OVERVIEW OF STREAM RESTORATION

Justin Lennon, PE

3 Rivers Wet Weather Stream Seminar

June 22, 2018

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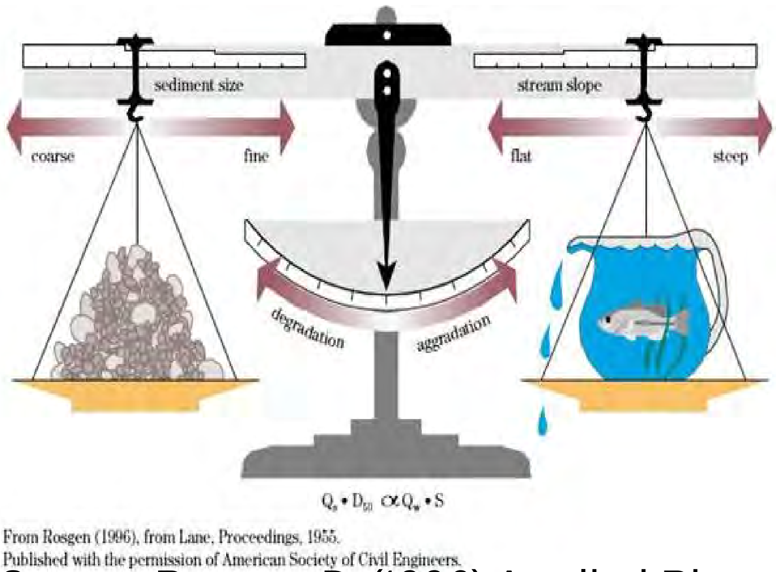
Justin Lennon, PE

- WSP Water & Environment
  - *Baltimore, MD*
- National Technical Leader
  - *Stream & Ecosystem Restoration*
  - *River and Bridge Hydraulics*
  - *Sustainability & Climate Change*
- 16-Years of experience
- Over 20 miles of stream restoration design
  - Maryland, Delaware, New York, Virginia, Pennsylvania, North Carolina, Florida, Washington, and Hawaii
- Over $12 million of restoration designs under construction in 2018

Understanding streams

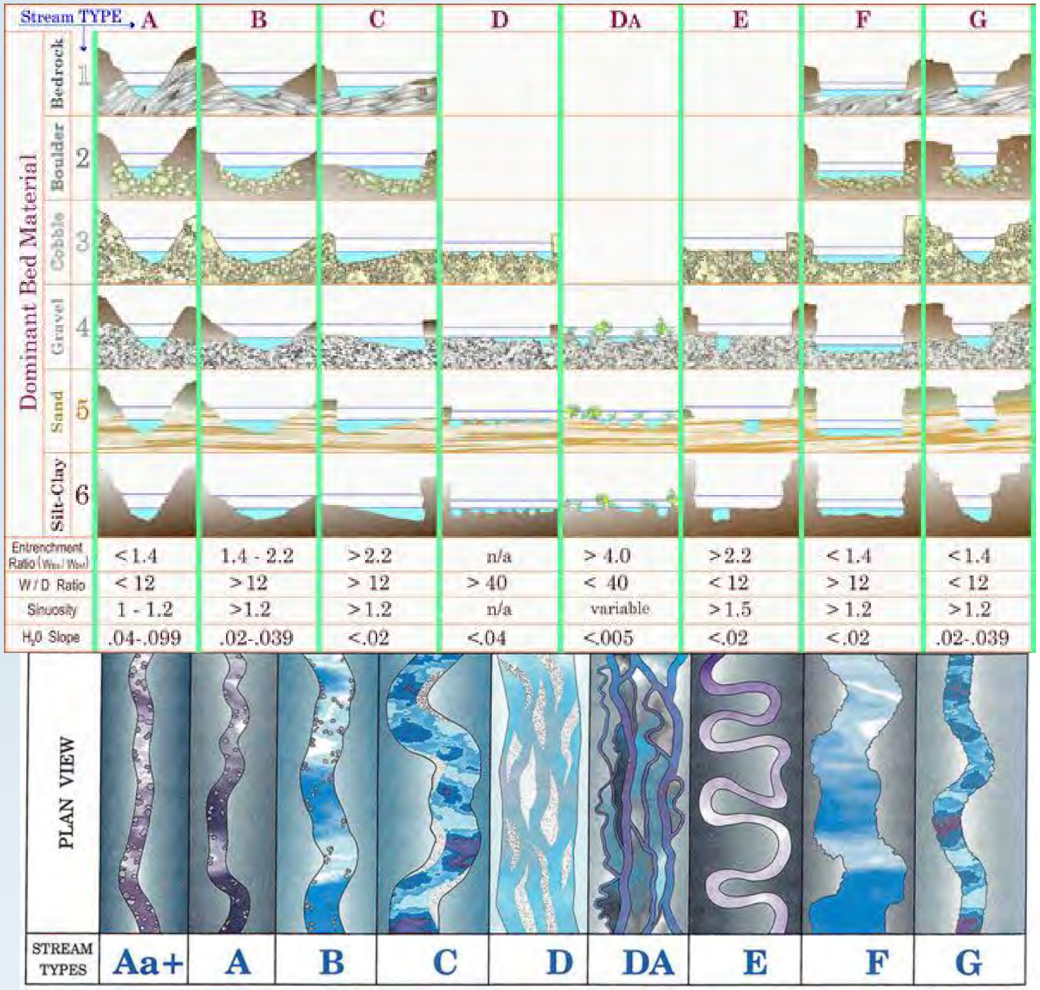
- What is a stable channel?
  - *Sustainability*
  - *Sediment balance*
  - *Floodplain connectivity*



Source: Rosgen, D. (1996) Applied River Morphology, Wildland Hydrology.

Stream Classification

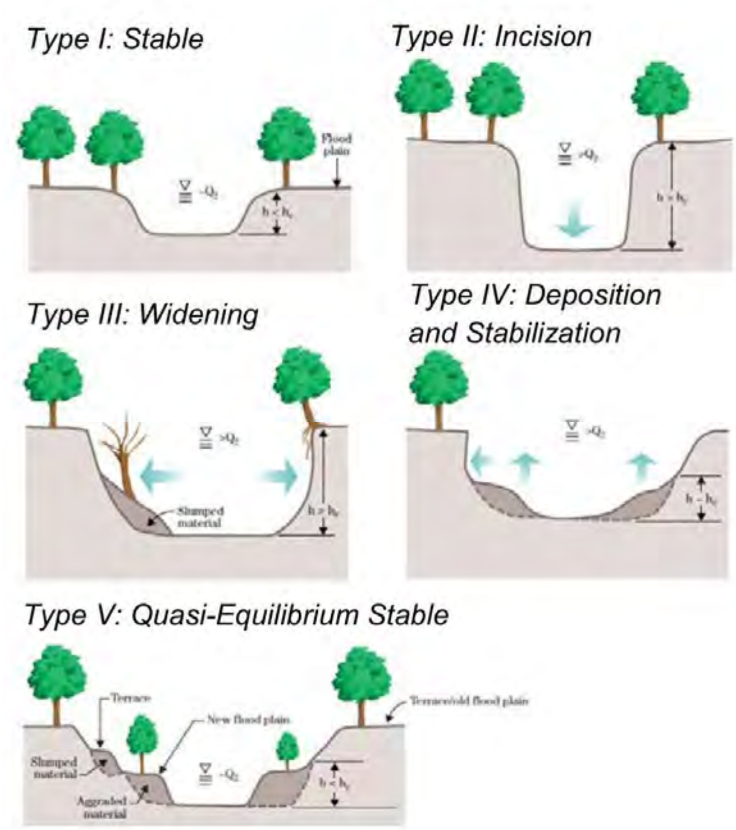
- Most widely used system for defining stream condition and function
- Defines a range of stable and unstable stream types
- Bankfull based classification system
  - *Bankfull discharge ~ channel forming flow*
- Differentiates stream types based upon geomorphic characteristics
  - *Bankfull width, depth, entrenchment, sinuosity, and slope*



Source: Rosgen, D. (1996) Applied River Morphology, Wildland Hydrology.

