(E)	BEHI Score

Weighted Root Density (G)

Root Density as % =	(F)	(F) x (E) =	(G)	BEHI Score

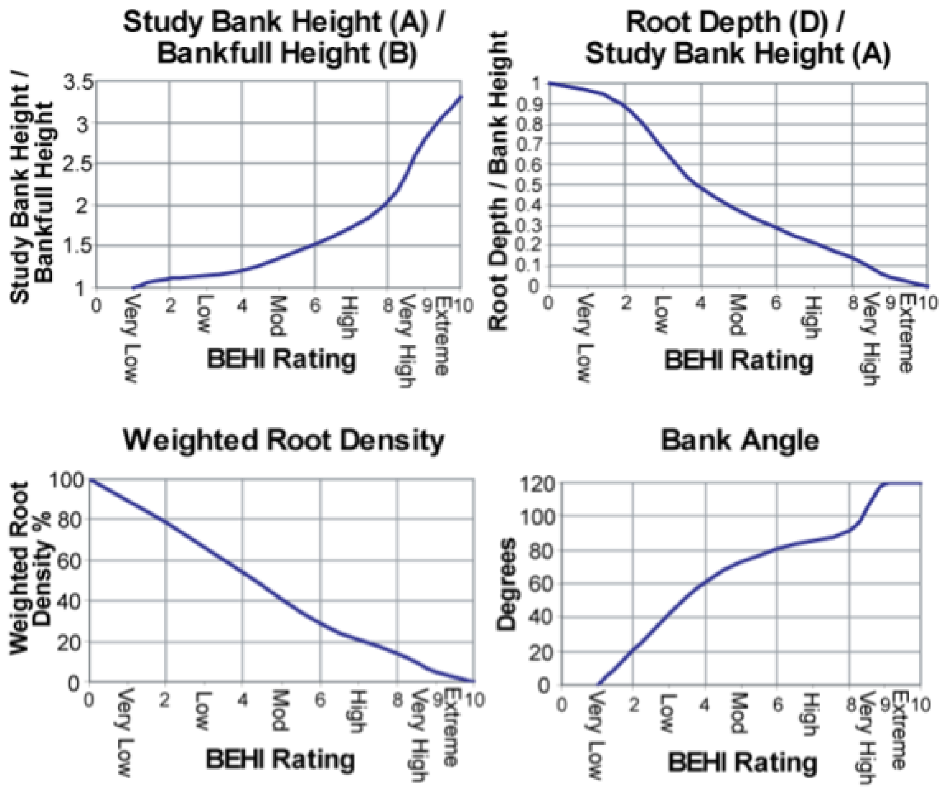
Bank Angle (H)

Bank Angle as *Degrees* =	(H)	BEHI Score

Surface Protection (I)

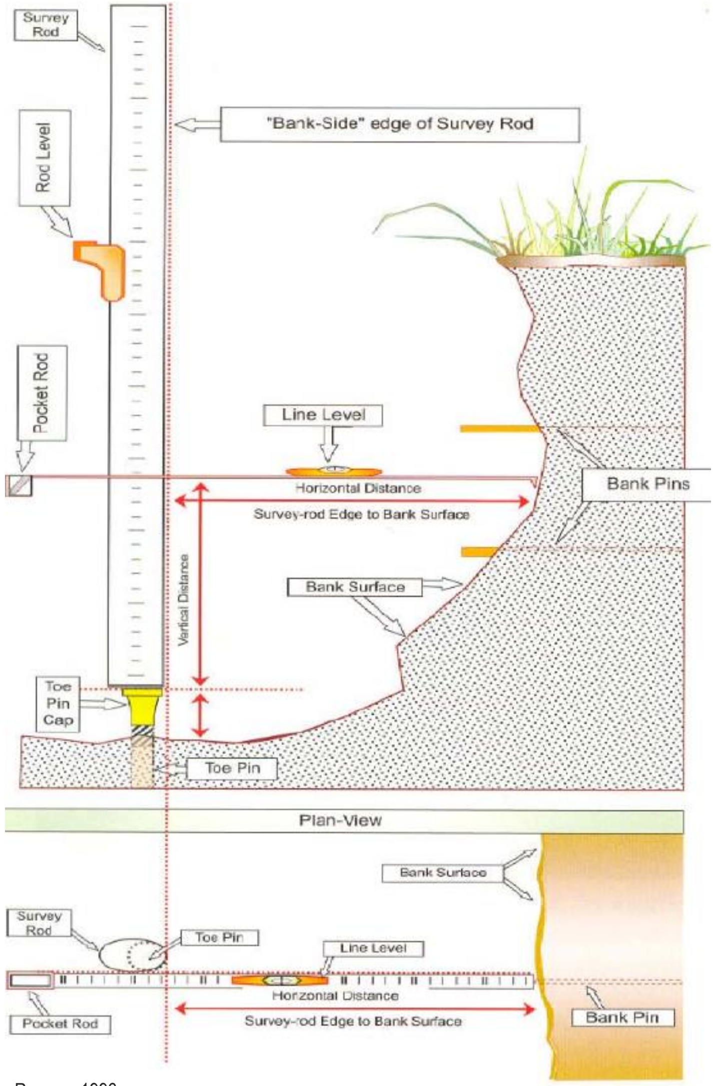
Surface Protection as % =	(I)	BEHI Score

Bank Material Adjustment:



