

# Water Quality Credits from Stream Restoration Projects

**Harbans Lal**, PhD, Environmental Engineer, National Water Quality & Quantity Team (WQQT), West National Technology Support Center, NRCS/USDA, Portland, OR

**Barry Southerland**, PhD, Fluvial Geomorphologist, WQQT, WNTSC NRCS/USDA, Portland, OR

**Marc Leisenring**, PE, Principal Engineer at Geosyntec Consultants, Portland, OR

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# Highlights

- 1. Environmental Markets & Water Quality Trading** (Trading Approaches, Trading Commodities, WQ Credits, Tools and Techniques)
- 2. Non-Point Pollution Sources and WQ credits**
- 3. Fluvial Geomorphology Principles** (In-stream Factors Contributing to Water Quality)
- 4. Tools and Techniques**
  - International BMP Database
  - WE&RF Guidance for Estimating WQ Credits from Stream Restoration



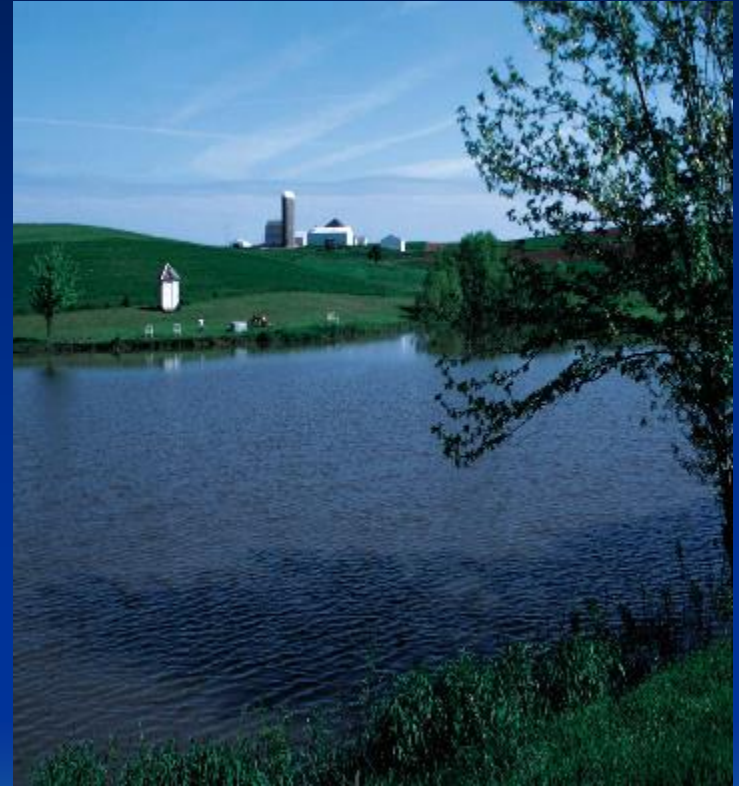
# Ecosystem Markets

## Definition

One entity paying (\$) to another entity for **ecosystem service(s)** offered by ecosystem management

## Benefits

Facilitates and encourages private sector to invest in conservation on private lands to sustain and improve the environment



# ECOSYSTEM MARKETS (WATER)

## Water Quantity Trading

Transfer of water rights

Temporary/Permanent

## Wetland Mitigation (Banking Credits)

Mechanism for offsetting  
for expected adverse  
impact on ecosystem

## Water Quality Trading

One entity to meet its regulatory  
obligations by using pollution  
reduction by another entity  
(N, P, Temp & Sediments)

# WQ Trading Systems

## Voluntary

- Purely voluntary approach
- No restriction on buyer or seller
- No fixed WQ target to achieve



## Cap and Trade

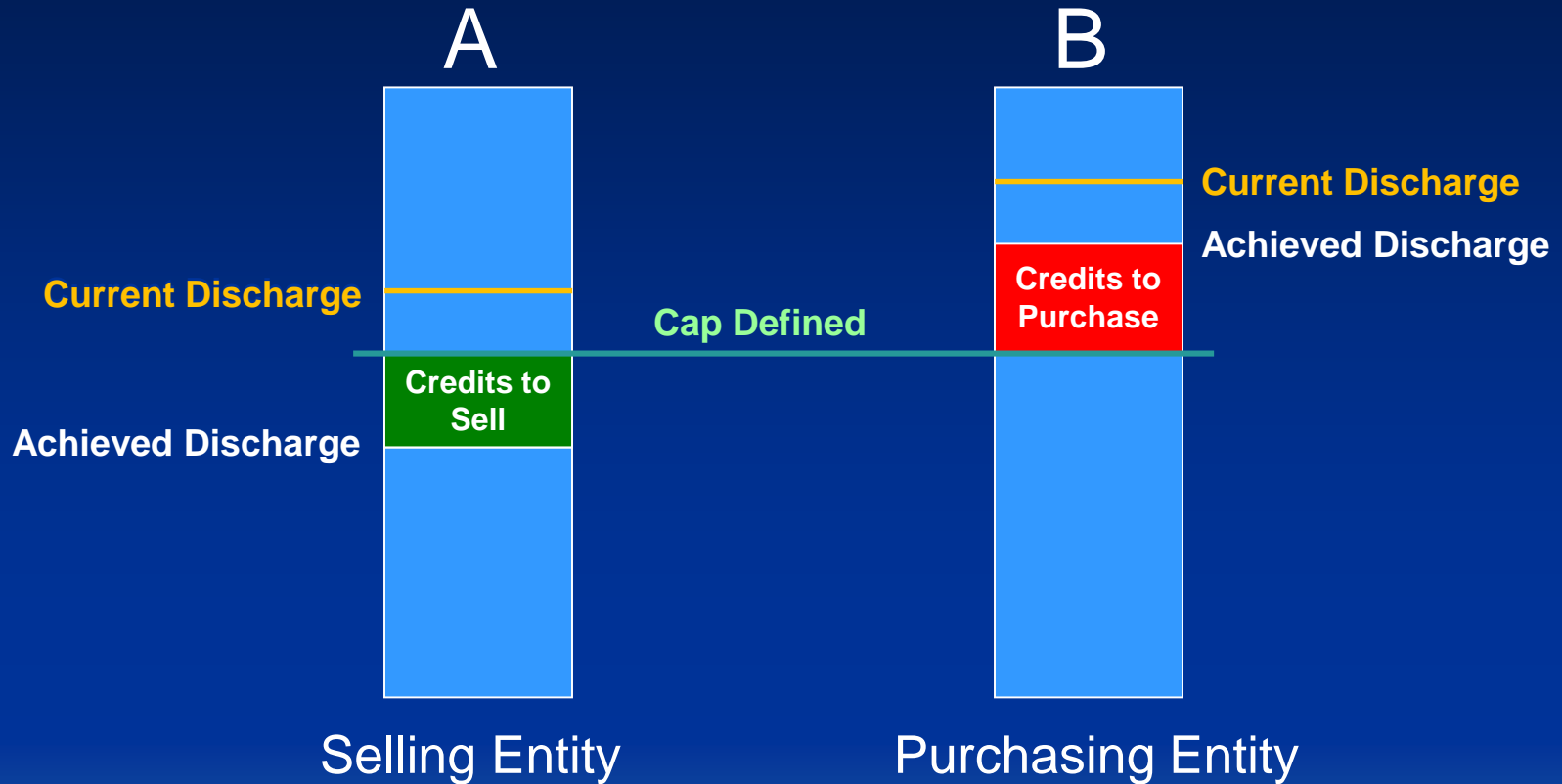
- Well defined WQ target to achieve (TMDLs)
- Buyers (WWTP, MS4, etc.) to meet NPDES permit requirement
- Buyers (WWTP, MS4, etc.) to acquire credits or install expensive on-site technology

Total Maximum Daily Loads

**TMDLS**  
*at Work*



# Baseline and Tradable Credits (Cap and Trade)



# WQ Trading Types



Point source (WWTPs) to point source (WWTPs)



Non point source (Ag Ops) to permitted point sources

# WQ Trading

## Why Non-point Sources?

- Cost Benefits
- Control pollutants at source
- Control multiple nutrients
- Promote ecosystem approach
- Provide wildlife habitat



**Buy one get many free !**

# WQ TRADING

Cost difference and effectiveness of conservation practices in pollution control due to site specific characteristics

BMP / Control Practice	Phosphorus (\$/lb)	Nitrogen (\$/lb)
Municipal waste treatment	\$4.78-\$105.67	\$5.73-\$10.78
Conservation tillage	\$7.39	\$1.59
Agricultural grass buffer	\$20.69	\$1.03
Animal waste management / runoff control	\$30.55	\$3.93

Nutrient Reduction Costs (Chesapeake Bay) EPA, 2007



# Non-Point Water Pollution Sources

Farm/Field Level  
Ag. Runoff



Stream bed/bank  
erosion

In-stream and floodplain  
sediment/nutrient processing



# Non-Point Practices for WQ Credits

## Field Level Management

- Cropping System (Cover Crops)
- Nutrient Management
- Tillage Management (Cons.Tillage)



## Farm Level Structural Practices (Buffers, Grass Waterways, etc.)

## Stream Restoration



# History of Water Quality Trading (WQT)

- States began experimenting as early as the 1980s
- In 2003 EPA issued a policy statement expressing its support and basic expectations from trading programs
- EPA's 2003 policy NOT prescriptive, and allows states to take their own unique approach, which they all do
- Experience has shown that viable WQT programs require rigor and transparency that is trusted by the public, which is why public involvement in the design process is encouraged

Adjusted from Slides by Bob Rose, EPA



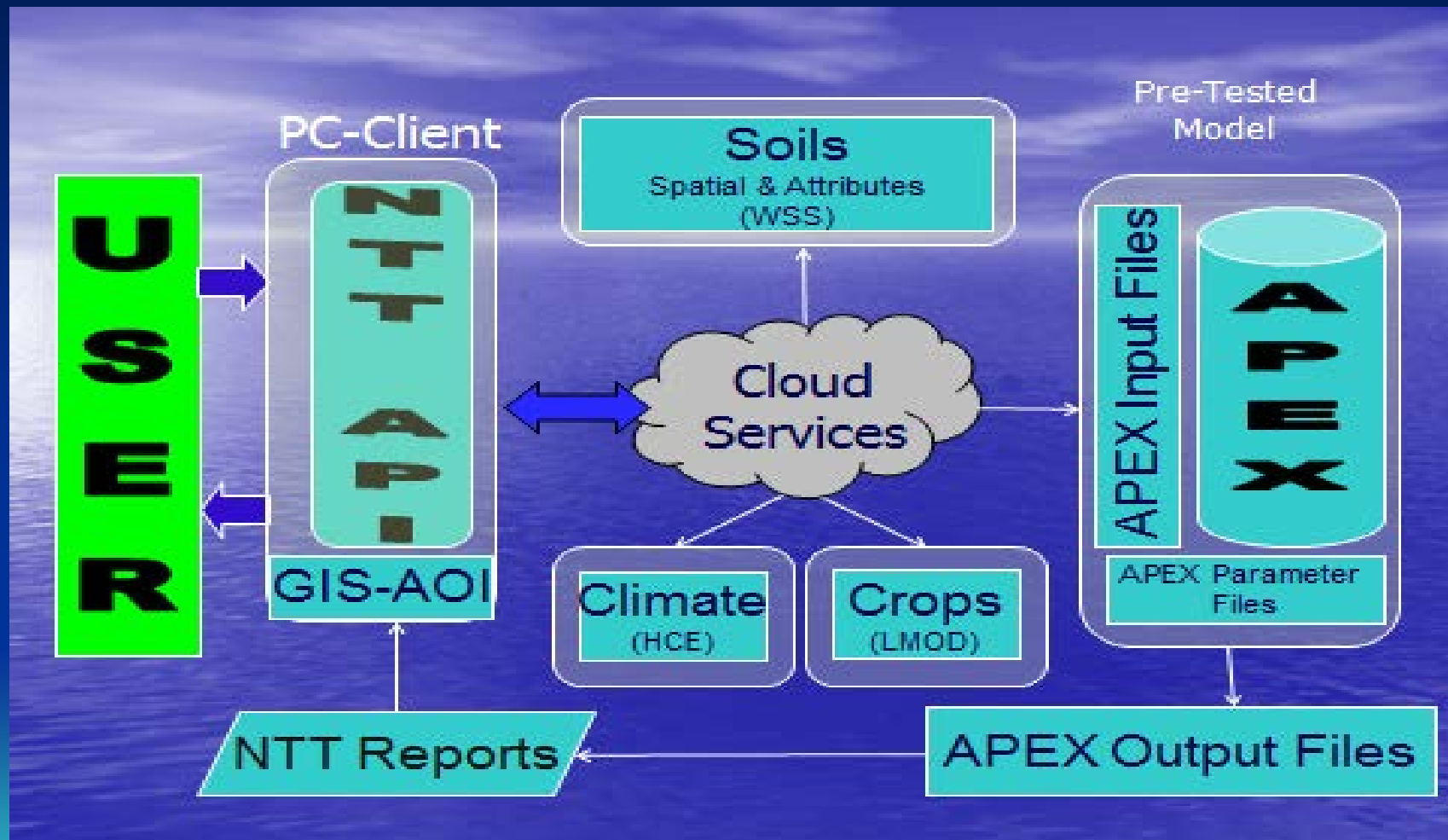
# USDA/NRCS Role in Water Quality Trading (WQT)

- USDA Office of Environmental Markets (OEM)
  - To provide leadership in the development of environmental markets for carbon, water quality, wetlands, and biodiversity
  - To build national environmental market infrastructure, supporting regional market innovation, and fostering collaboration around market-based conservation within USDA and across the federal government.
- Funding CIGs on Water Quality Trading (WQT) since 2012
- Developing science-based tools for promoting WQT (NTT, WQIag, etc.)