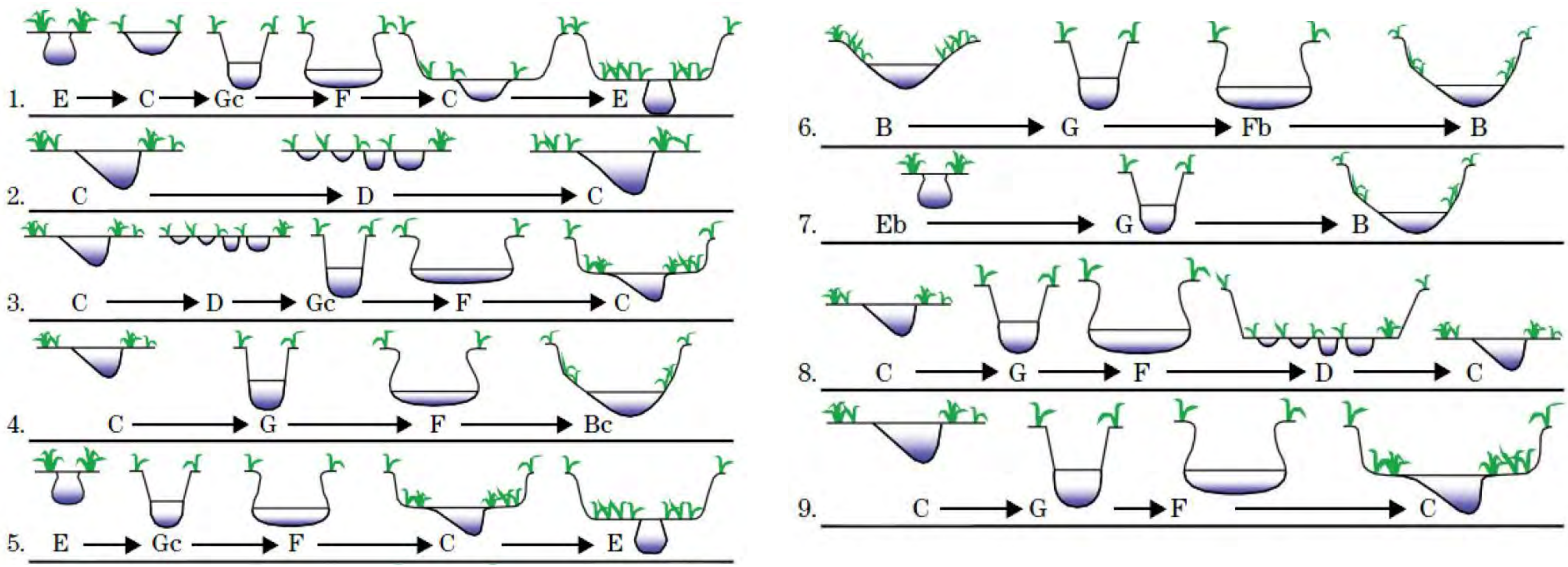
Stream impairment and evolution

- What happens when a channel destabilizes?
  - *Schumm evolution model (1984)*
- Loss of bed level control
  - *Incision / entrenchment*
- Widening
  - *Bank erosion & mass wasting*
  - *General widening versus meandering*
- Quazi-equilibrium



Source: Rosgen, D. (2006) Watershed Assessment of River Stability and Sediment Supply (WARSSS), Wildland Hydrology

Rosgen Stream Evolution Models



Source: Rosgen, D. (2006) Watershed Assessment of River Stability and Sediment Supply (WARSSS), Wildland Hydrology

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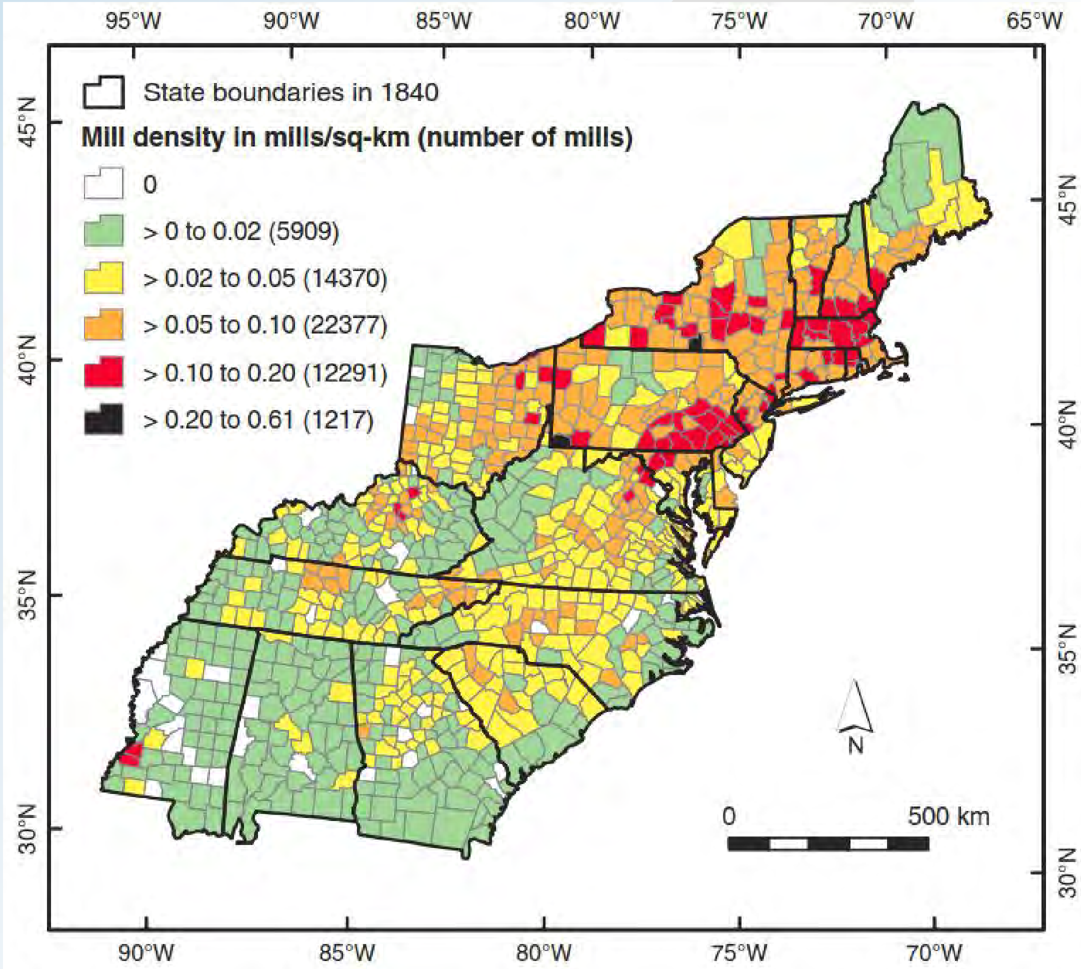
Why are our streams impaired?