Quantify Annual Sediment Loss – Repeat Survey

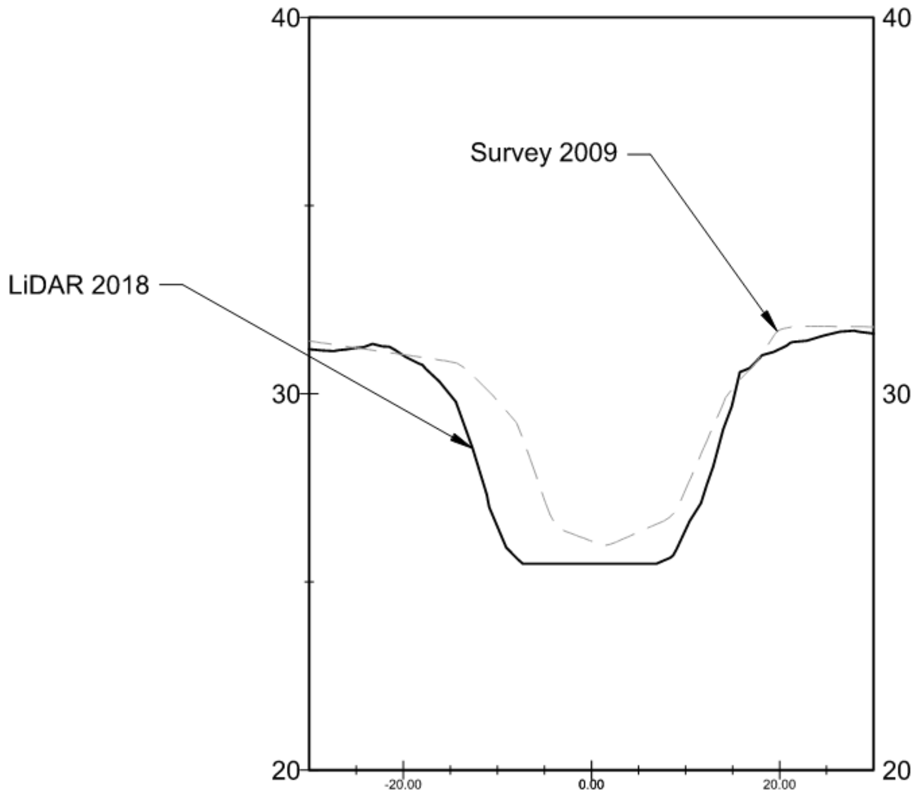
Repeated Streambank Measurement



Rosgen, 1996

Quantify Annual Sediment Loss – Repeat Survey

Capitalize on Historic Data



Using available historic survey data compared to recent field-verified LiDAR data, we were able to quantify a bank erosion rate between 0.5 and 1.2 feet/year depending on location.

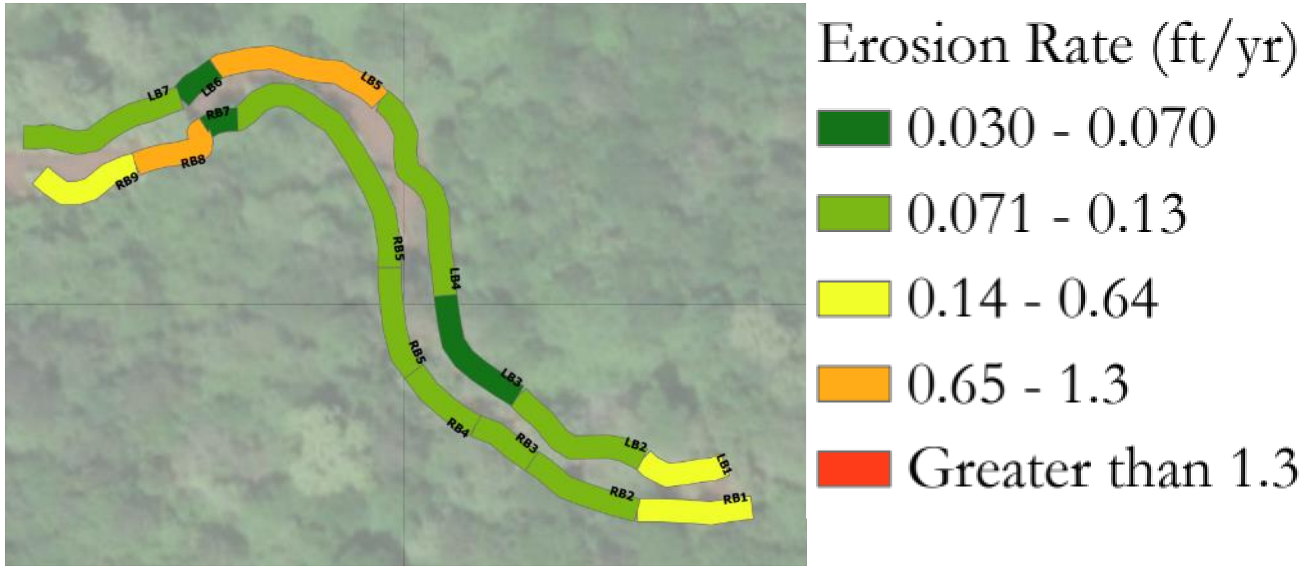
Quantify Annual Sediment Loss – Dendrochronology

Dendrochronology

Erosion rate estimation extrapolated from the age and exposure of living tree roots

Quantify Annual Sediment Loss – Dendrochronology

Dendrochronology



Erosion rate estimation extrapolated from the age and exposure of living tree roots

How About Nutrients? – Streambank Samples

Sampling Florida bank sediments to test for phosphorus and nitrogen

How can stream restoration reduce nutrients?

1. Prevented Sediment
2. Nutrient Reduction for In-Stream and Riparian Nutrient Processing in the Hyporheic Zone
3. Floodplain Reconnection

Protocol 1

Credit for Prevented Sediment during Storm Flow

Step 1: Estimate stream sediment erosion rate

Erosion Rate =	244.1	tons/yr*	*-From Howell Creek stream bank erosion rate (BEHI-NBS data)*
Study Length =	630	LF	Left bank
Unit Density of Soil =	2099	lb/CY	per bulk density testing of this location
Unit Erosion Rate =	0.387	tons/ft/yr	
Existing Stream length to be restored =	630	LF	
x	0.387	tons/ft/yr	
Total Erosion =	244.1	tons/yr	

Step 2: Convert stream bank erosion to nutrient loading

Nitrogen Concentration =	0.20	lbs/ton	*-from Waypoint Analytical lab testing of Howell Creek bank soil samples*
Phosphorus Concentration =	0.46	lbs/ton	*(concentrations reflect Priority Site average conditions)*

Step 3: Estimate stream restoration efficiency

Load Reductions		
Sediment (TSS) =	488,200	lbs/yr
Nitrogen (TN) =	48.8	lbs/yr
Phosphorus (TP) =	112.3	lbs/yr