# Nutrient Tracking Tool (NTT)

(Being Re-designed and Re-engineered)



# Water Quality Index for Agricultural Runoff (WQIag)

Web-Interface

Tech Note

Water Quality Index  
 United States Department of Agriculture  
 Natural Resources Conservation Service

**Water Quality Index** WQIag

Runoff Water Quality Index Version: 1.0.15 Date: 07/03/2013

Site Information \* Required

\* State: South Dakota \* County: Lawrence HUC:   
 \* Field #: 1 \* Field name: Field 1 \* Acres: 100  
 \* Project date: 9/24/2016 \* Description: Test Run for Deadwood Presentation

FACTORS	DESCRIPTION	WQI RANKING FACTOR	WEIGHTING	WEIGHT
<b>Field Physical Sensitivity Factors</b>				
Slope (%)	Get Slope Interaction (2% to 5%)			
HS group	(B - moderately low runoff potential)	8.00	0.25	2.00
K-factor	(0.33 - 0.43 high erodibility)	7.00	0.25	1.75
OM content	2-4%	6.00	0.25	1.50
Rainfall/Veg	Get Rain / Vegetation Interaction	5.25	0.25	1.31
Duration	By Year By Month By Season Year: January - December		0.25	1.64
<b>Nutrient Management Factors</b>				
Application rate	LGU recommendations	5.00	0.25	1.25
N-source and timing	Uncomposted manure, split application, 1-2 days prior	6.00	0.25	1.50
P-source and timing	Uncomposted manure, split application, < 1 week prior	8.00	0.25	2.00
Soil condition / application	Moist, N/P fertilizer, broadcasted & incorporated	4.00	0.25	1.00
	(Tile Drain adjusted NTP)		0.25	1.51
<b>Tillage Management Factors</b>				
Description / STIR	Mulch Till or STIR Value 31 to 60	7.50	1.00	7.50
	(Tile Drain adjusted NTP)		0.25	1.97
<b>Pest Management Factors</b>				
Description	Basic IPM - Threshold-based suppression with additions	7.00	1.00	7.00
	(Tile Drain adjusted NTP)		0.25	1.84
<b>Irrigation / Tile Drain Management</b>				
Irrigation	Surface - Graded border and surge (-15%)			
Tile Drain	High density with Drainage Water Management (+5% & )			
Runoff Water Quality Index (WQIag#)				5.91
<b>Conservation Practices</b>				
Get Conservation Practice(s)		# Selected		2
Runoff Water Quality Index (WQIag#) with additional Conservation Practices				8.28
Project file:	TestRunforDeadwoodPresentation.wqii	Close	Report	

USDA United States Department of Agriculture

March 2017

Agronomy Technical Note No. 12

**WQIag-Water Quality Index for Runoff Water from Agricultural Fields**

Natural Resources Conservation Service  
 nrcs.usda.gov/

<http://wqiag.sc.egov.usda.gov/>

# Fluvial Processes and Sediment impacts on Water Quality

## Instream factors contributing to Water Quality Issues



**RECLAMATION** *Managing Water in the West*  
*The Knowledge Stream*  
Spring 2016  
Research and Development Office  
Newsletter 2016-02  
Reservoir Sedimentation and Sustainability Issue

Paonia Dam Colorado 2014

*Sedimentation—filling up a reservoir in less than a lifetime.*

1961

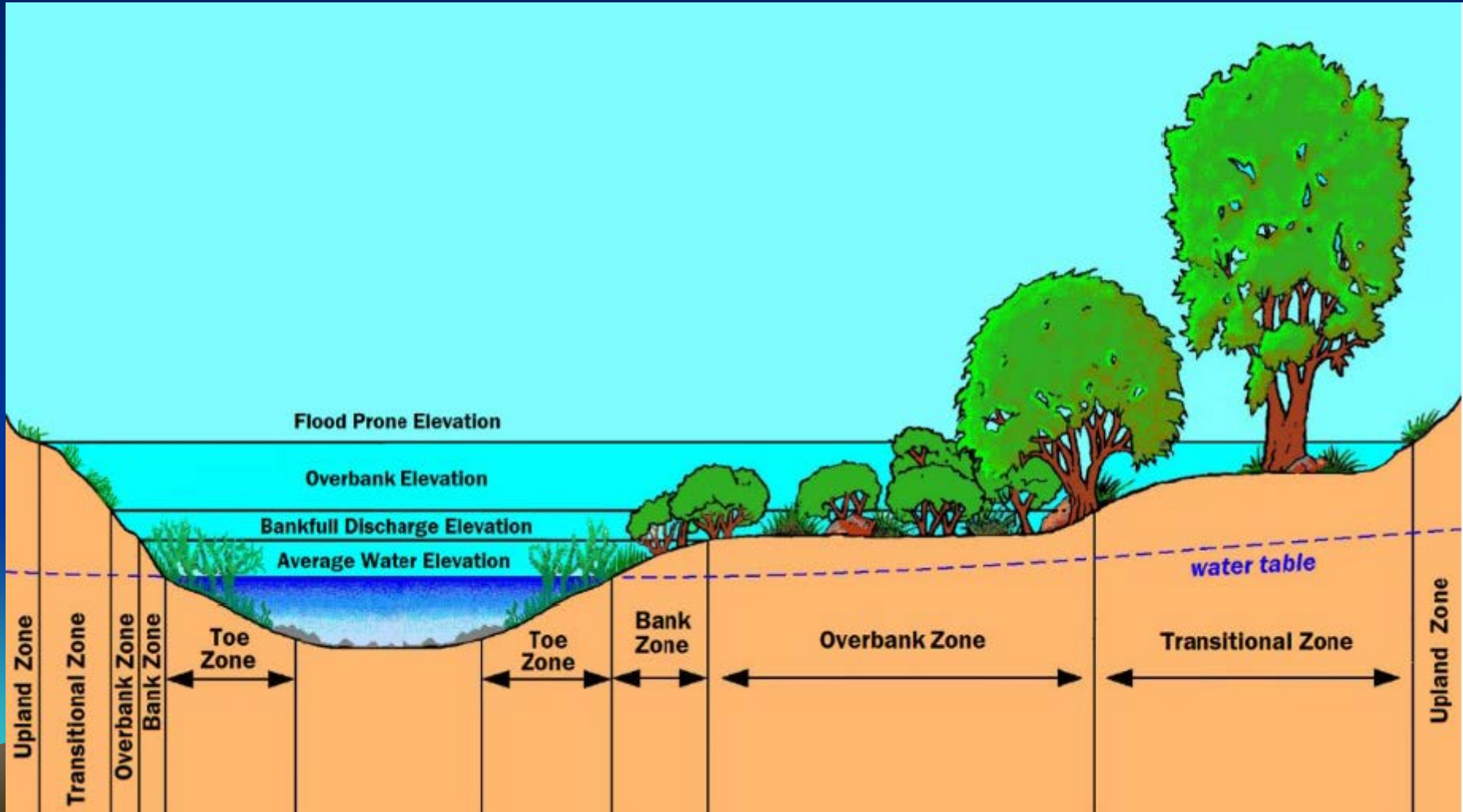
Presented by  
W. Barry Southerland, PhD,  
Fluvial Geomorphologist, CPESC#514

# Objectives of this Presentation

- Become aware of fluvial processes that impact water quality.
- Discuss channel evolution process and its impacts on WQ.
- Discuss role and function of floodplain and its impacts on WQ.