- Changing hydrology
  - *Development impacts on stream flows*
  - *Loss of balance between sediment mobility and Channel form*
- Man-made alteration
  - *Straightening*
  - *Floodplain fill*
  - *Levees*
- Legacy sediment
  - *Colonial era mill dams*

Western Run, Baltimore, MD Image Source: Google Earth

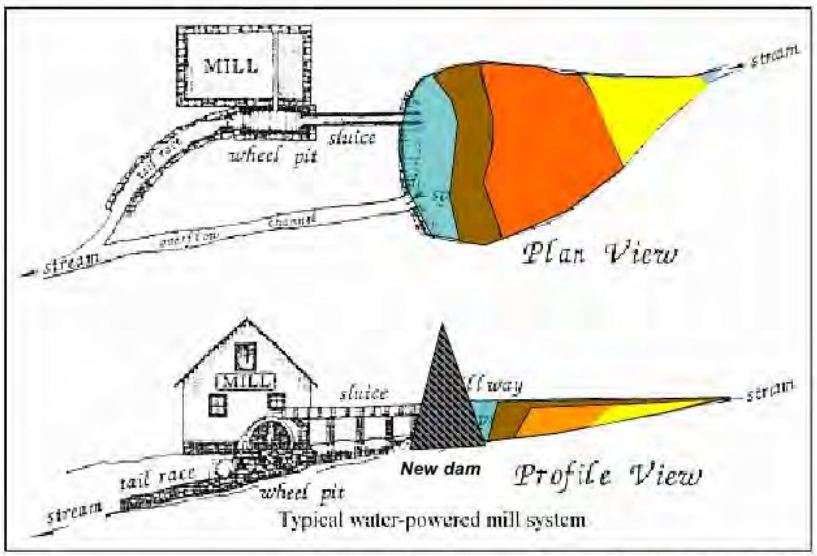
Pre-Industrial Mill Dams

- Research pioneered by Merritts and Walter (F&M College)
- ~1,700 mill dams by 1840
  - *Allegheny, Beaver, Butler, Westmoreland, Fayette, Greene, and Washington Counties*

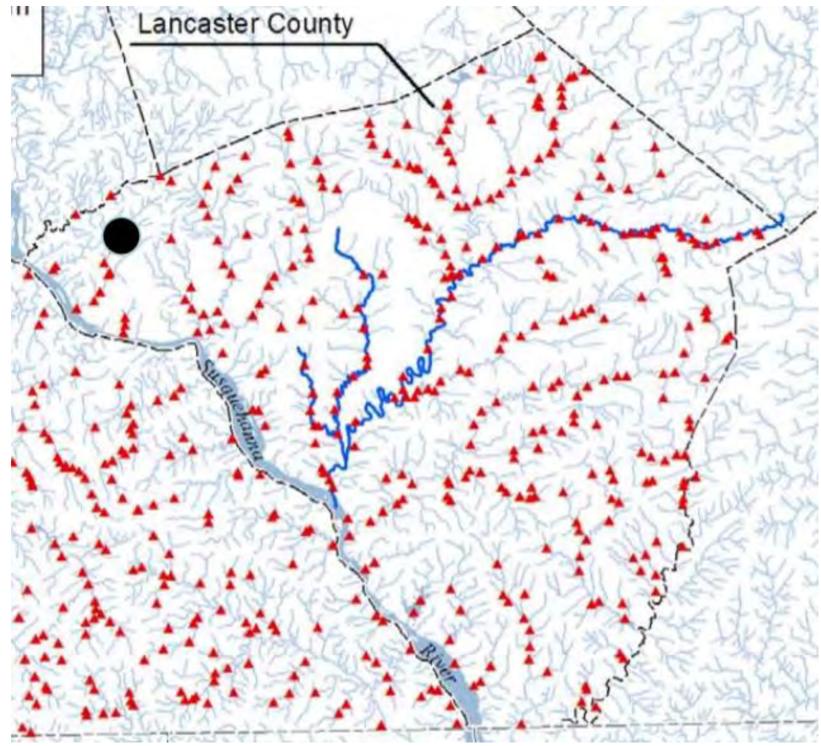


Density of water-powered mill in eastern U.S. by 1840. Source: Walter, R. and Merritts, D. (2008) "Natural Streams and the Legacy of Water-Powered Mills", Science