Protocol 2

Credit for in-stream and riparian nutrient processing within the hypor

Step 1: Determine the total post construction stream length that has

Restored (proposed) Stream Length =	2263.7	LF

Step 2: Determine the dimensions of the hyporheic box

Channel Width =	4	ft
Left Floodplain Width =	5	ft
Right Floodplain Width =	5	ft
Width Hyporheic Box =	14	ft
Depth Hyporheic Box =	5	ft
x	2263.7	LF
Total Vol. Hyporheic Zone =	158,459	ft^3
Mass of hyporheic box =	7494.5	tons*

Step 3: Multiply the hyporheic box mass by the unit denitrification rat

Unit Denitrification Rate =	1.06E-04	lbs/ton/day

Load Reduction		
Nitrogen (TN) =	290.0	lbs/yr*

Protocol 3

Credit for Floodplain Reconnection Volume

Step 1: Determine the floodplain connection volume in the available floodplain area

Estimated Floodplain Area =	4.68	ac	-from proposed grading
Total Vol. =	4.68	ac-ft	-max. 1.0' depth across floodplain surface
Watershed Area =	1965	ac	
Floodplain Storage Volume =	0.0023807	ft	-function of watershed rainfall
=	0.029	in	-rainfall necessary to inundate floodplain area

Step 2: Estimate the nitrogen and phophorus removal rate attributable to floodlain reconnection for the floodplain connection volume achieved

Rainfall Depth @ BKF =	0.1	inches	-from H&H Modeling (HEC-RAS and TR-20)
TN Removal % =	3.5%		-from Figure 4, Annual TN Removal (@ 0.1" FP Storage Volume)
TP Removal % =	6.0%		-from Figure 5, Annual TP Removal (@ 0.1" FP Storage Volume)
TSS Removal % =	3.5%		-from Figure 6, Annual TSS Removal (@ 0.1" FP Storage Volume)

Step 3: Compute the annual N, P, and TSS load delivered to the project

Watershed Area =	1965	ac	
Impervious Cover =	40.5%		
Raw Loading Rates			
Nitrogen (TN) =	0.4	lbs/yr	-from Table 6: Edge of Stream Unit Loading rates for Bay States using CBWM v. 5.3.2
Phosphorus (TP) =	0.0	lbs/yr	
Sediment (TSS) =	15	lbs/yr	
Actual Loading Rates			
Nitrogen (TN) =	0.0	lbs/yr	-multiply Raw Loading Rates by the removal efficiencies from Step 2.
Phosphorus (TP) =	0.0	lbs/yr	
Sediment (TSS) =	1	lbs/yr	

Step 4: Multiply the pollutant load by the project removal rate to define reduction credit

Estimated Floodplain Area =	4.68	ac
Watershed Area =	1965	ac
Ratio (FP/WA) =	0.238%	

Credited Loading Rates

Case Study: Howell Creek

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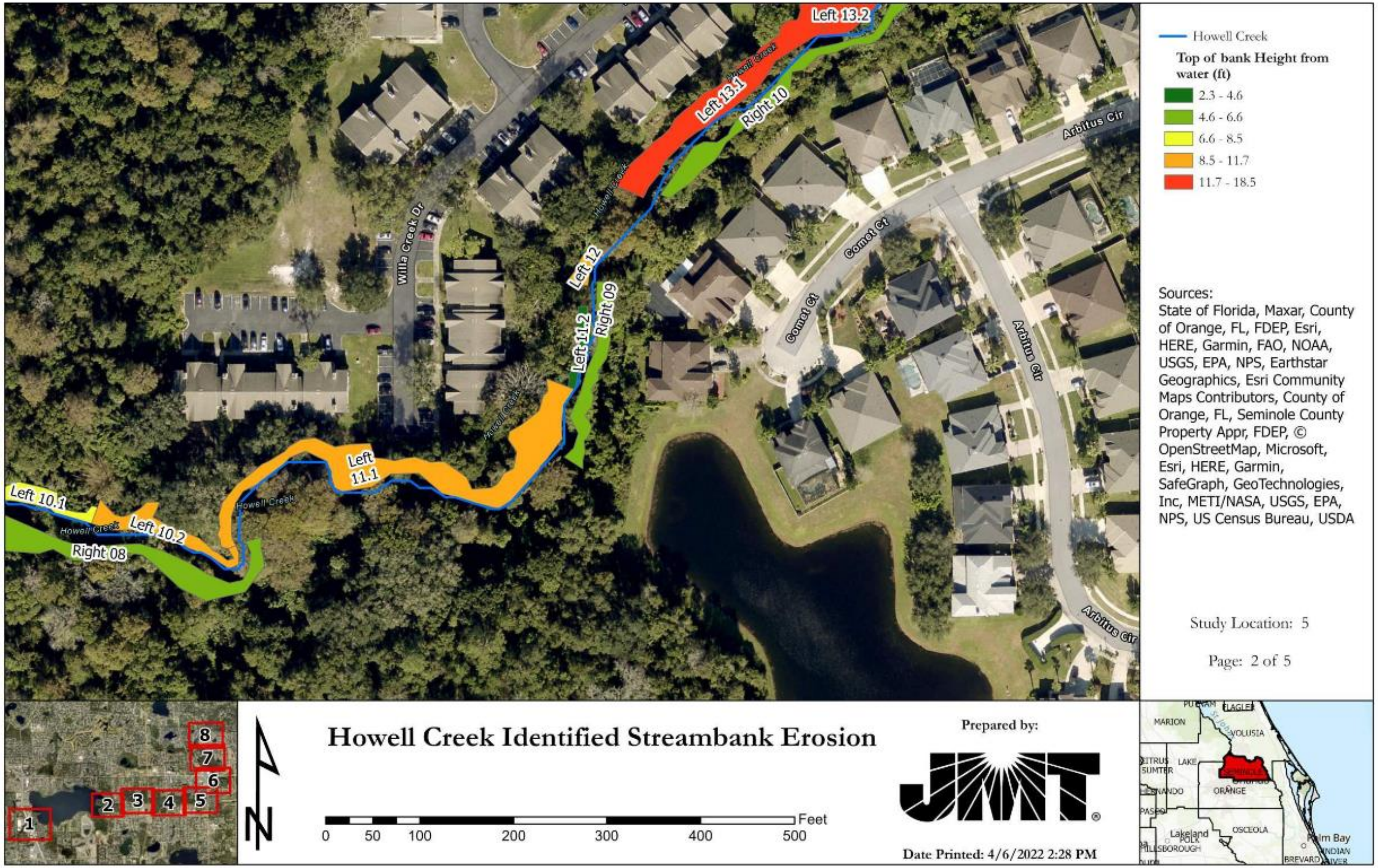