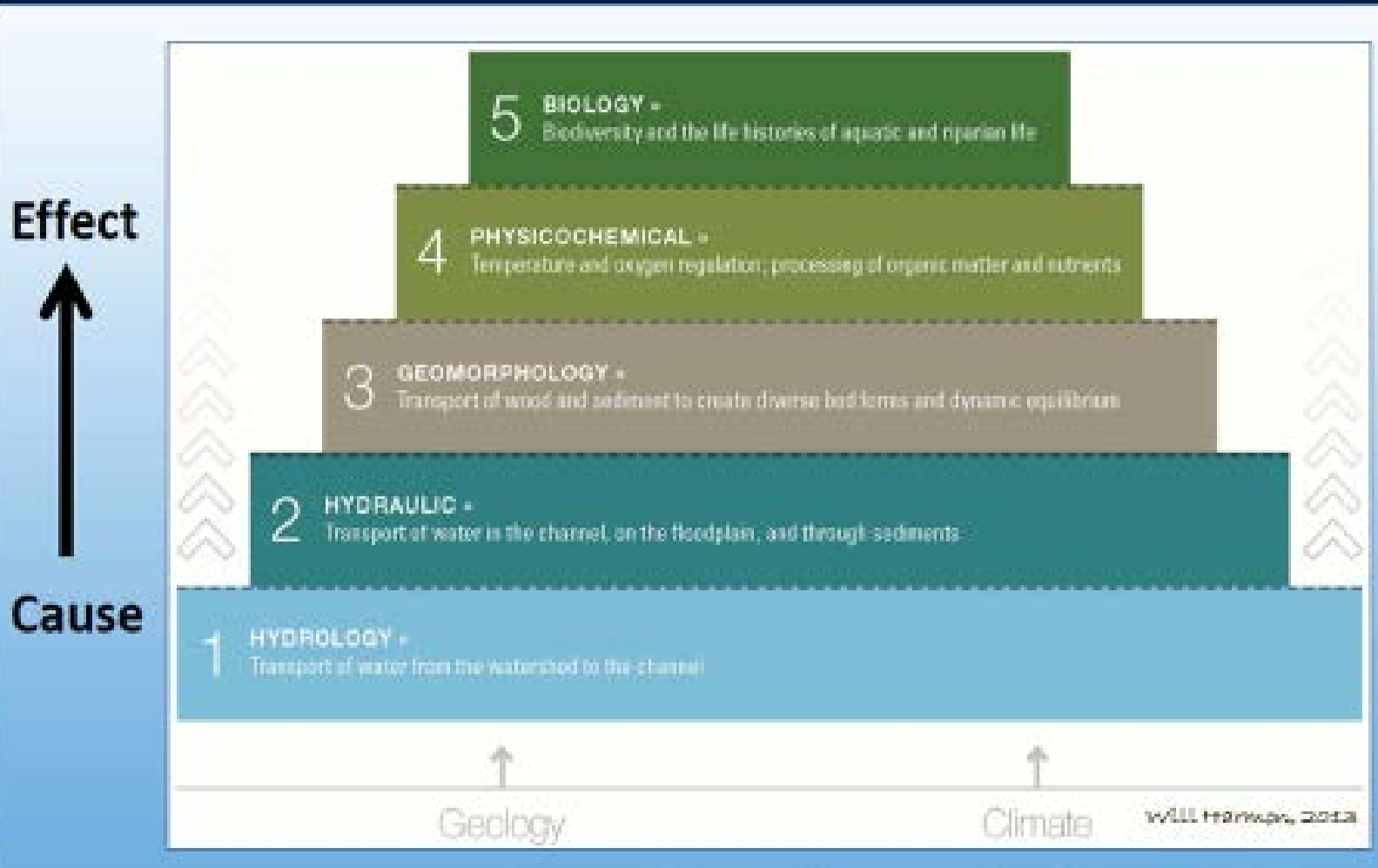


# A cross-sectional look at a stream



# Cause and effect and how streams function to move sediments impacting WQ

Stream Functional Pyramid

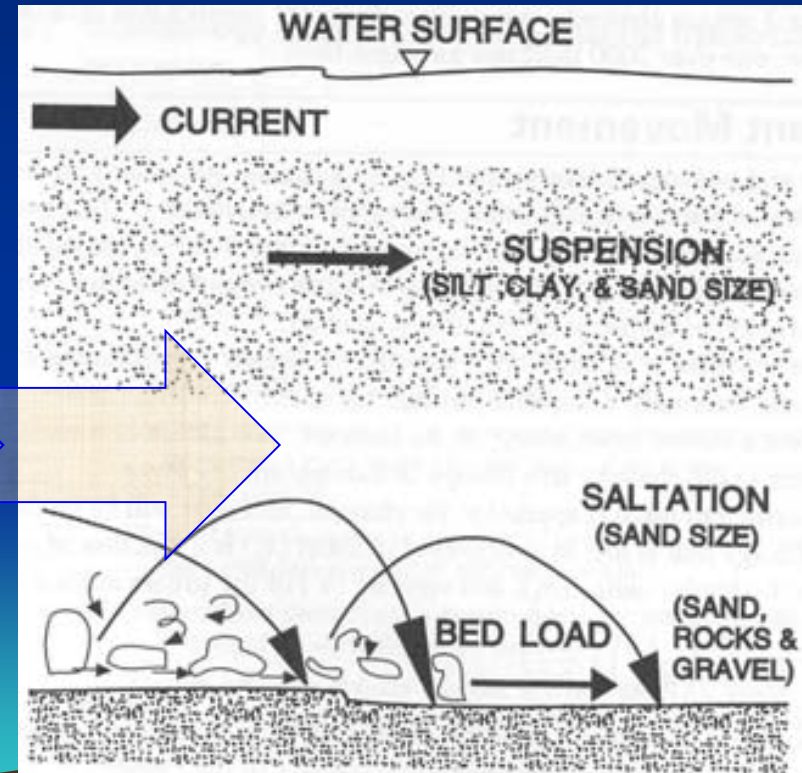


# The impacts of straightening a stream



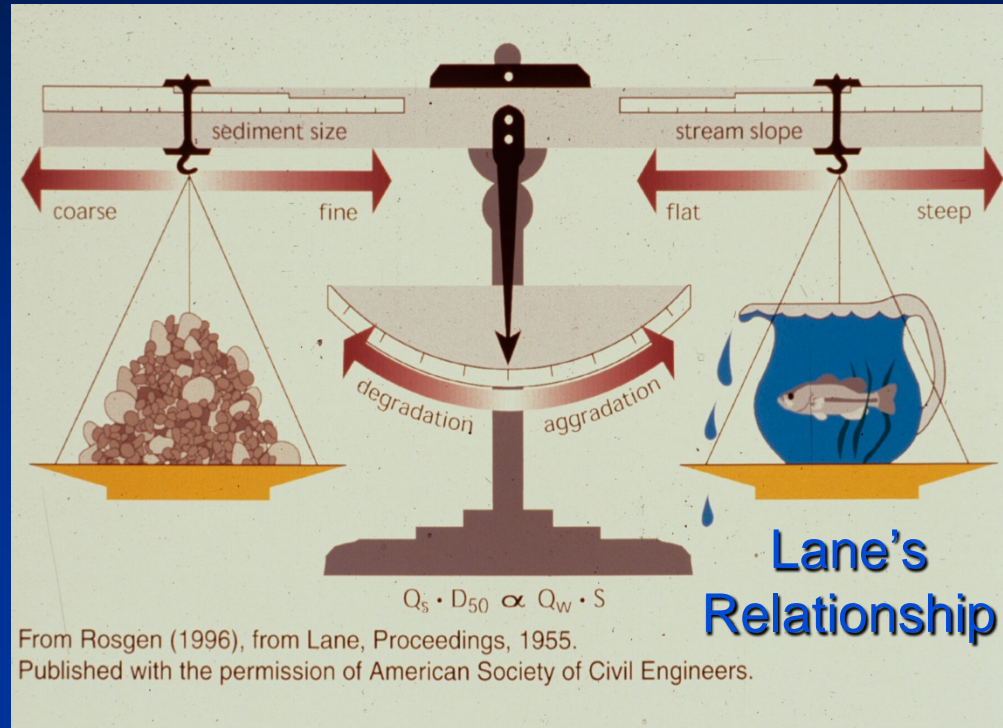
- **Suspended load- Clay, Silts and non- saltation fraction of sands**
- **Wash Load Component of the suspended load is  $< 62$  microns or (.062mm)**
- **Bedload: that portion of the load that entrains and mobilizes along the bed.**
- **Dissolved load – the portion of the total load that is carried in solution such as chemical ion yielded by erosion.**

Dissolved Load →



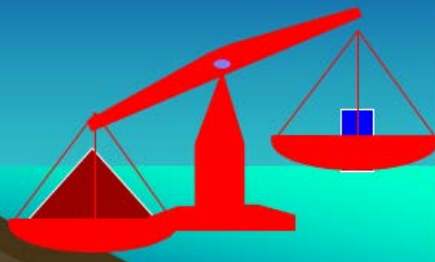
Transportation of particles of sediment in running water.

# Stream aggradation and Incision: opposite problems severely impacting WQ.



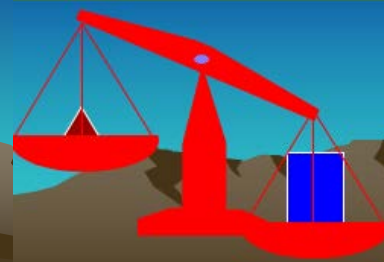
Lane's balance

$$Q_s \cdot d_{50} \sim S \cdot Q$$

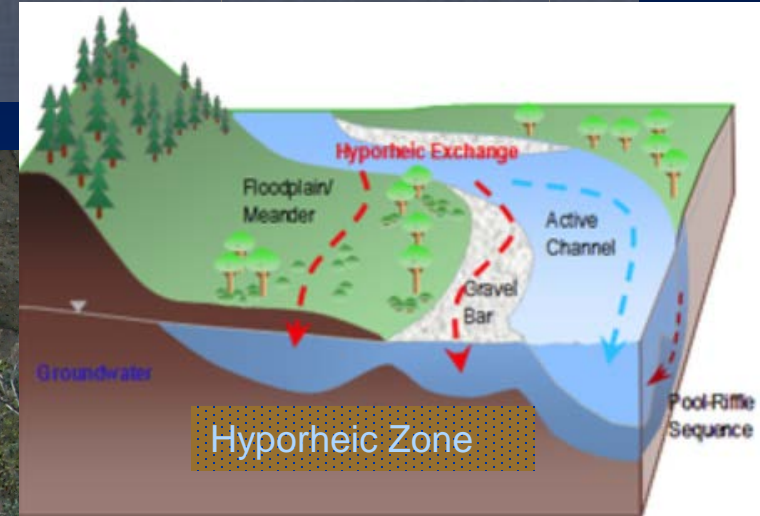


Lane's balance

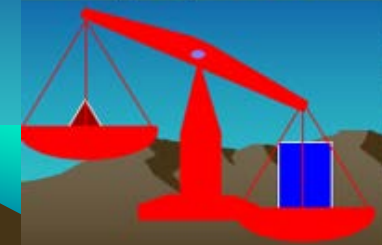
$$Q_s \cdot d_{50} \sim S \cdot Q$$



# Impacts of incising and loosing floodplain on WQ



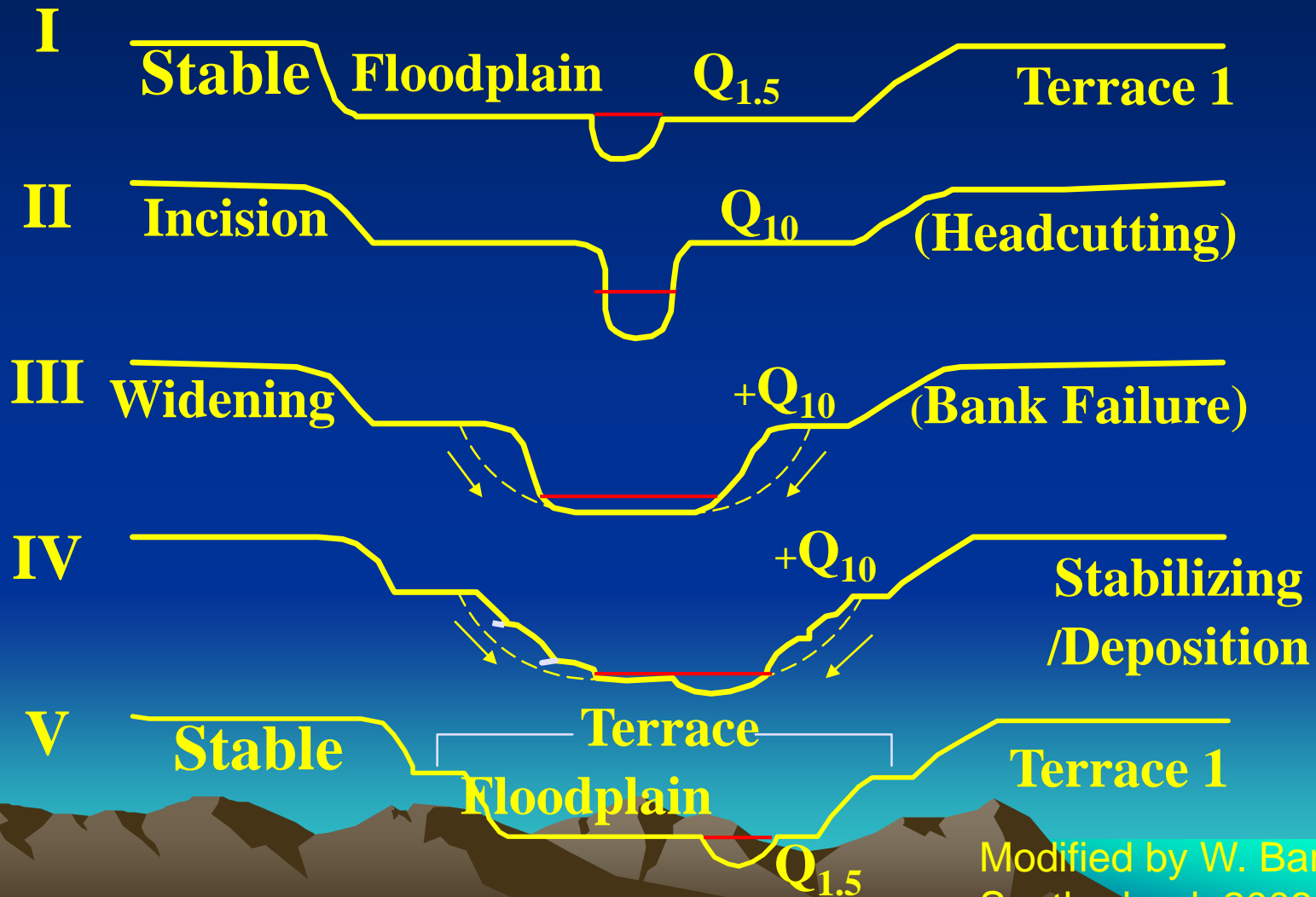
Lane's balance  
 $Q_S * d_{50} \sim S * Q$



# Channel Evolution Model

Schumm, Harvey, Watson (1984):