Mill Dam influence on River Valleys

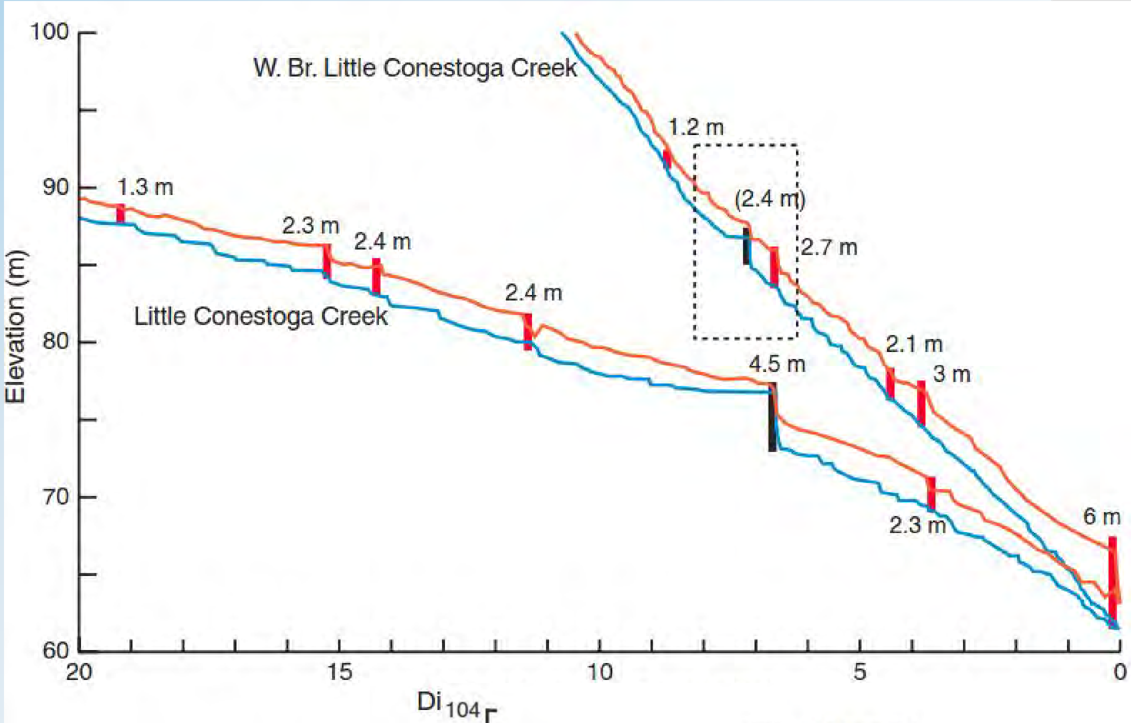


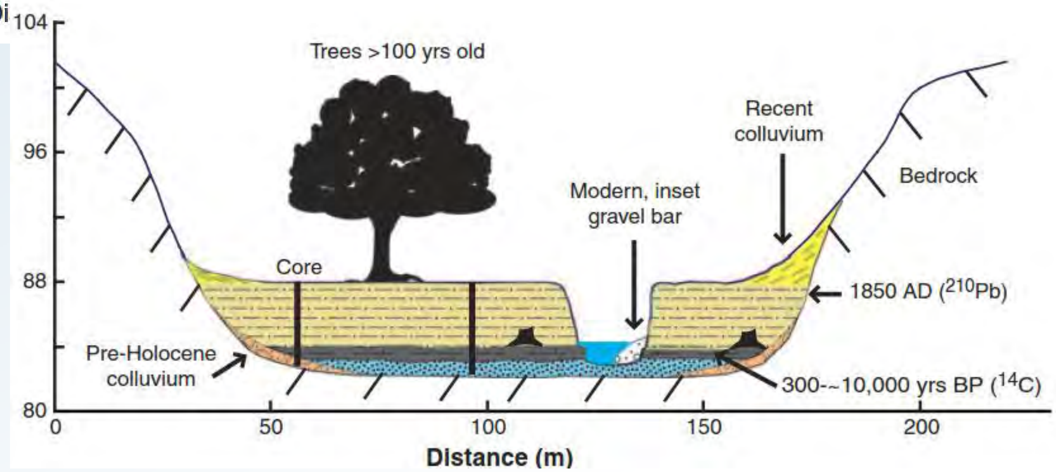
Courtesy Franklin & Marshall College



Left: Typical mill dam with sedimentation patterns.
Lower: Lancaster County mill dam location map (1840).
Source: Walter, R. and Merritts, D. (2008) "Natural Streams and the Legacy of Water-Powered Mills", Science

What happened to the mill dams?



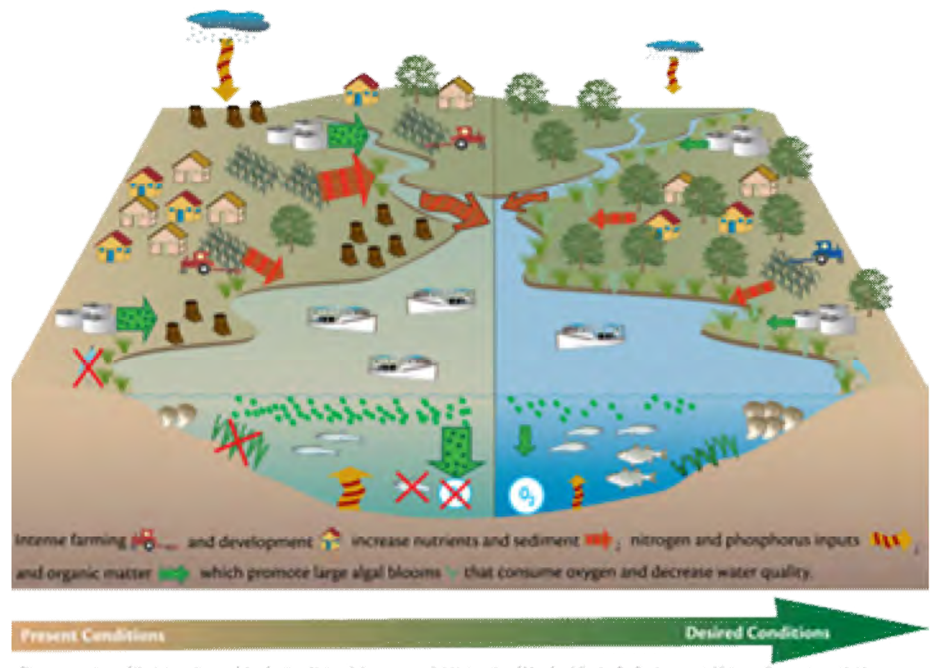


Upper: Profile of Little Conestoga Creek and West Branch with Mill Dam locations.
Lower: Conceptual model of legacy sediment stratified stream.
Source: Walter, R. and Merritts, D. (2008) "Natural Streams and the Legacy of Water-Powered Mills", Science

Legacy Sediment Stream Valleys

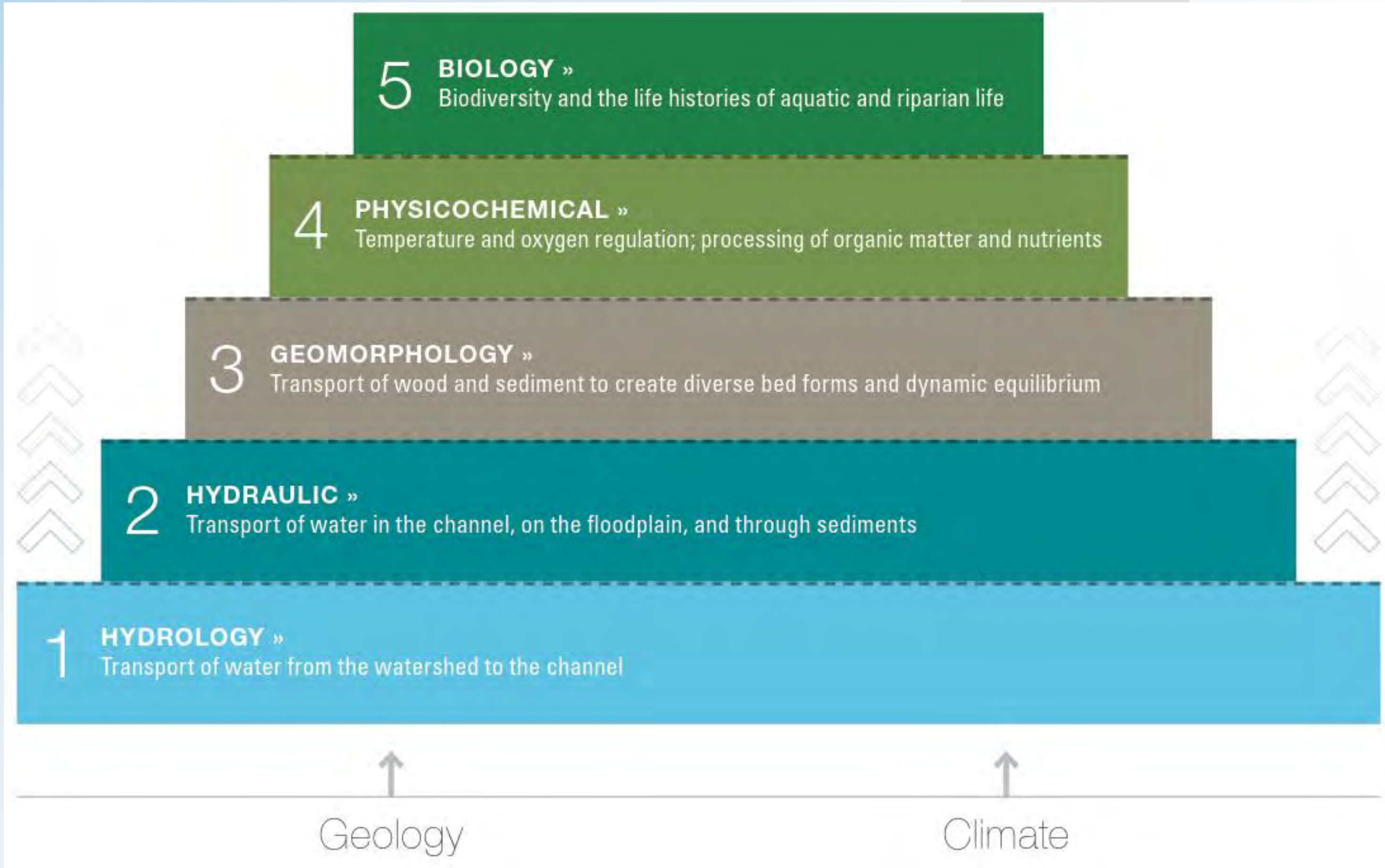
What are our options?