Case Study: Howell Creek

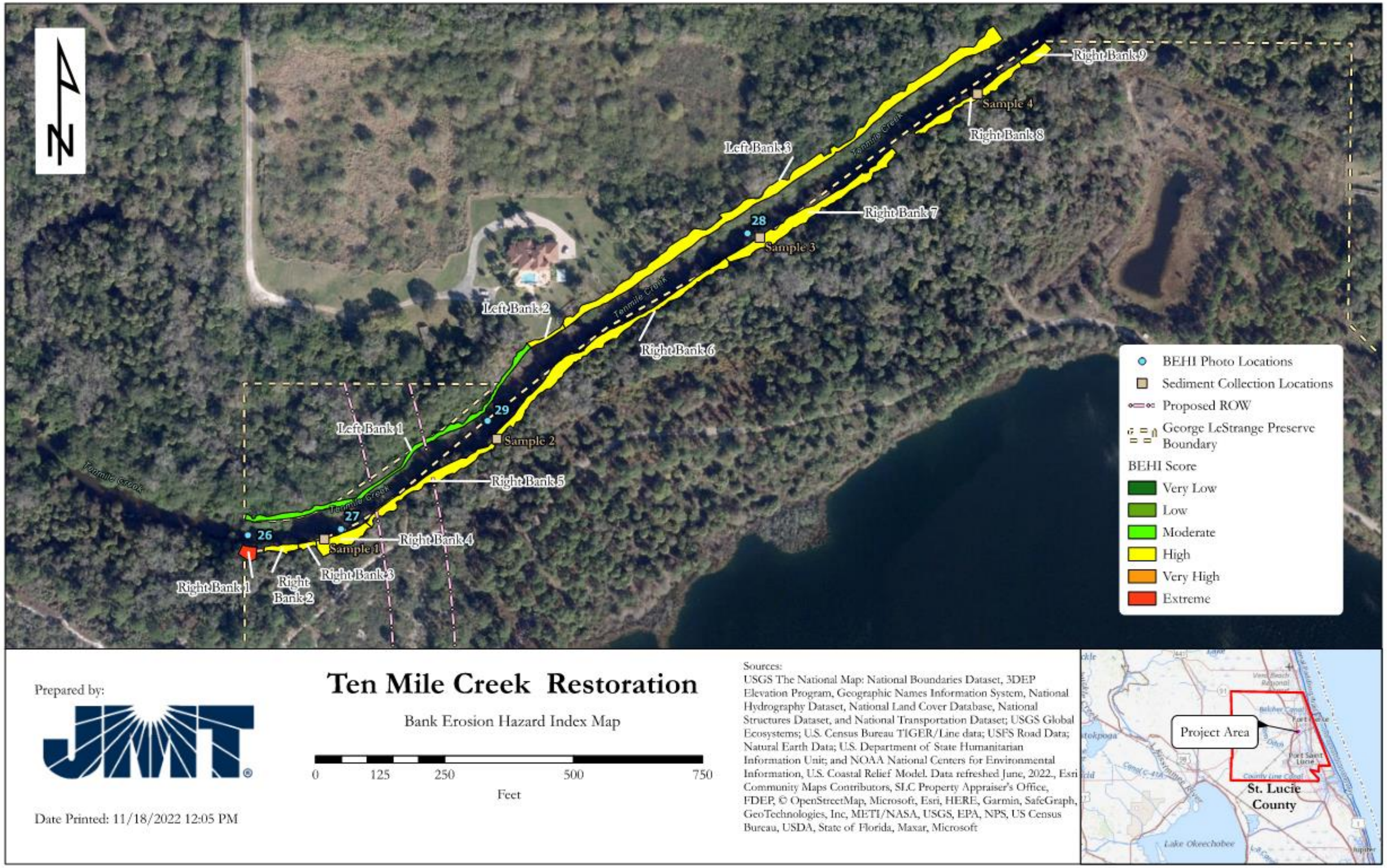
Sampling Florida bank sediments to test for phosphorus and nitrogen

Annual Sediment and Nutrient Load

- The mass erosion rate for all identified eroding streambanks throughout the total 25,560-foot (4.84-mile) Howell Creek assessment reach is **3,385 tons/year of sediment loss**.
- As much as **2,211 lbs/year Nitrogen**
- As much as **775 lbs/year Phosphorus**