— = Bankfull Q

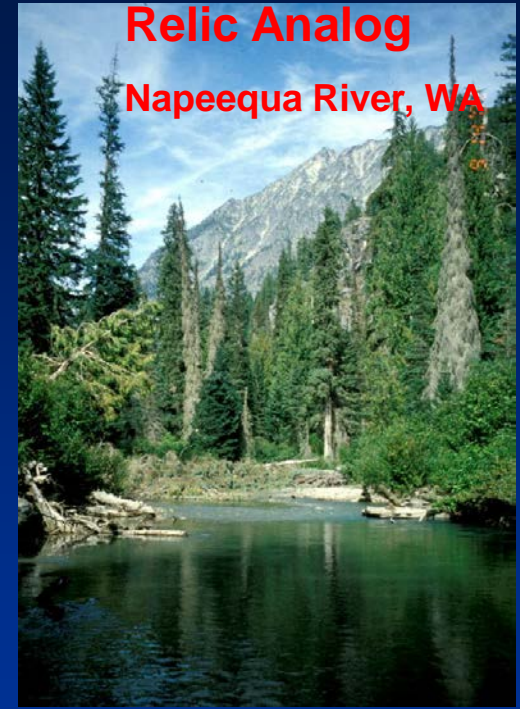


Modified by W. Barry  
Southernland, 2003

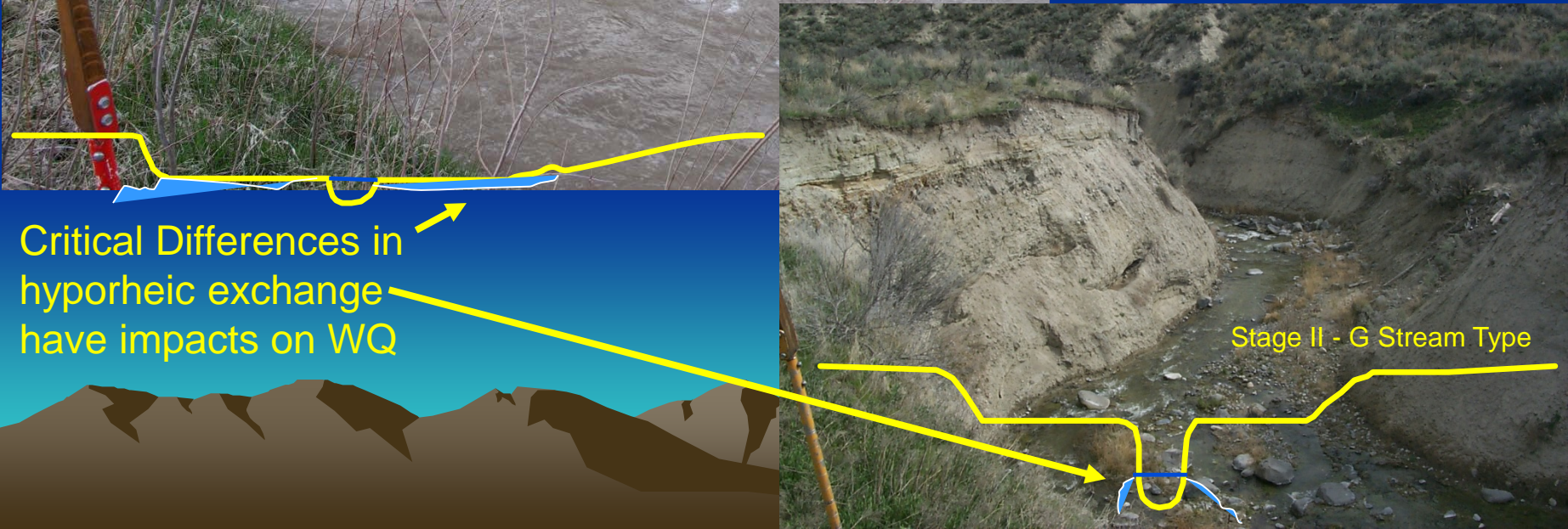
# Channel Incision Impacts on WQ

What are the buffer opportunities on a current stable stage I CEM? (excellent floodplain connectivity).

Current Stable Analog – Chalk Creek, UT



Relic Analog  
Napeequa River, WA



Stage II - G Stream Type

Critical Differences in  
hyporheic exchange  
have impacts on WQ



# Opposite Problems

## Incised Stream – J-Bar - South Fork Asotin Creek

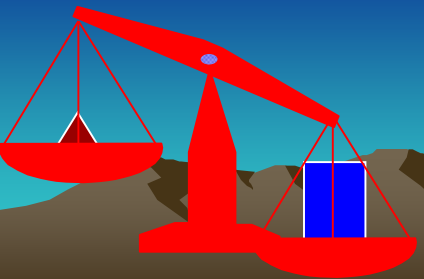
12 inch annual prec.



Photo by WBS, South Fork Asotin CK, 1997

Lane's balance

$$Q_S * d_{50} \sim S * Q$$



## Braided and Aggraded Stream – Koch - Asotin Creek

Asotin 1997

10 inch annual prec.

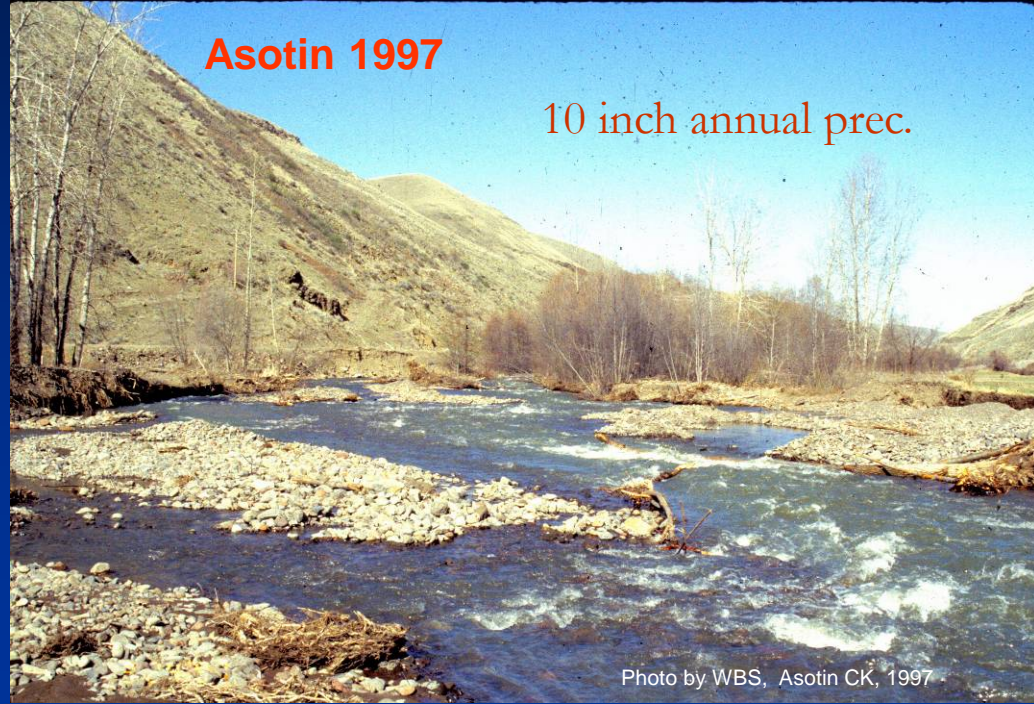
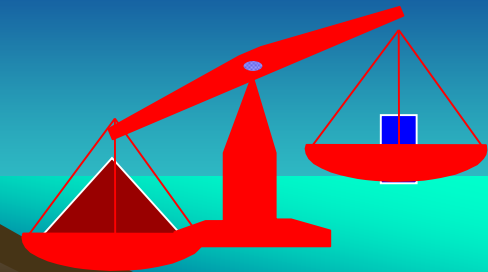


Photo by WBS, Asotin CK, 1997

Lane's balance

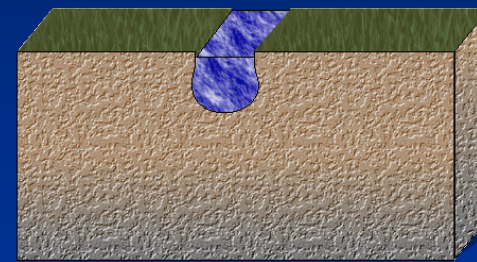
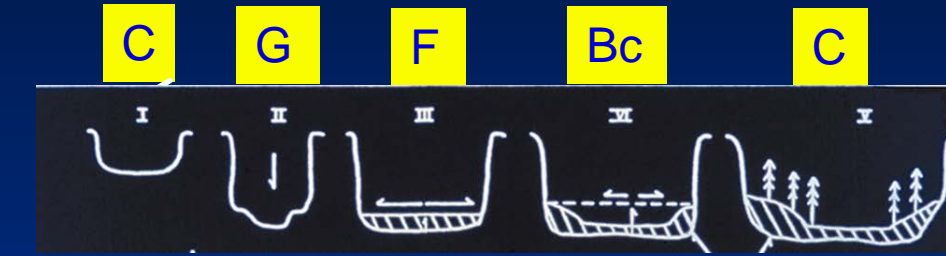
$$Q_S * d_{50} \sim S * Q$$



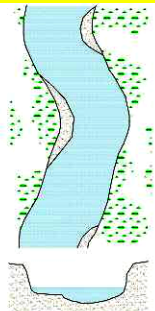
# Aquatic Habitat Response to Stream Type Change – Water Quality & Physical Stream Change

Stage II Stage III Stage V No Stage Change

Variable	C→G	G→F	F→C	C→D
Instream Cover	↓	↓	↑	↓
Overhead Cover	↓	↓	↑	↓
Substrate Composition	↑	↓	↑	↓
Pool Quality	↓	↓	↑	↓
Holding Cover Velocity	↓	↓	↑	↓
Temperature	→	↑	↓	↑
Oxygen	→	↓	↑	↓
Macro Invertebrates	↓	↓	↑	↓
Spawning Habitat	↓	↓	↑	↓
Diversity	↓	↓	↑	↓
Rearing	↓	↑	↑	↑
IBI Score	↓	↓	↑	↓

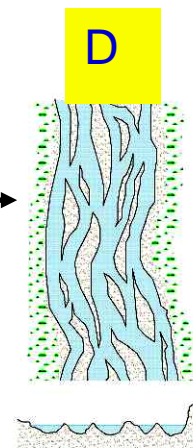
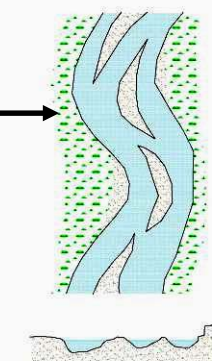
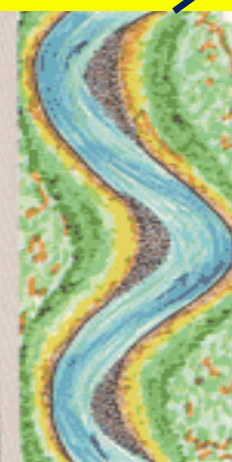


F stage III

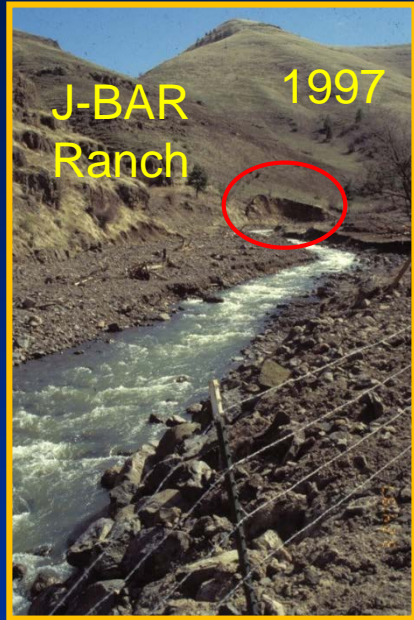


C Stable

C unstable



# Natural Geomorphic Channel Restoration benefits to WQ



**“Natural stream channel stability is achieved by allowing the river to develop a stable dimension, pattern, and profile such that, over time, the stream system neither aggrades or degrades (incision). For a stream to be stable it must be able to consistently transport its sediment load, both is size and type, associated with local deposition and scour.”**