- Stabilization
  - *broadly defined as any activity targeted at protection / hardening of stream banks / bed*
- Restoration
  - *stream construction activity targeted at achieving one or more levels of functional uplift*



Functional uplift

- Stream function pyramid
- Developed by RiverMechanics and USFWS
- Basis for defining functional uplift



Source: Harman, W., Starr, R. *et al* (2012) "A Function-based Framework for Stream Assessment and Restoration Projects", US EPA

Hydrologic Uplift

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

Parameter
Channel-forming discharges
Rainfall/Runoff relationship
Flood frequency
Flow duration

- Processes that transport water from the watershed to the channel
- Base of the pyramid as it strongly effects higher level functions
- Without surface flow there would be no aquatic ecosystem

Hydraulic Uplift

2 **HYDRAULIC** » **FUNCTION:** Transport of water in the channel, on the floodplain, and through sediments » **PARAMETERS:** Floodplain Connectivity, Flow Dynamics, Groundwater/Surface Water Exchange

Parameter	Metric
Floodplain connectivity	Bank height ratio Entrenchment ratio
Flow dynamics	Stream velocity Shear stress
Groundwater / surface water interchange	GW level Hyporheic interaction

- Transport of water in the channel, on the floodplain and through the ground
- Supported by hydrologic function
- Closely related to geomorphologic functions

Geomorphic Uplift

3 GEOMORPHOLOGY » FUNCTION: Transport of wood and sediment to create diverse bed forms and dynamic equilibrium » PARAMETERS: Sediment Transport Competency, Sediment Transport Capacity, Large Woody Debris Transport and Storage, Channel Evolution, Bank Migration/Lateral Stability, Riparian Vegetation, Bed Form Diversity,

Parameter	Metric
Sediment Competency	Mobility of bedload and riffle armor
Sediment Transport Capacity	Transport supply versus capacity
Bank Migration / Lateral Stability	BANCS Surveys
Riparian Vegetation	Buffer width and composition
Bed Form Diversity	Percentage of riffles and pools
Bed Material Stability	Riffle armor stability

— The transport of sediment to create and maintain diverse bed forms

— Dynamic equilibrium

— Direct support of upper level functions

  — *Habitat diversity*

  — *Creation and transport of water quality contaminants*

Physio-chemical Uplift

4 **PHYSICOCHEMICAL** » **FUNCTION:** Temperature and oxygen regulation; processing of organic matter and nutrients » **PARAMETERS:** Water Quality, Nutrients, Organic Carbon

Parameter	Metric
Water Quality	Temperature, DO, pH, Turbidity
Nutrients	TN, TP
Organic Carbon	

- Water quality
- Designs targeted at Level 3 – geomorphology in order to provide Level 4 uplift

Biological Uplift

5

BIOLOGY » FUNCTION: Biodiversity and the life histories of aquatic and riparian life » **PARAMETERS:** Microbial Communities, Macrophyte Communities, Benthic Macroinvertebrate Communities, Fish Communities, Landscape Connectivity

Parameter
Microbial Communities
Macrophyte Communities
Benthic Macroinvertebrate Communities
Fish Communities
Landscape Connectivity

- Dependent on all underlying functions
  - *Impairment at any level will impair Level 5*
- Biodiversity of aquatic and riparian organisms

Stream Restoration Design methods

— Natural Channel Design
— Valley Restoration / Legacy Sediment Design
— Regenerative Stormwater Conveyance (RSC)
— Hybrid Design Approaches

Natural Channel Design

- Pioneered by Dave Rosgen
- Bankfull discharge based design technique
- Reference reach / natural analog based design
  - *Channel sizing based on bankfull scaling of reference reach*
- Reference reach identified as an undisturbed naturally sustainable system
- Sediment transport evaluations based upon non-dimensionalized curves

Natural Channel Design

- Pros:
  - *Widely accepted / permittable methodology*
  - *Track record of successful projects across the Country*
- Cons:
  - *Difficulty in identifying appropriate reference reach*
  - *Methodology is too focused on a singular discharge*
  - *Methodology is too cook-book, may not be well understood by practitioners*
  - *May not properly address the source of impairment*
  - *Degree of riparian root zone reconnection is more limited than other options*

Valley Restoration / Legacy Sediment Design

- Method pioneered based upon research and observation into the role of colonial era development on valley landforms and attendant stream interaction
- Mill dams, legacy sediments and stream evolution
- Design approach generally involves excavation and removal of legacy sediments from valley bottom
- Channel sizing target is << bankfull
- Channel sizing largely based upon threshold transport of historic gravels

Legacy Sediment Design

- Pros:
  - *Addressed the source of impairment*
  - *Greatly decreases in-channel velocity and erosive stresses*
  - *Highest degree of phreatic zone connection*
  - *Highest degree of floodplain connection*
- Cons:
  - *Very high per LF project cost*
  - *May have significant natural resource impacts*
  - *May have bedload transport limitations in high yield systems*