Case Study: Ten Mile Creek

Case Study: Ten Mile Creek

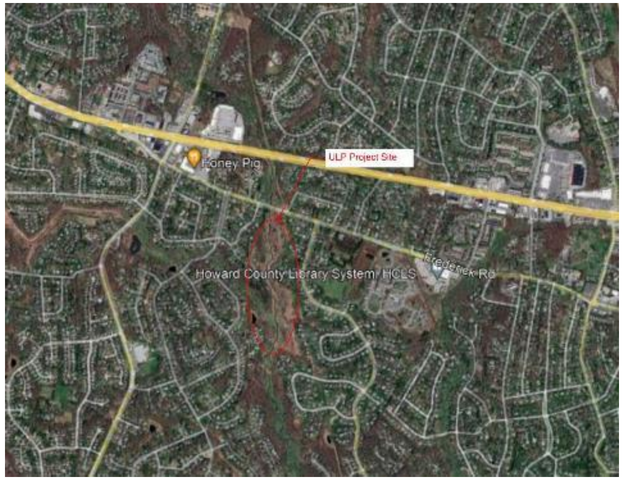


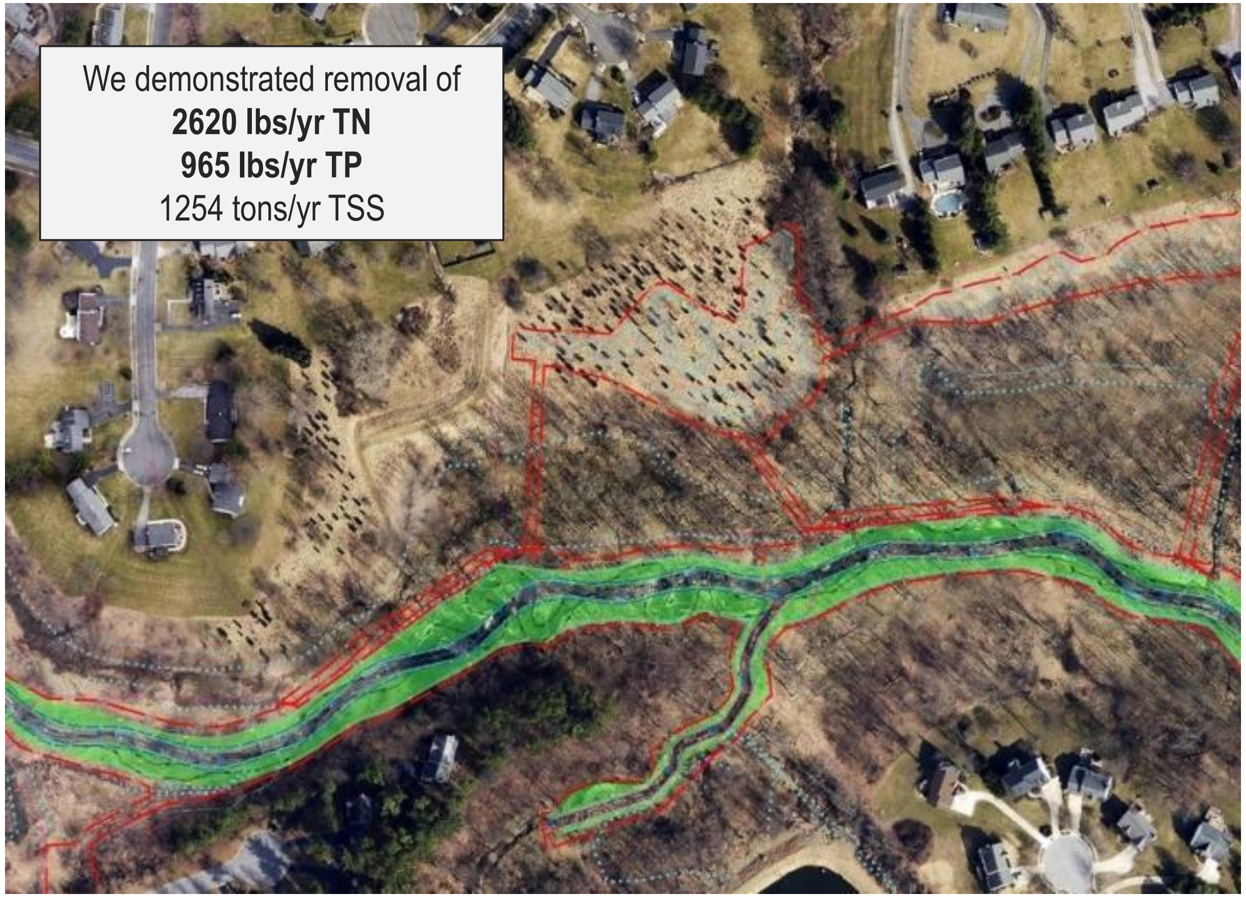
Case Study: Ten Mile Creek

Annual Sediment and Nutrient Load

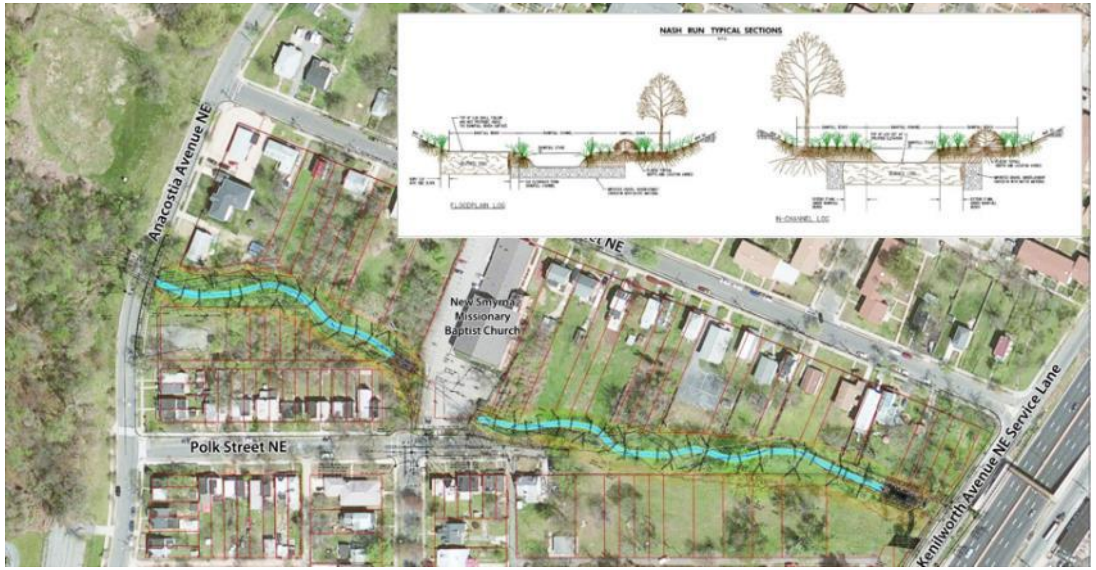
- The mass erosion rate for all identified eroding streambanks (3,583 feet) of Ten Mile Creek is **280.5 tons/year of sediment loss**.
- As much as **203 lbs/year Nitrogen**
- As much as **90 lbs/year Phosphorus**

Case Study: Upper Little Patuxent





Case Study: Nash Run



Project	Font Hill	Little Catoctin Creek	Nash Run
Stream Length (ft)	5,564	3,089	1,269
Sediment Loss (tons)	1,357	2,108	123
TN Load (lbs)	2,736	5,299	731
TP Load (lbs)	741	2,129	95

Where do we start?