**Entiat Reference Reach**

**Width Depth Ratio = 20**

**Entiat Immediately Upstream**

**Width Depth Ratio = 48**

# How dropping stream bed elevation impacts water quality

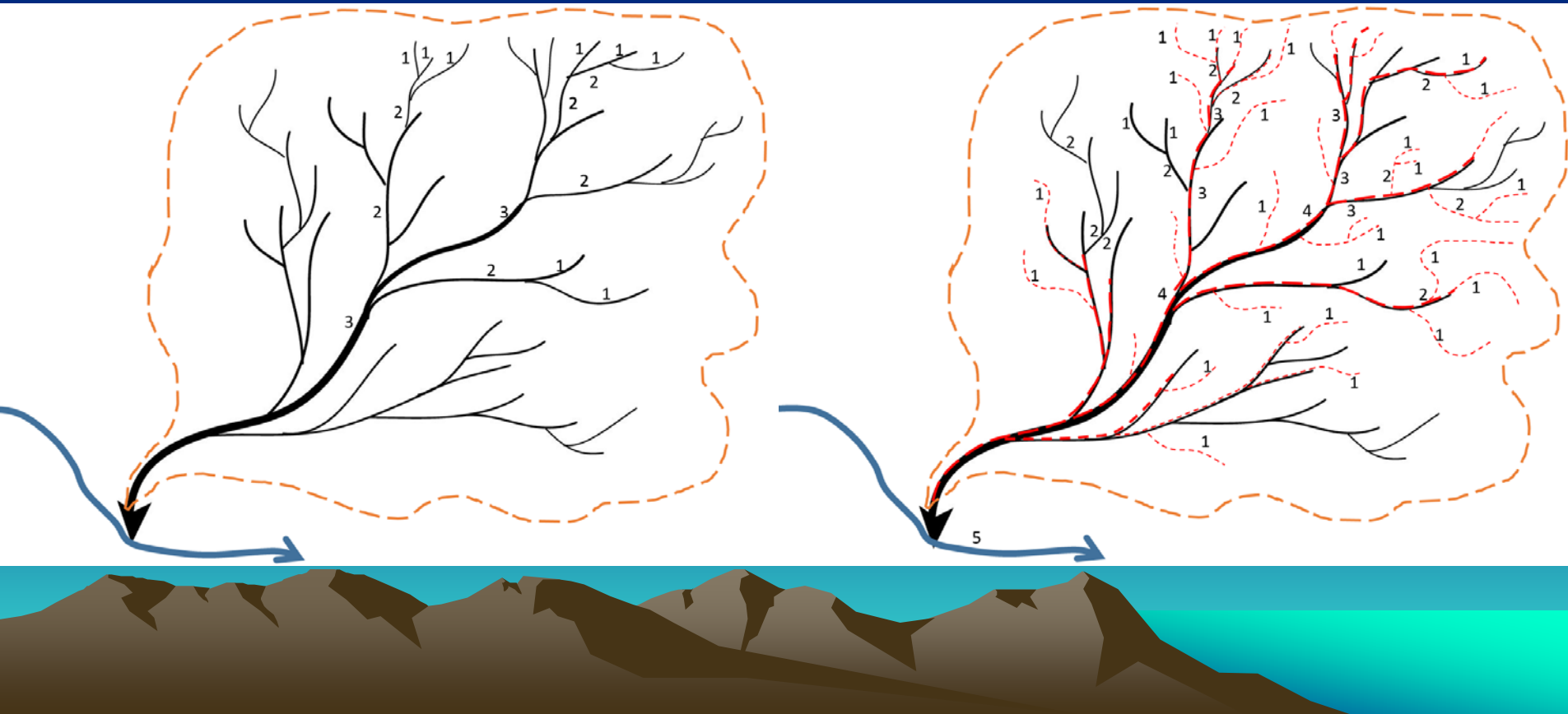
## Watershed incision

- The increase network of concentrated flow, due to watershed incision.
- The result? Higher sediment delivery ratios to the water courses. More intense, shorter duration events have bigger impact on water bodies and WQ.



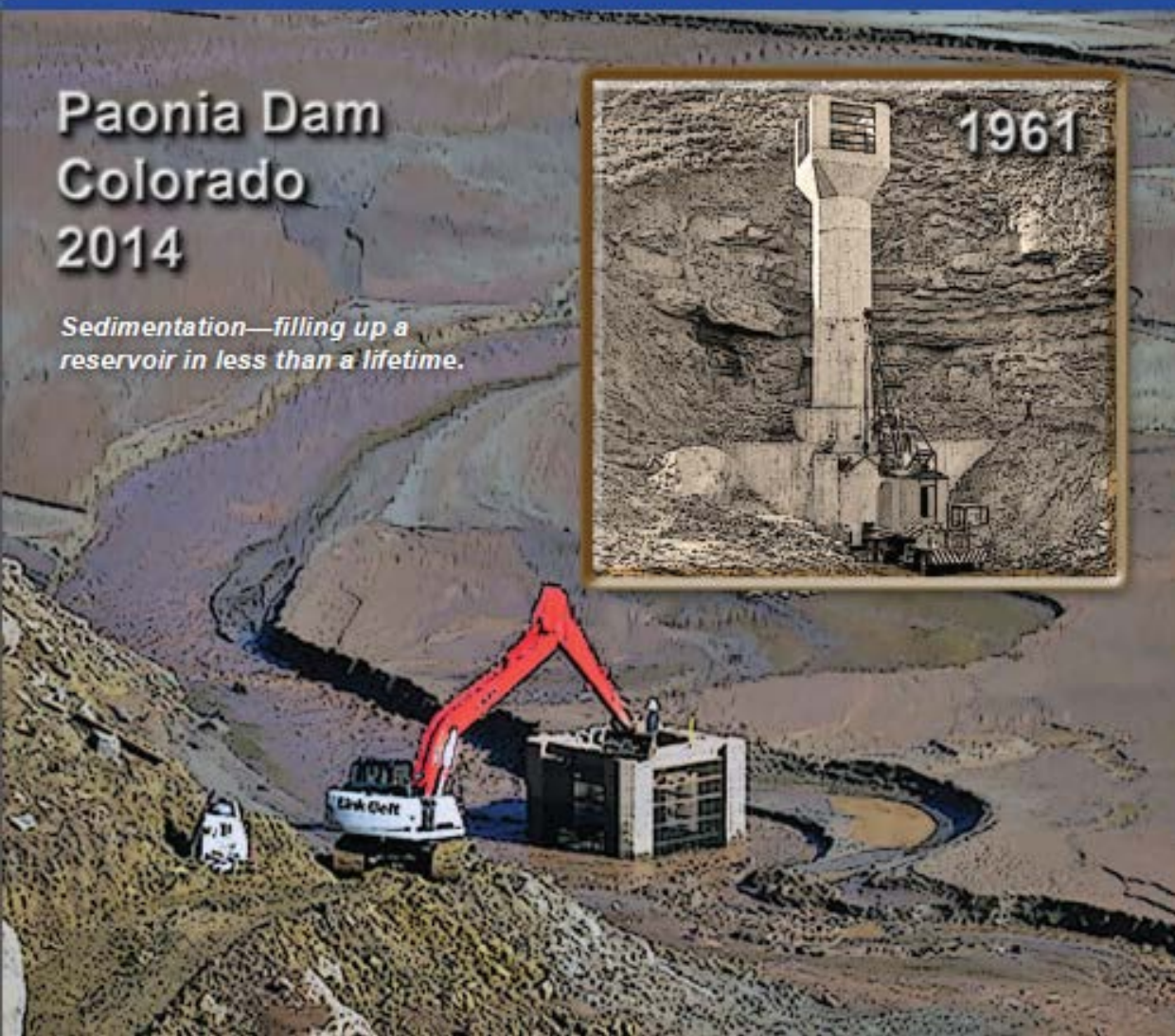
# Changing the flow regime? When the streams incise and the watershed incision follows.

Lowering of the base grade of the watershed catchment increases streambank and upland erosion



**Paonia Dam  
Colorado  
2014**

*Sedimentation—filling up a  
reservoir in less than a lifetime.*



Filled in 2013  
working on it  
in 2014  
52 years with  
rapid reduced  
capacity.

Accelerated  
reservoir filling is  
a WQ problem for  
a variety of  
reasons  
**CREDITS!**

# Conclusions

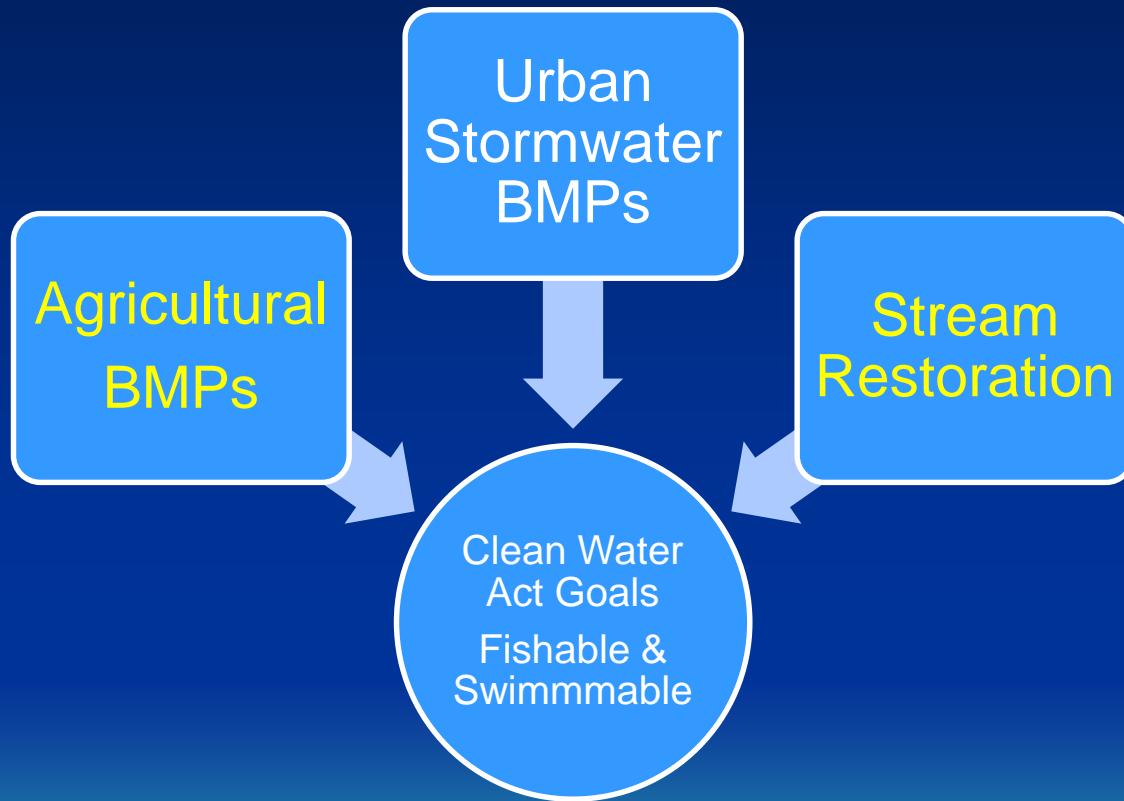
1. Accelerated streambank erosion and a shift to an unstable channel evolution stage can easily create accelerated erosion one or two magnitudes of order greater than natural channel erosion negatively impacting WQ.
2. Loss of floodplains, due to incision or channelization will have long-term negative impacts on not only WQ but aquatic life, hyporheic exchange and stream stability.
3. The closer we plan to natural channel stability, reestablishing floodplains, and stable streambanks, the more long-term positive impact we will have on WQ and lower operation and maintenance.

International BMP Database

# A DATA SOURCE TO SUPPORT WQ CREDITING

# International BMP Database

[www.bmpdatabase.org](http://www.bmpdatabase.org)



# What is the Agricultural BMP Database (AgBMPDB)?

- Centralized repository agricultural BMP field studies (e.g., conservation practices and structural controls)
- Performance data and *metadata* that document the variables and practices that reduce pollutant loading from agricultural sites
- Developed and initially populated in 2014

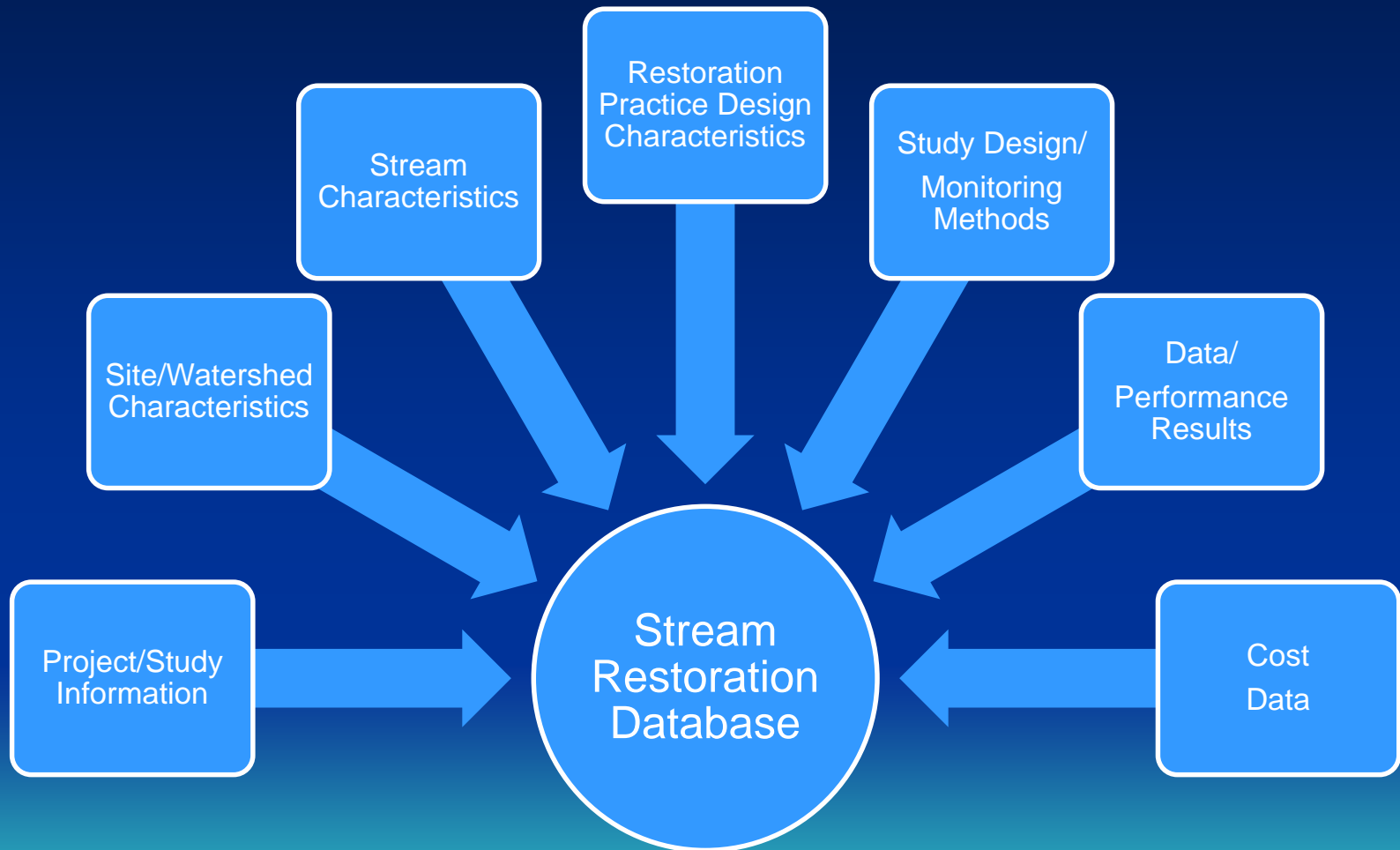


# What is the Stream Restoration Database (SRDB)?

- Centralized repository stream restoration studies
- Performance data and *metadata* that document the variables and practices that reduce pollutant loading from stream restoration projects
- Developed and initially populated in 2016