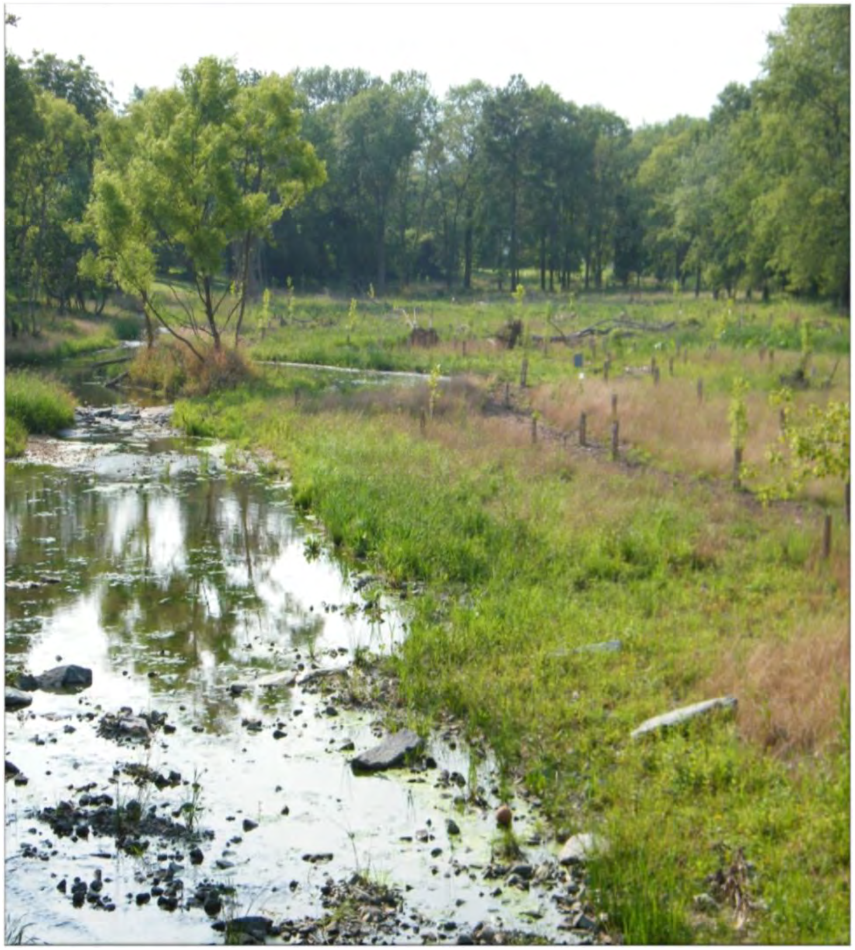
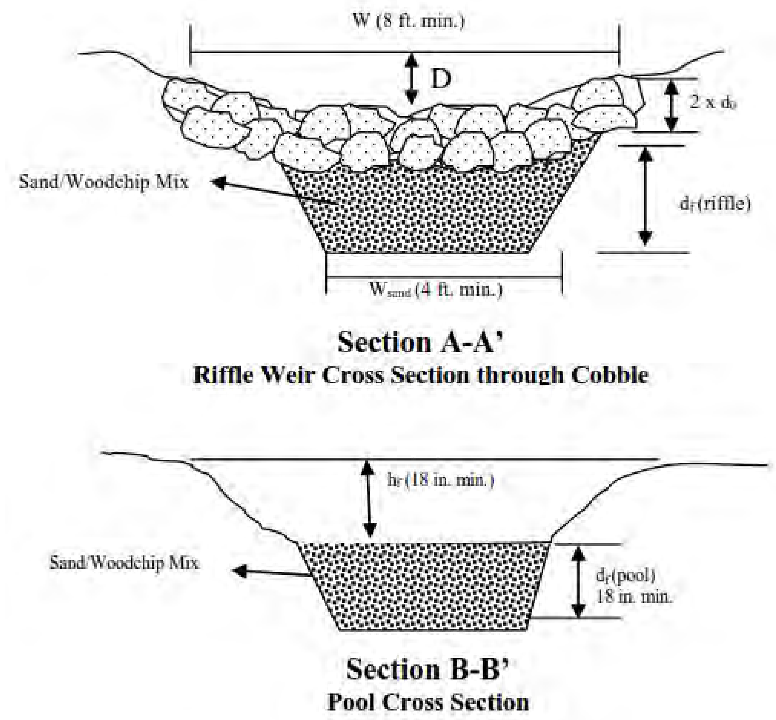


Image source: www.landstudies.com

Regenerative Stormwater Conveyance

- Coastal plain outfalls or regenerative step pool storm conveyance
- Developed in Anne Arundle County, MD
- Channel and pool sizing driven to capture up to the 10-year flow in pool areas for infiltration
- Sandfilter or bio media sub-base along channel



Source: Anne Arundel County (2012) "Design Guidelines for Step Pool Storm Conveyance".

Regenerative Stormwater Conveyance

- Pros
  - *Hydrologic function uplift*
  - *Water quality treatment*
  - *Can work with impaired landscape*
- Cons
  - *Limited applicability*
  - *Space limitations may limit treatment effectiveness*
  - *Specialized construction materials*
    - Sandstone

Image source: Anne Arundel County (2012) "Design Guidelines for Step Pool Storm Conveyance".

Hybrid Design Approaches

— Borrow concepts from other methodologies to adapt to context of any situation

— Generally more heavily reliant on sediment transport role in the design of the channel

— Frequently sub-bankfull design, but not exclusively so

— Design typically considers a wide range of flow conditions

Priority levels of Restoration

- Developed by Dave Rosgen (1997)
- Simple descriptive classification system for restoration approaches
- Priority levels 1 through 4

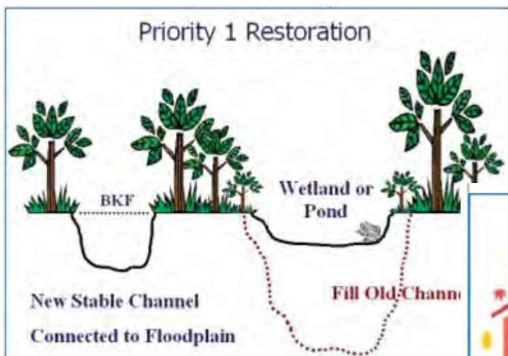


Image Source: North Carolina Stream Restoration Institute; Stream Restoration – A Natural Channel Design Handbook

Priority 1

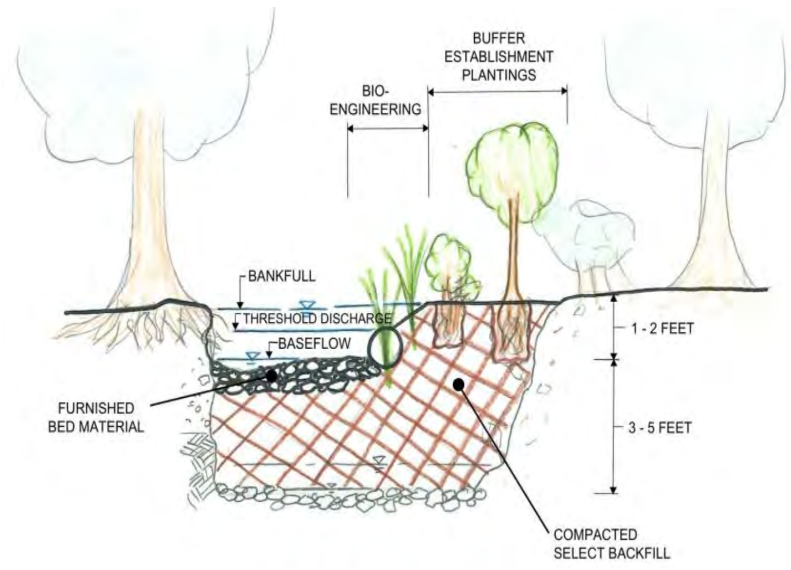
— Construct channel to reconnect to the upper terrace floodplain