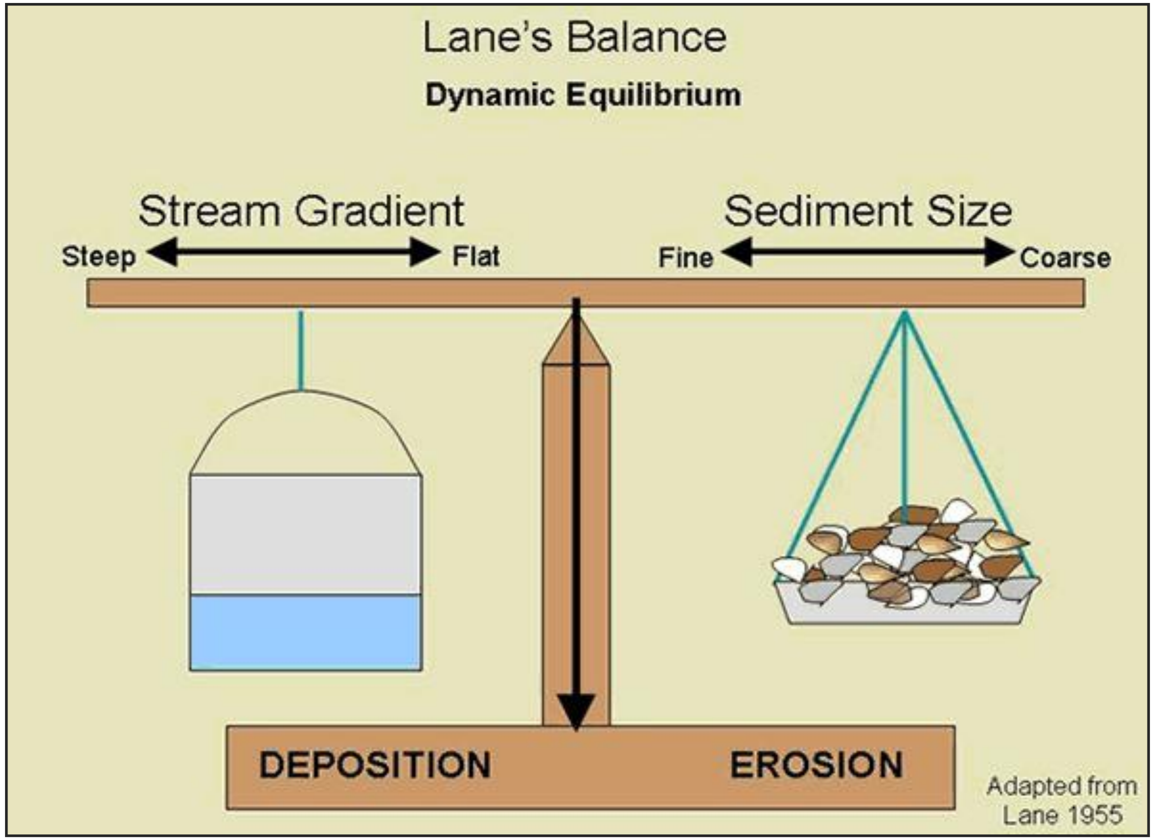
Restoration Techniques – Geomorphic Assessment

A geomorphic assessment is necessary to understand

- the sources of impairment,
- sediment supply and transport,
- stable dimension, pattern, and profile, and
- channel evolutionary state.

Then a design can focus on alleviating the sources of impairment within available constraints.

Restoration Techniques – Sediment Balance



"A simple relationship for a channel to remain stable exists when the size and load of the sediment supply is equal to the slope and discharge of a stream."
(Lane, E.W. The importance of fluvial morphology in hydraulic engineering. 1955).

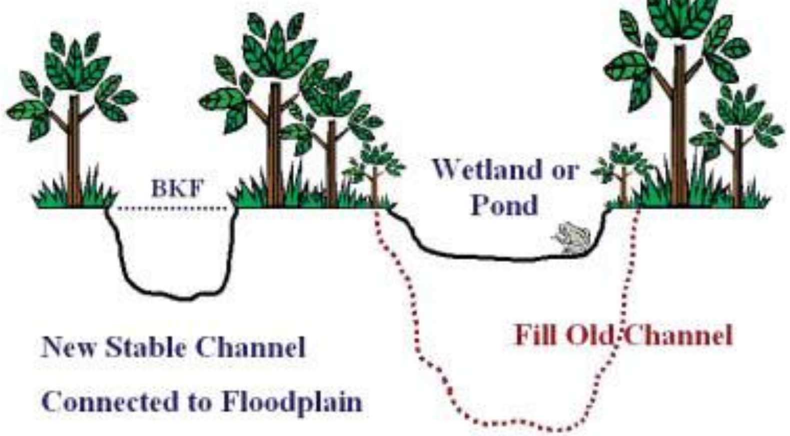
- Sediment Supply and Energy Balance
  - A cross section that is too narrow can lead to degradation
  - A cross section that is too wide can lead to aggradation

Restoration Techniques – Sediment Balance

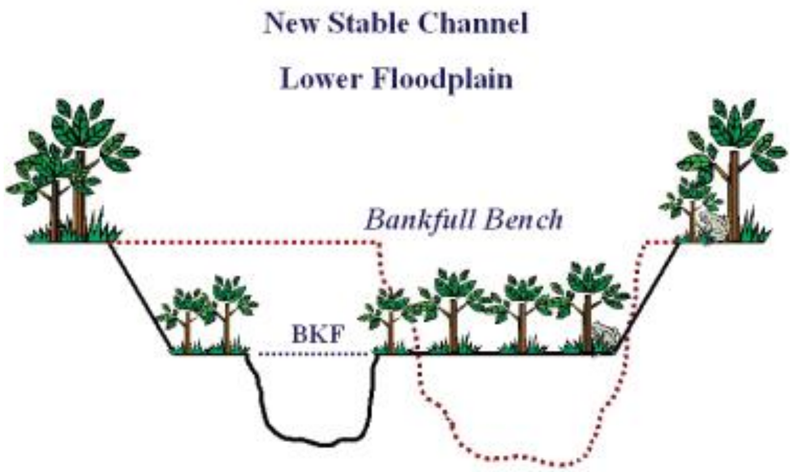
Sediment Supply and Energy Balance: Sections that are too wide lead to sediment aggradation