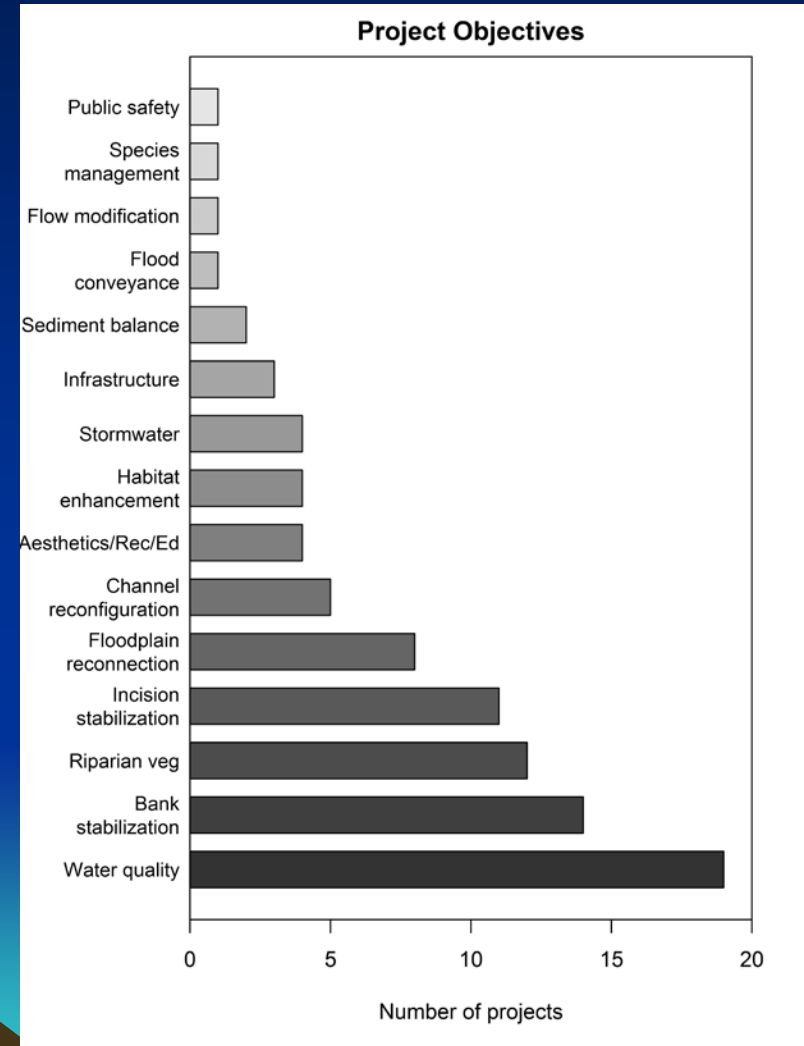
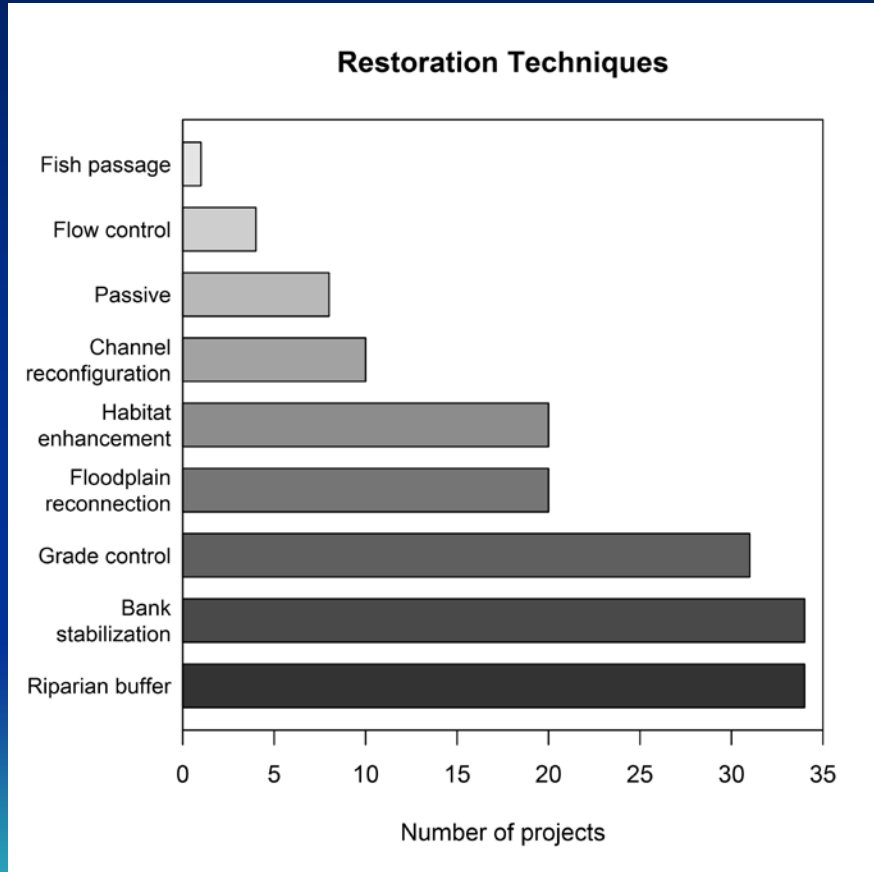


# SRDB Structure



# Studies in the Database

24 studies

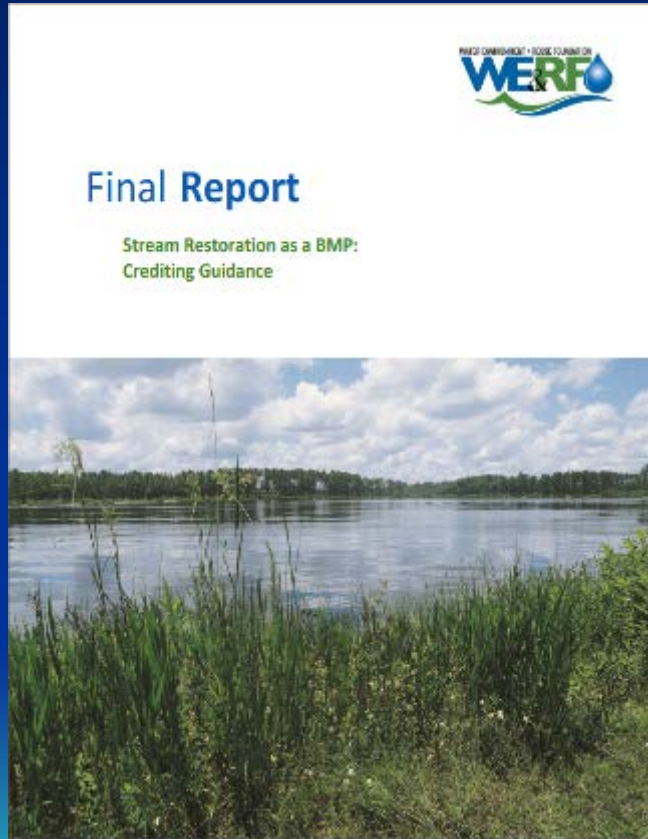




Stream Restoration

# CREDIT ESTIMATION APPROACHES

# Stream Restoration as a BMP Crediting Guidance



## Research Team

### Principal Investigators:

Brian Bledsoe, P.E., Ph.D.  
*University of Georgia*

Jonathan Jones, P.E.  
*Wright Water Engineers, Inc.*

Eric Strecker, P.E.  
*Geosyntec Consultants, Inc.*

### Project Team:

Jane Clary, M.S. and Andrew Earles, P.E., Ph.D.  
*Wright Water Engineers, Inc.*

Roderick Lammers, EIT  
*Colorado State University*

Marc Leisenring, P.E., Adam McGuire, and Scott Struck, Ph.D.  
*Geosyntec Consultants, Inc.*

# Acknowledgments

## Sponsors

- Water Environment & Reuse Foundation
- Urban Drainage and Flood Control District in Denver, CO
- City of Charlotte, NC
- City of Santa Rosa, CA

## Project Subcommittee

- Jason T. Berner, US EPA
- Fernando Pasquel, ARCADIS U.S., Inc.
- William P. Stack, P.E., Center for Watershed Protection
- Justin A. Vick, Metropolitan Water Reclamation District of Greater Chicago



# Stream Restoration Strategies

## Included

- Bed and bank stabilization
- Riparian buffers
- Floodplain reconnection
- In-stream enhancement