— Preserves natural resources

— Floodplain Impacts

  — *CLOMR?*

— Net fill



BANKFULL STAGE RESTORED TO UPPER TERRACE FLOODPLAIN

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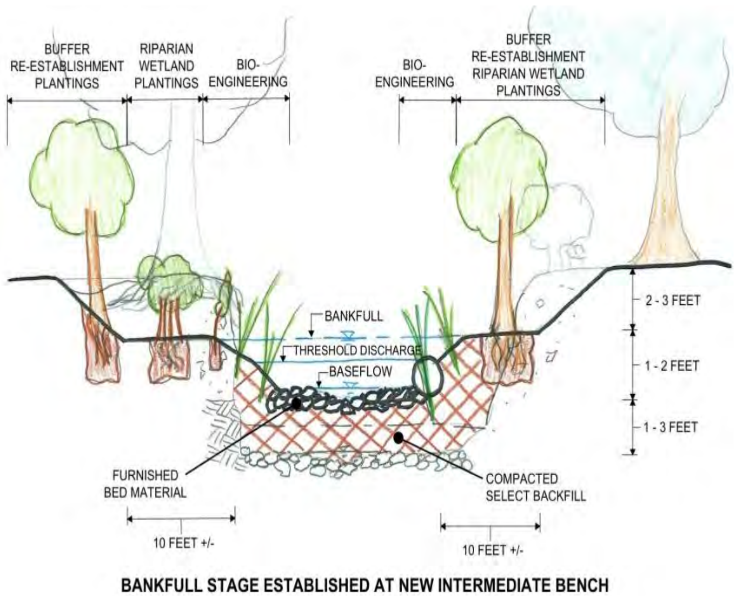
Peachwood Park Tributary

— BEFORE

— AFTER

Priority 2 & 3

- Balanced construction, raising of channel bed / grading of in-set floodplain benches
- Potential for cut / fill balance
  - *Not likely though*
- Priority 2 vs 3
- Balance or improve floodplain management



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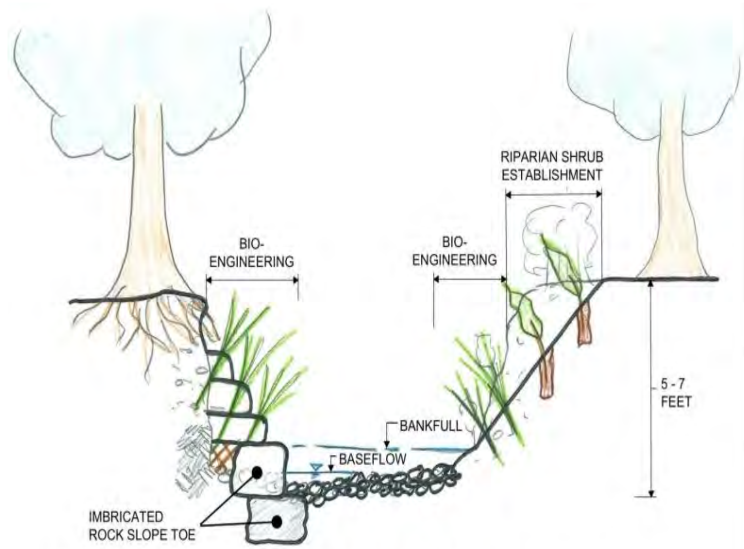
Foster Branch

— Before

— After

Priority 4

- Hardening of streambanks in situ
- Stream stabilization
- No reconnection of riparian root zone
- High material costs
- Highest expected maintenance needs



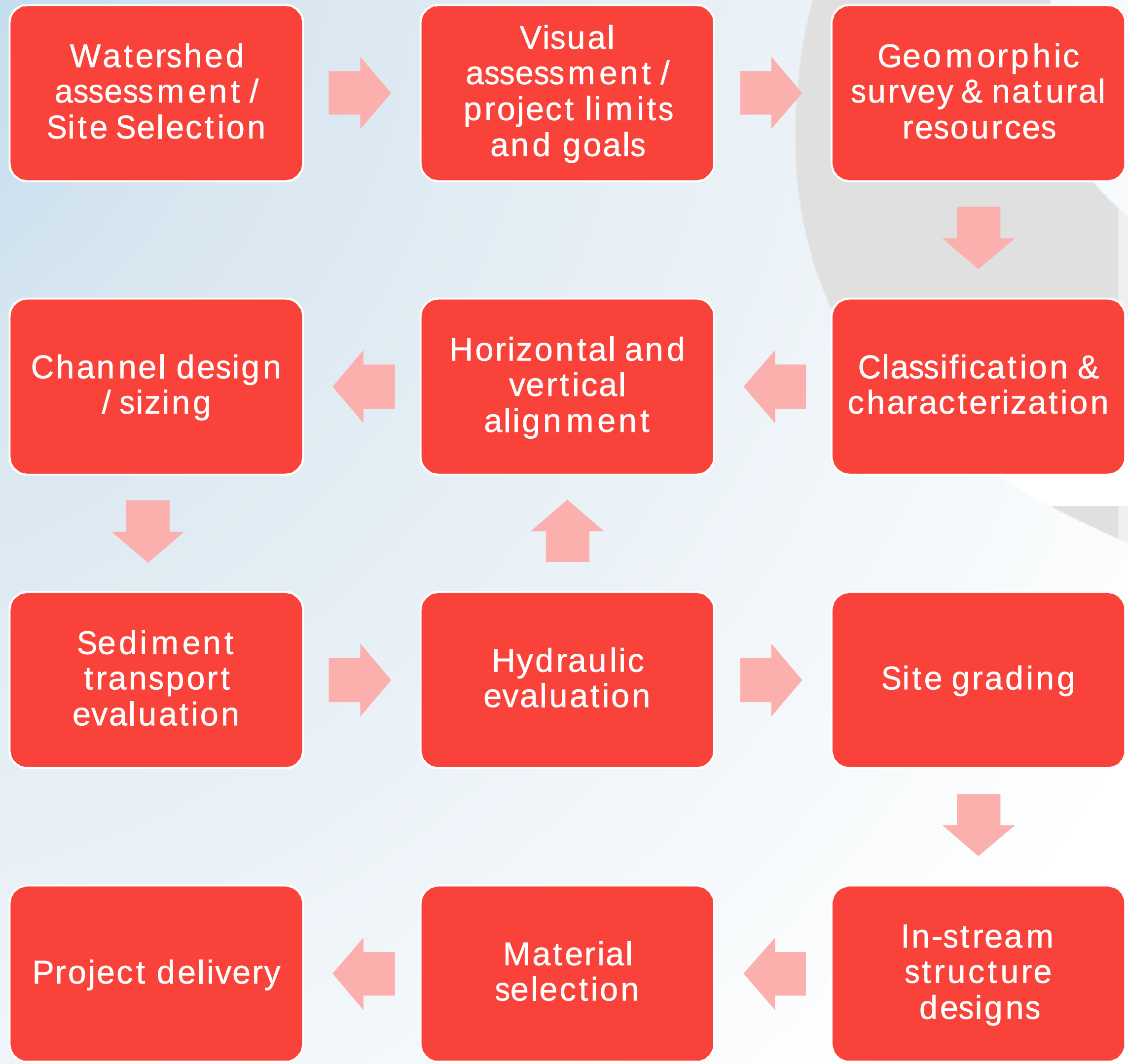
STREAMBANK STABILIZATION USING IMBRICATED ROCK STRUCTURES AND BIOENGINEERING TECHNIQUES