Restoration Techniques

Priority 1 Restoration

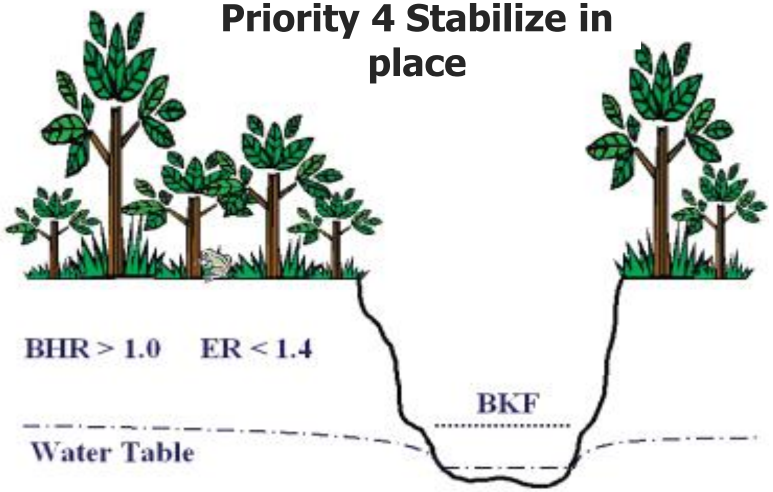


Priority 2 Restoration



Priority 3 Restoration

Priority 4 Stabilize in place

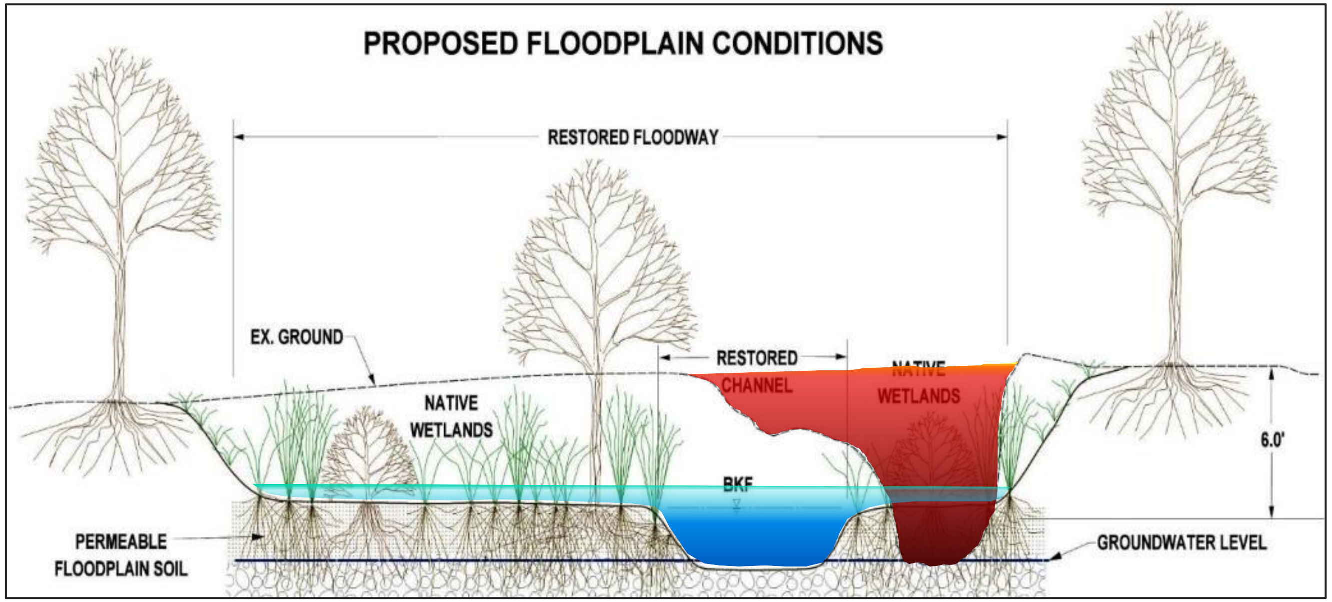


Figures from North Carolina Stream Restoration Institute

Restoration Techniques – Floodplain Restoration

Benefits compared to other options

- Long-term Stability with Low Risk of Failure
- Wetland Re-establishment
- Ecological Uplift
- Water Quality Improvement
- Stormwater Management
- Groundwater Recharge
- Riparian Buffer Enhancement
- Wildlife Habitat Enhancement
- Fish Passage Improvement
- Invasive Species Removal
- Aesthetic Value
- Increased Recreation/Education Opportunities



Restoration Techniques – Stabilize in Place

Benefits compared to other options

- ~~Long-term~~ Stability ~~with Low Risk of Failure~~
- ~~Wetland Re-establishment~~
- ~~Ecological Uplift~~
- Water Quality Improvement ?
- ~~Stormwater Management~~
- ~~Groundwater Recharge~~
- ~~Riparian Buffer Enhancement~~
- ~~Wildlife Habitat Enhancement~~
- ~~Fish Passage Improvement~~
- ~~Invasive Species Removal~~
- ~~Aesthetic Value~~
- ~~Increased Recreation/Education Opportunities~~