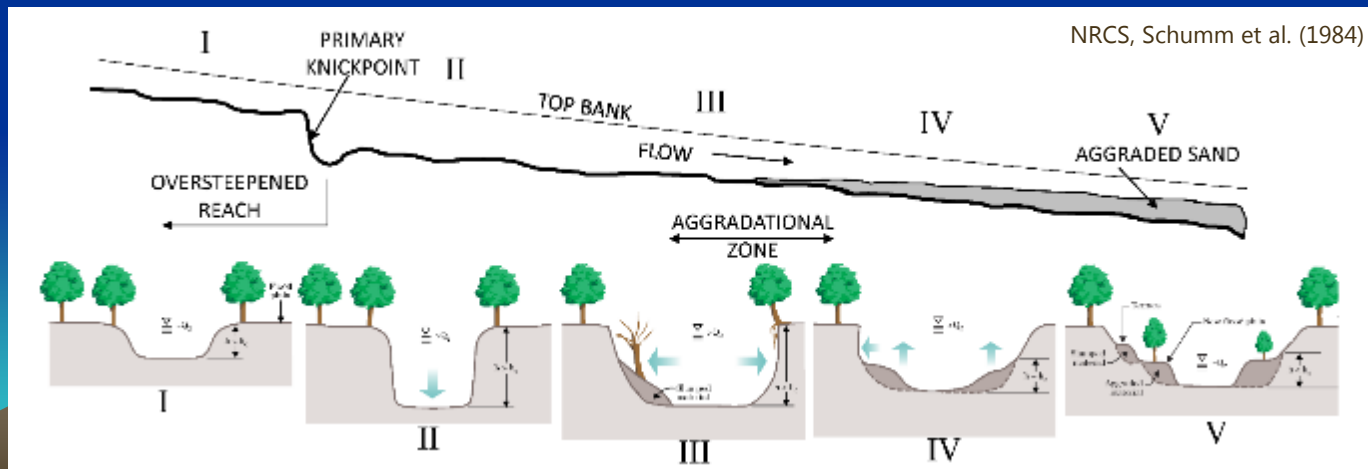
## Excluded

- Channel reconfiguration
- Watershed processes



# Bank and Bed Stabilization

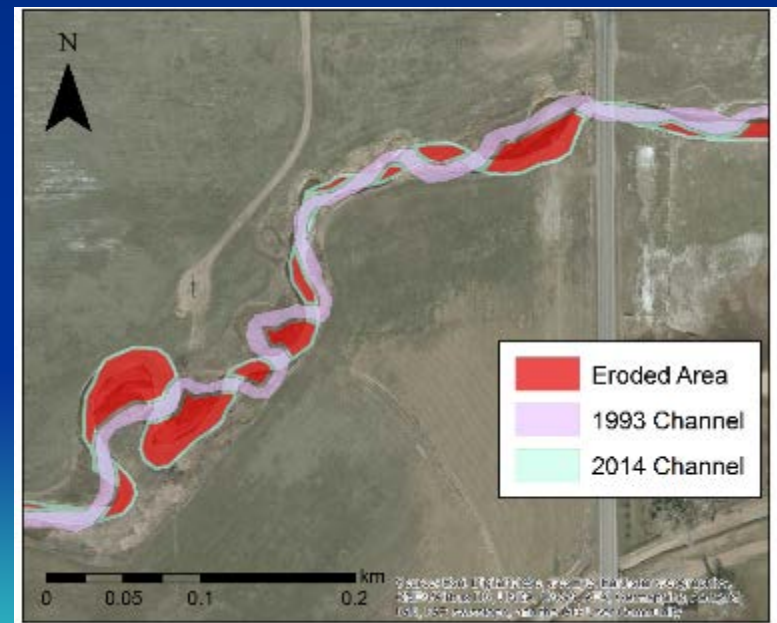
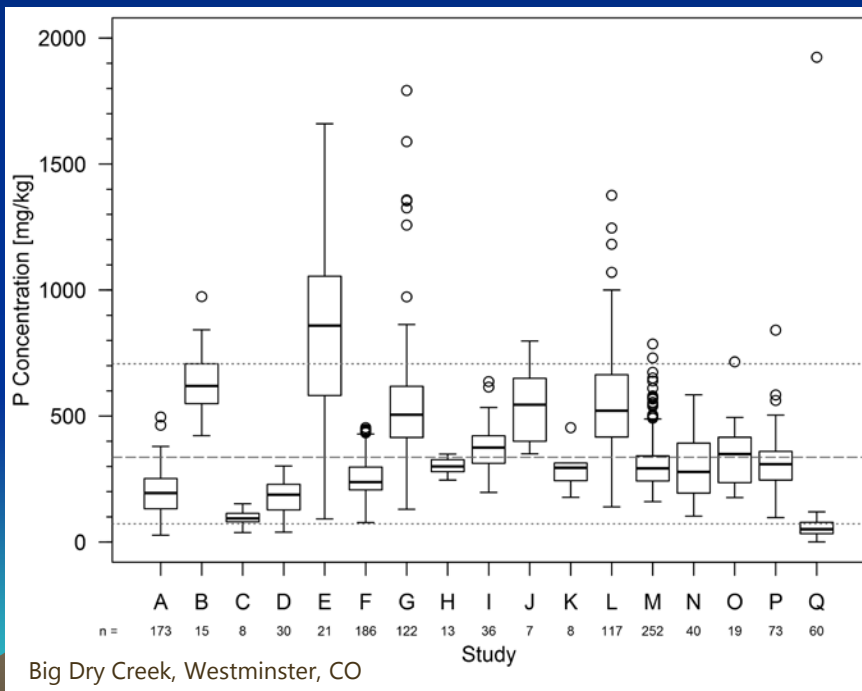
- Limit loading from a potentially large sediment and nutrient source
- Quantifying benefits is complicated



# Bank and Bed Stabilization [P]

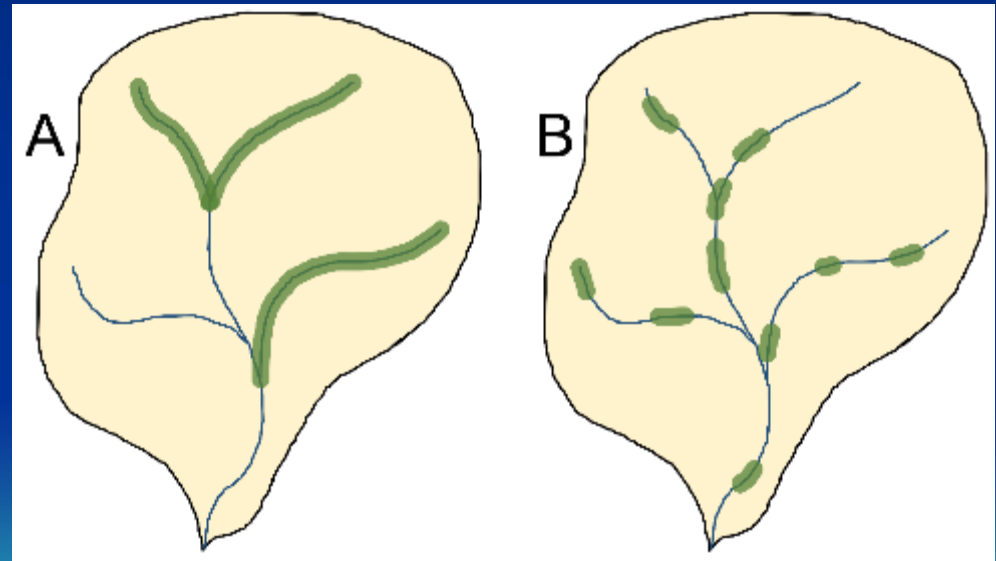
$$\text{Avoided bank erosion} \left[ \frac{m^3}{km * yr} \right] * \text{Soil density} \left[ \frac{kg}{m^3} \right] * P \text{ concentration} \left[ \frac{mg P}{kg \text{ soil}} \right]$$

$$* \text{Restored stream length [km]} = \text{Avoided P loading} \left[ \frac{mg P}{yr} \right]$$



# Riparian Buffers

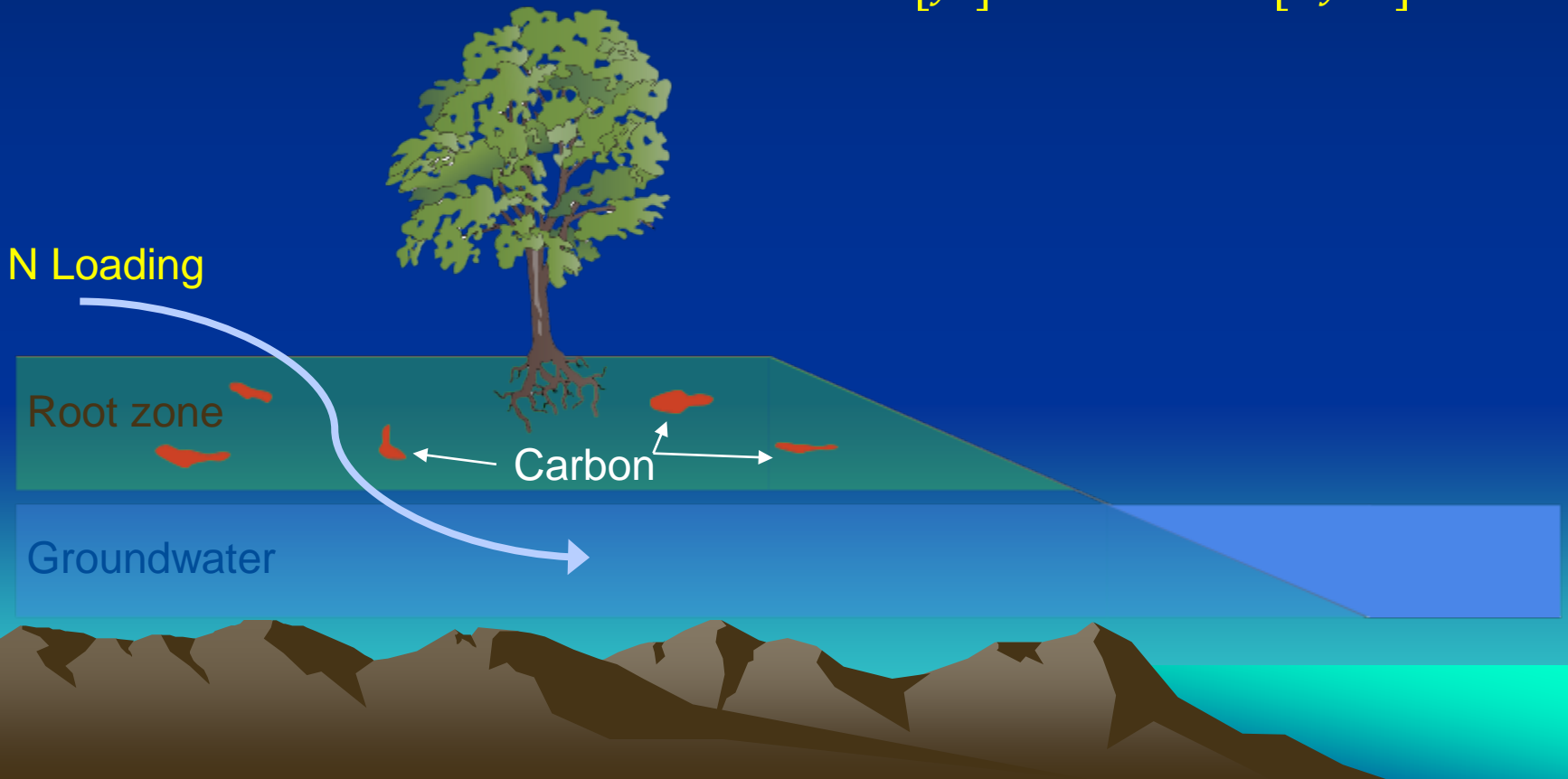
- High plot-scale removal but more uncertain in-stream benefits



# Riparian Buffers [N]

Denitrification rate  $\left[ \frac{\text{mg N}}{\text{m}^2 \text{ hr}} \right] * \text{Area of active denitrification} [\text{m}^2]$

\* Time groundwater intersects root zone  $\left[ \frac{\text{hr}}{\text{yr}} \right] = \text{N removal} \left[ \frac{\text{mg N}}{\text{yr}} \right]$

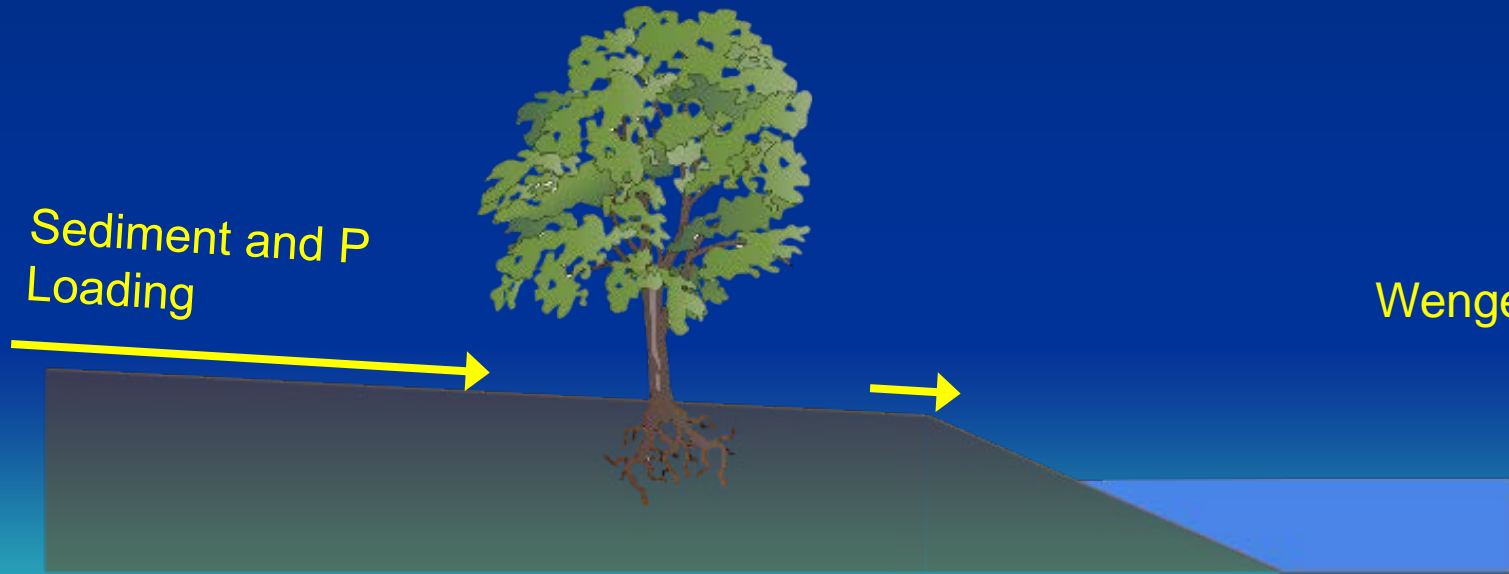


# Riparian Buffers [S & P]

$$\frac{\text{Buffer width [m]}}{(30.5 + 0.61 * \% \text{ slope}) [m]} * \text{Incoming sediment load} \left[ \frac{\text{kg}}{\text{yr} - \text{m}} \right]$$