Western Run

— Imbricated Rock Wall

— Constructed Riffle & Rock Sill

Design Process



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Dead Run Stream Restoration

Catonsville, MD

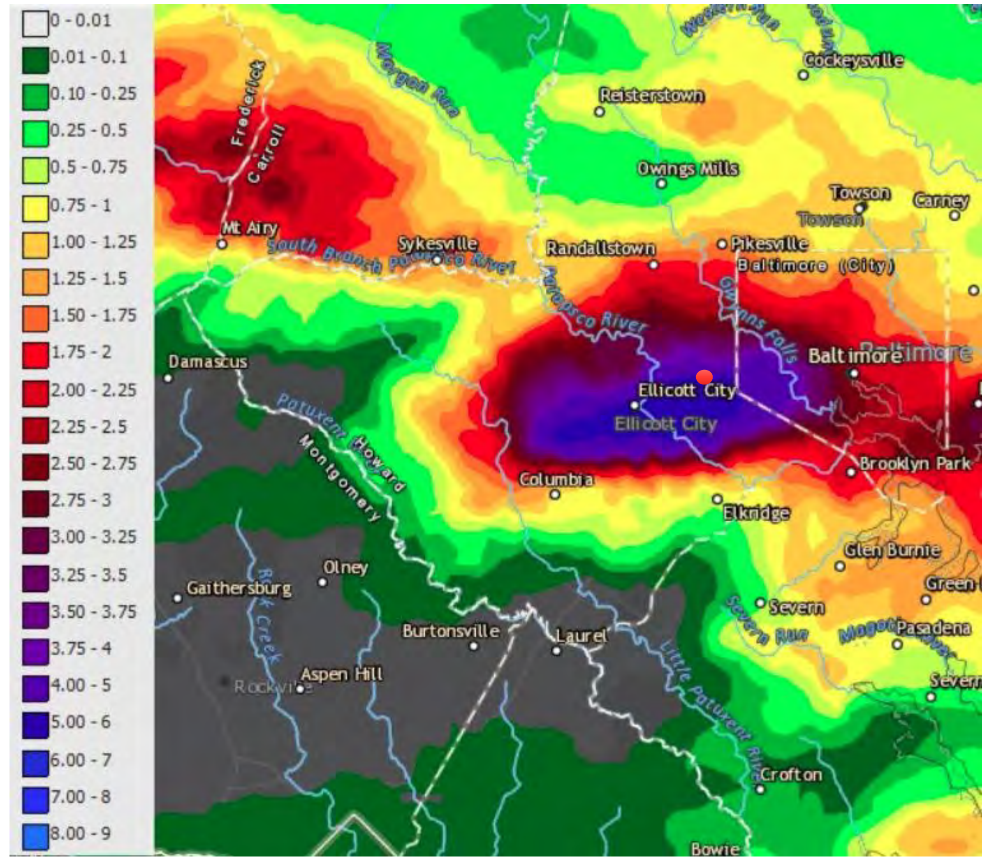
Dead Run Stream Restoration

- Baltimore County Dept. Environmental Protection and Sustainability
- 4,700 lf of 1st and 2nd order stream channel
  - *Included an off-line wet pond SWM facility*
- Channel systemically impaired
  - *Entrenched F Type channel*
- Priority 2 / 3 Restoration Design
- Hybrid design approach
- $2.2 Million Low Bid
- Environmental Quality Resources LLC
- 6 month in-stream construction period

Construction Completed Dec. 2017

May 27, 2018 – 3pm to 6pm

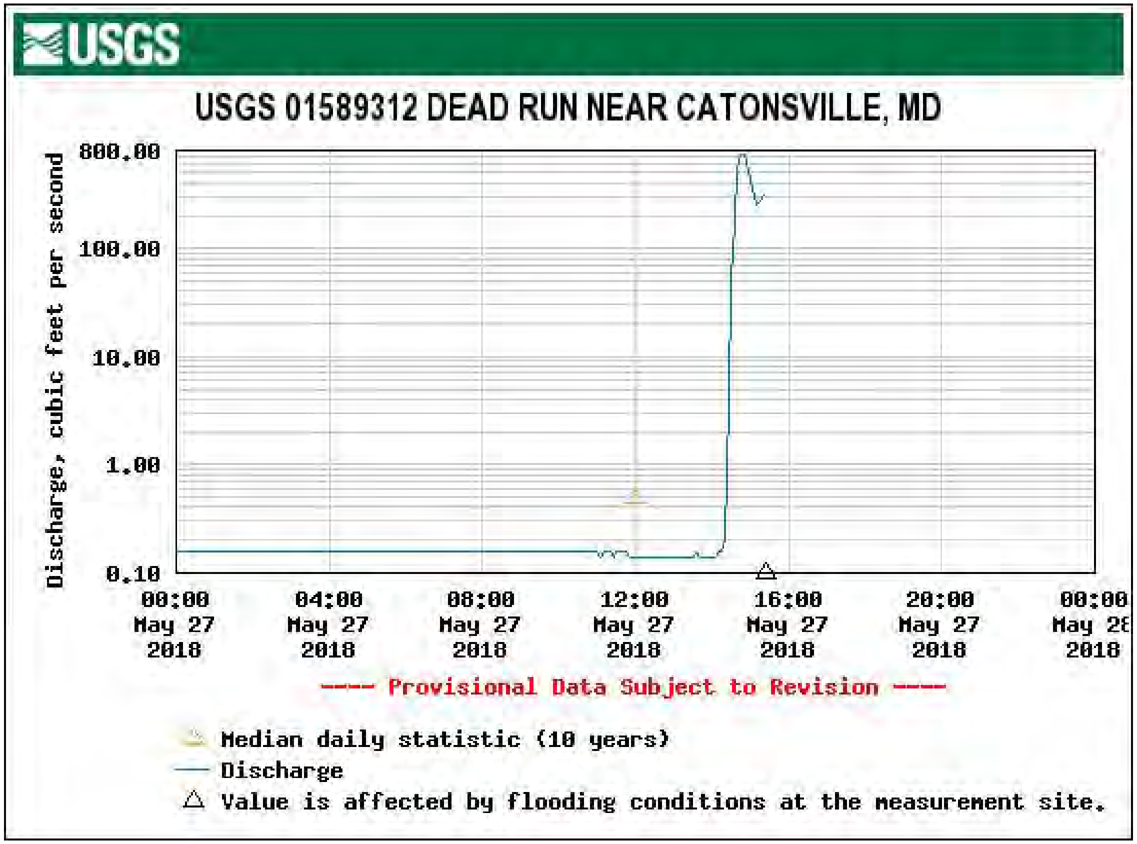
Ellicott City, MD



Left Image Source: Washington Post
Right Source: National Weather Service

Dead Run - May 27, 2018

- Gauge failed at 3:30pm
- Gauge is located 1,500 l.f. downstream of project area



Dead Run

May 28, 2018


Not perfect, but not bad…

Design Resources

- Rosgen - Wildland Hydrology
  - *Short Courses, Applied River Morphology, and Watershed Assessment of River Stability and Sediment Supply (WARSSS)*
- NRCS Stream Restoration Handbook (NEH 654)
- Regenerative Step Pool Conveyance – Design Guidelines
  - *Anne Arundel County, MD*
- A Function-based Framework for Stream Assessment & Restoration Projects (EPA 843-K-12-006)

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QUESTIONS?

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