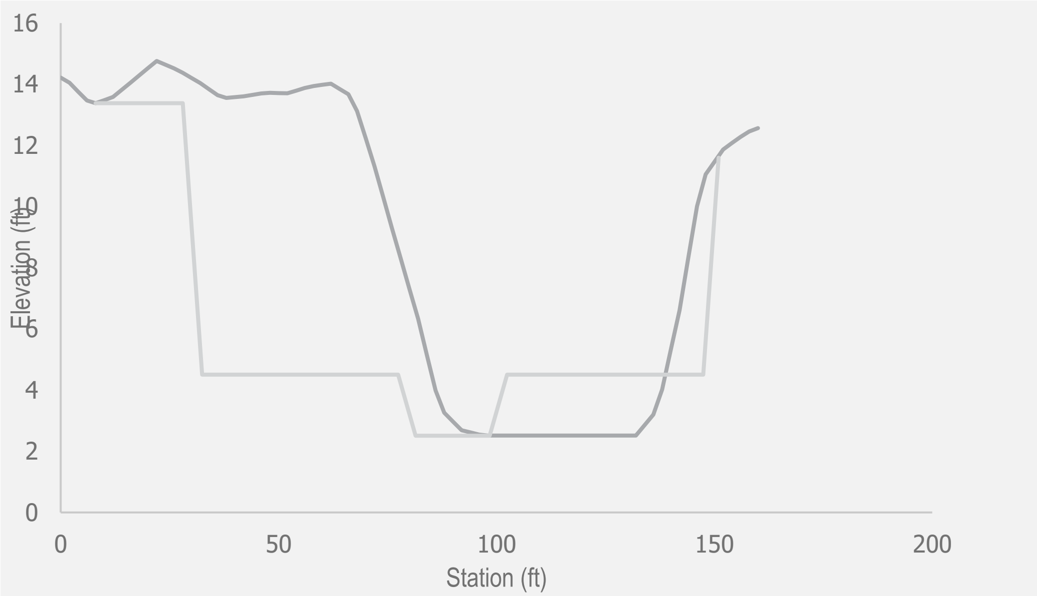
Expensive

Sometimes the best of bad options

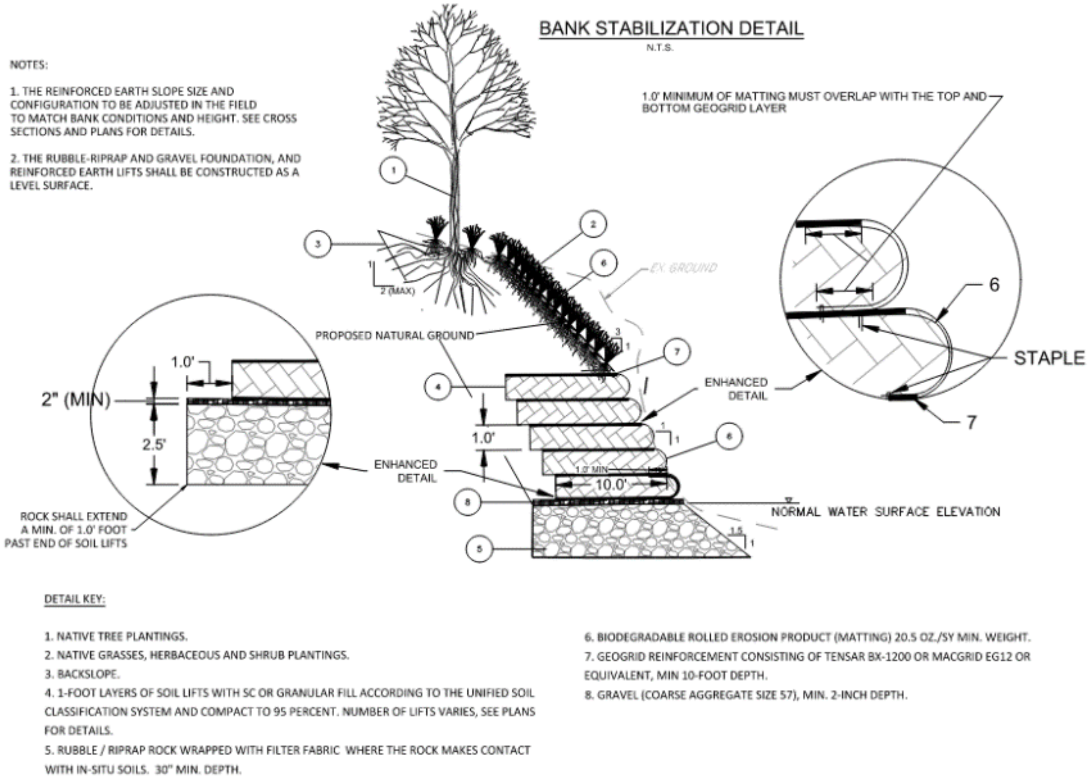
Restoration Techniques – Stabilize in Place

A better option

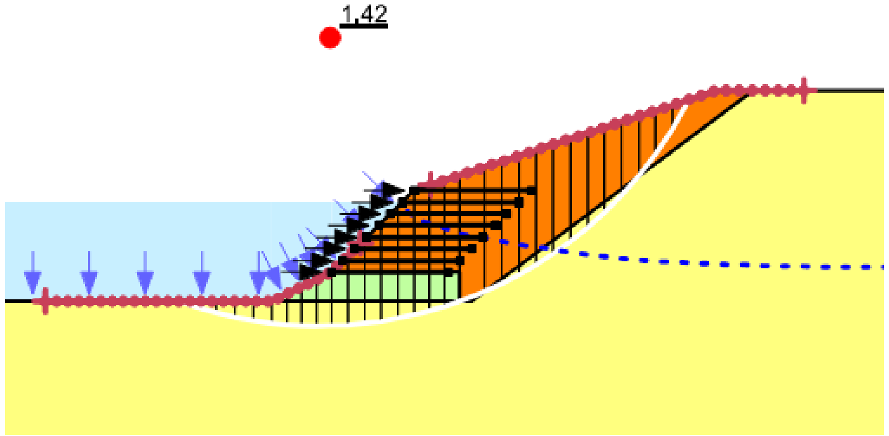
- Maximize Floodplain with Limited Real Estate
- Ideally Use Vegetation which Will Gain Strength over Time



Restoration Techniques – Stabilize in Place



Reinforced Earth Slope from Ten Mile Creek
Oxbow Restoration



Stable under rapid drawdown

Restoration Techniques – Stabilize in Place

Failing retaining wall on left. Reinforced earth wall on right.

Restoration Examples

BEFORE

AFTER

BEFORE

AFTER

BEFORE

AFTER

BEFORE

AFTER

Restoration Examples

AFTER

AFTER

Restoration Examples

Restoration Examples

Upper Little Patuxent restoration remained stable during two 1,000-year flood events.

Nearby damage from same event
USA Today, Washington Post

Conclusion

- Stream restoration provides many benefits
- There are several ways to quantify nutrient loads from streambank erosion
- Restoration can prevent these loads from entering downstream waters
- Restoration can also promote nutrient removal through denitrification and floodplain reconnection

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