\* Sediment P concentration  $\left[ \frac{\text{mg}}{\text{kg}} \right]$  \* Length of restored buffer [m]

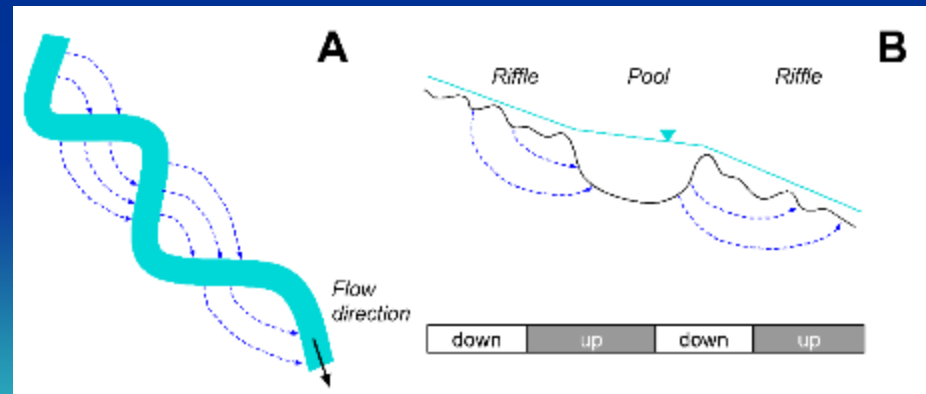
$$= P \text{ removal} \left[ \frac{\text{mg P}}{\text{yr}} \right]$$



Wenger (1999)

# In-Stream Enhancement

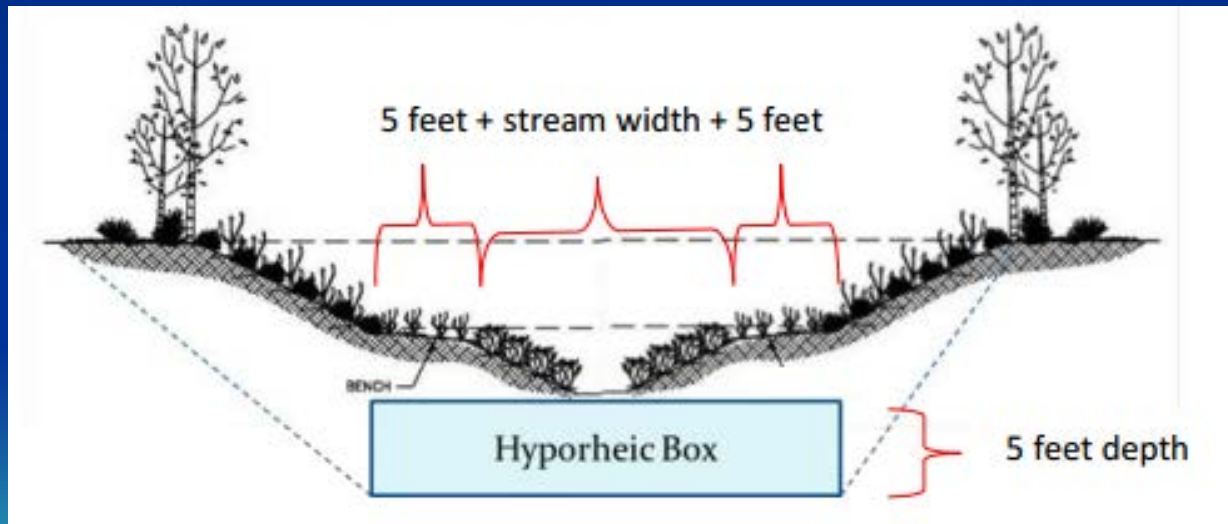
- Nutrient retention in backwater areas and hyporheic zone
- Enhance these natural removal areas



Hester and Gooseff (2010)

# In-Stream Enhancement [N] – Approach #1

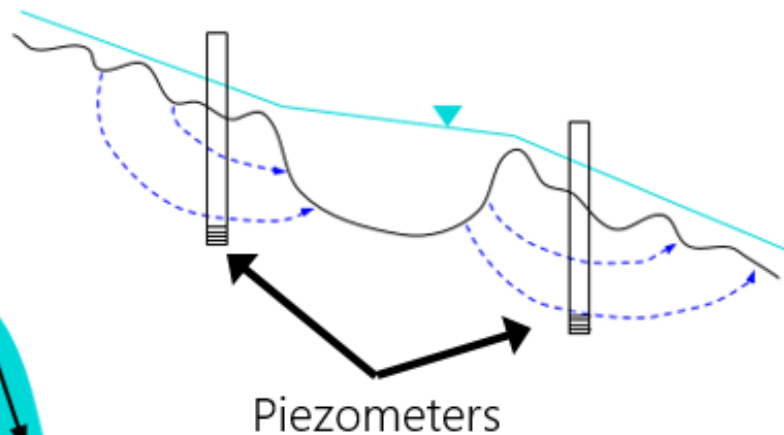
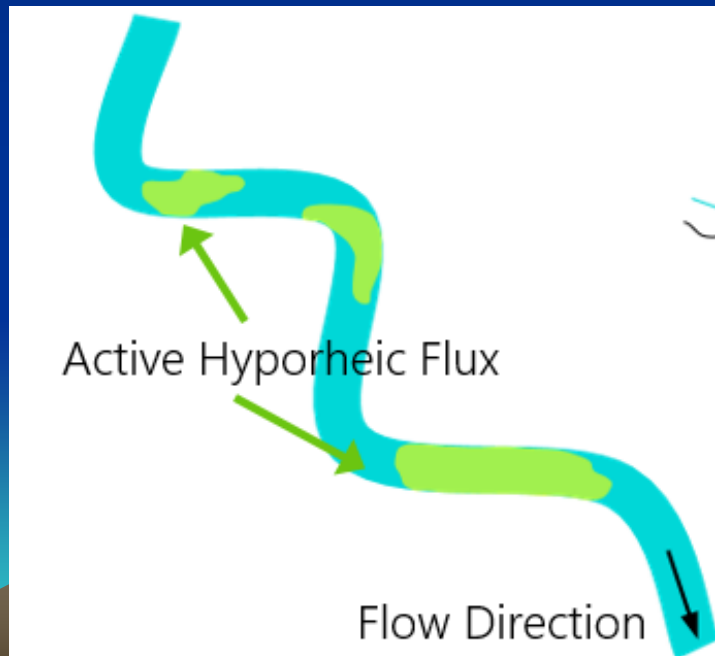
- Chesapeake Bay approach
- Hyporheic “box” and measured or assumed denitrification rate



Schueler and Stack (2013)

# In-Stream Enhancement [N] – Approach #2

- More detailed data collection
  - Hyporheic flux quantification
  - US/DS water quality



$$\text{Denitrification rate} \left[ \frac{\text{mg N}}{\text{m}^2 * \text{yr}} \right]$$

\* Area of bed with hyporheic exchange  $[\text{m}^2]$

$$= \text{Nitrogen removal} \left[ \frac{\text{mg N}}{\text{yr}} \right]$$

# Floodplain Reconnection

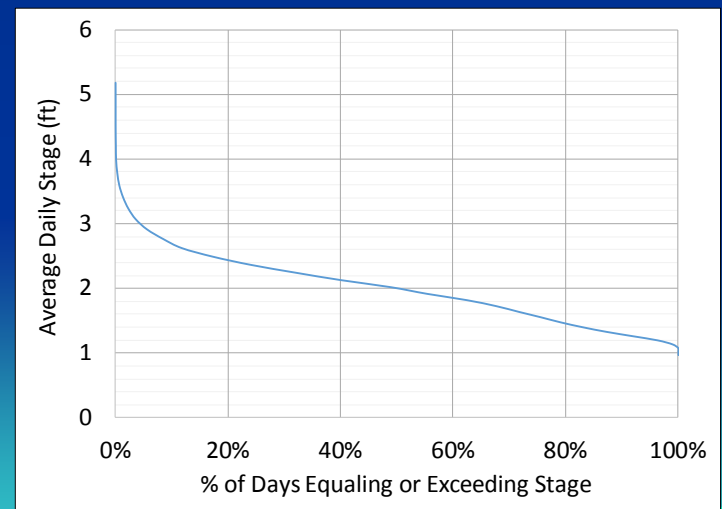
- Settling of particulate nutrients and biotic and abiotic removal
- Up to 10% of river loads retained



The Nature  
Conservancy

# Floodplain Reconnection [N, P, S]

- Estimate volume and loads interacting with floodplain
- Stage-duration curve derived from flow-duration and stream rating curve
- Requires instream water quality and long-term flow record



# Floodplain Reconnection [N, P, S]

$$\begin{aligned}
 & \text{Influent load } \left[ \frac{mg}{yr} \right] - \text{Annual floodplain volume } \left[ \frac{L}{yr} \right] \\
 & * \min \left( \text{Outflow concentration } \left[ \frac{mg}{L} \right], \text{Inflow concentration } \left[ \frac{mg}{L} \right] \right) \\
 & = \text{Load removed } \left[ \frac{mg}{yr} \right]
 \end{aligned}$$

Stage (ft)	Floodplain Area Accessed (acre)	Incremental Storage Volume (ac-ft)	% of Days Equaling or Exceeding Stage	% of Days within Stage Increment	No. of Days per Year that the Stream Accesses the Incremental Floodplain Volume	Estimated Volume per Year Accessing Floodplain (ac-ft)
2.00	2.0	0	50%	--	--	--
2.25	2.5	0.5625	30%	20%	73	41.1
2.50	3.5	0.75	17%	13%	47.45	35.6
2.75	5.0	1.0625	8%	9%	32.85	34.9
3.00	8.0	1.625	4%	4%	14.6	23.7
<b>Total Volume Accessing Floodplain per Year (ac-ft):</b>						<b>135.3</b>



# SUMMARY AND CONCLUSIONS

# Crediting/Trading Summary

- Water quality trading and ecosystem markets are a growing component of watershed and habitat management programs
- Cost-effective compliance for point source dischargers and an additional source of income for land owners and producers
- Field level conservation practices, farm level structural controls, and stream restoration projects can reduce non-point source pollution



# Supporting Data and Tools

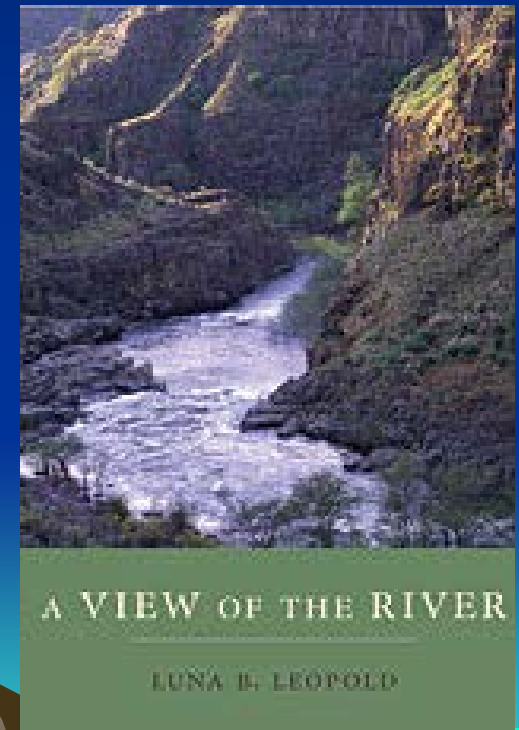
- Field data are important for an effective WQ crediting/trading program
- Agricultural BMP and stream restoration databases are an emerging resource of the International BMP Database project
- Approaches have been developed to quantify WQ credits for stream restoration
- More field studies needed



# Thank you!!

“Protect the best,  
restore the rest.”

*Thank you for your  
attendance. Questions?*



# Contacts

- Harbans Lal, PhD, Environmental Engineer  
[harbans.lal@por.usda.gov](mailto:harbans.lal@por.usda.gov)  
(503) 273-2441
- W. Barry Southerland PhD, Fluvial Geomorphologist,  
[barry.southerland@por.usda.gov](mailto:barry.southerland@por.usda.gov)  
(503) 273-2436
- **Marc Leisenring, PE, Principal Engineer**  
[mleisenring@geosyntec.com](mailto:mleisenring@geosyntec.com)  
(971) 271-5904

