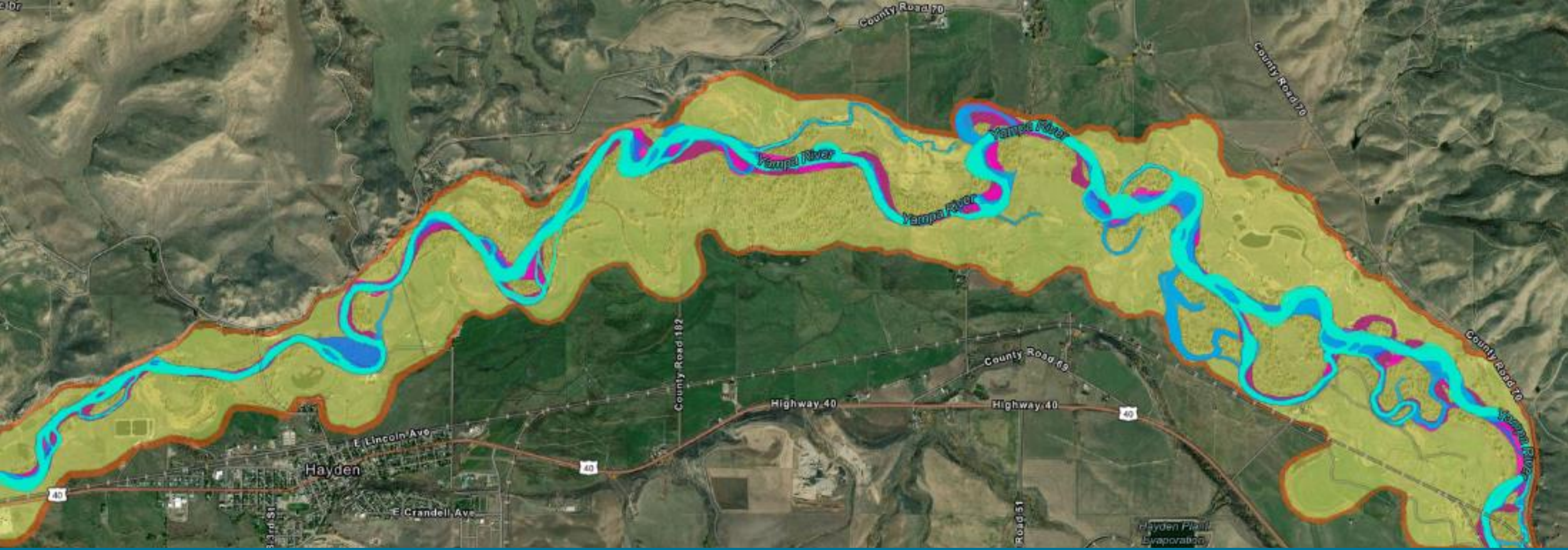

Fundamentals of Process-based Restoration

An Overview

June 17, 2024

Dr. Brian Murphy, P.E.

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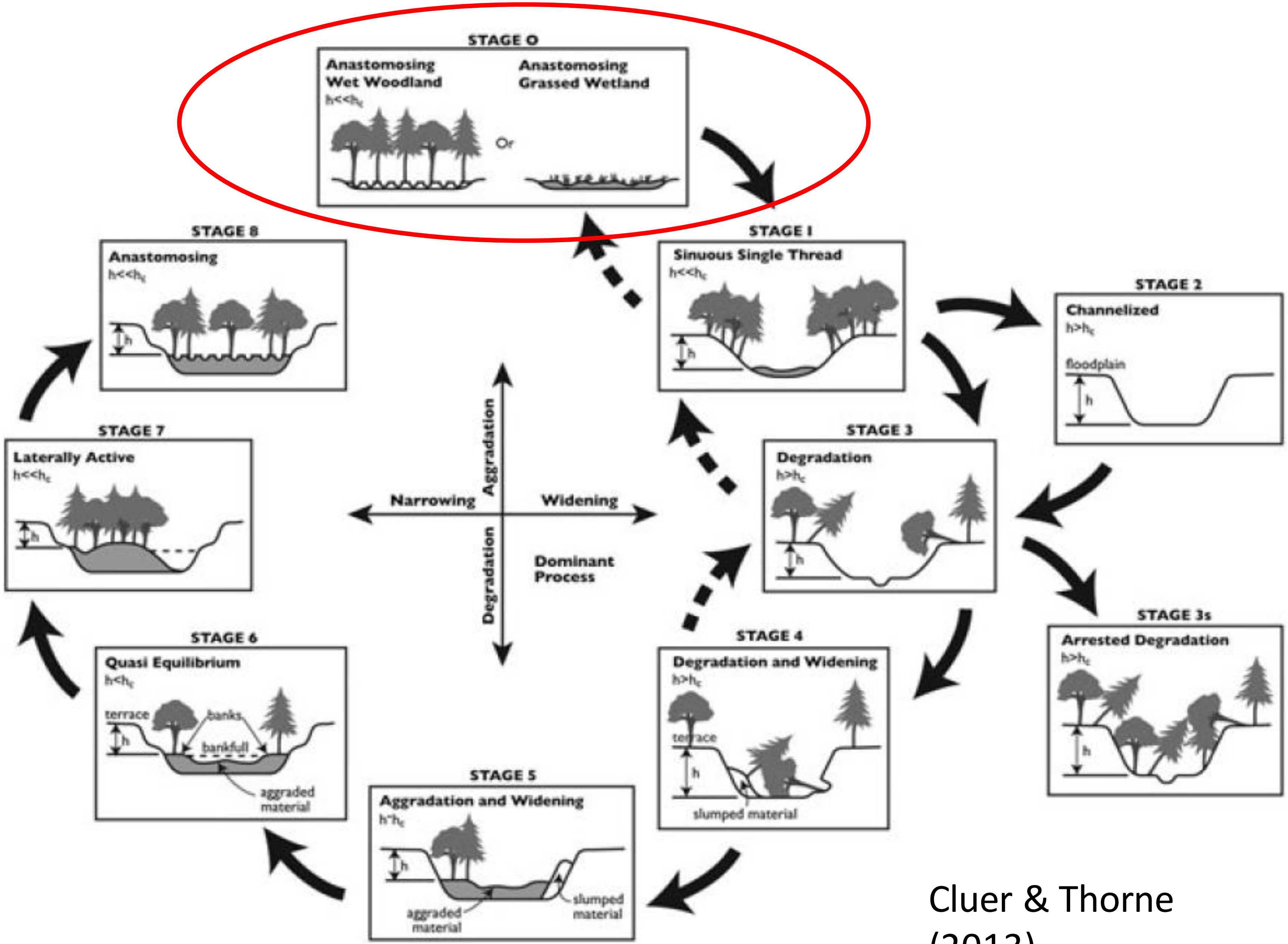
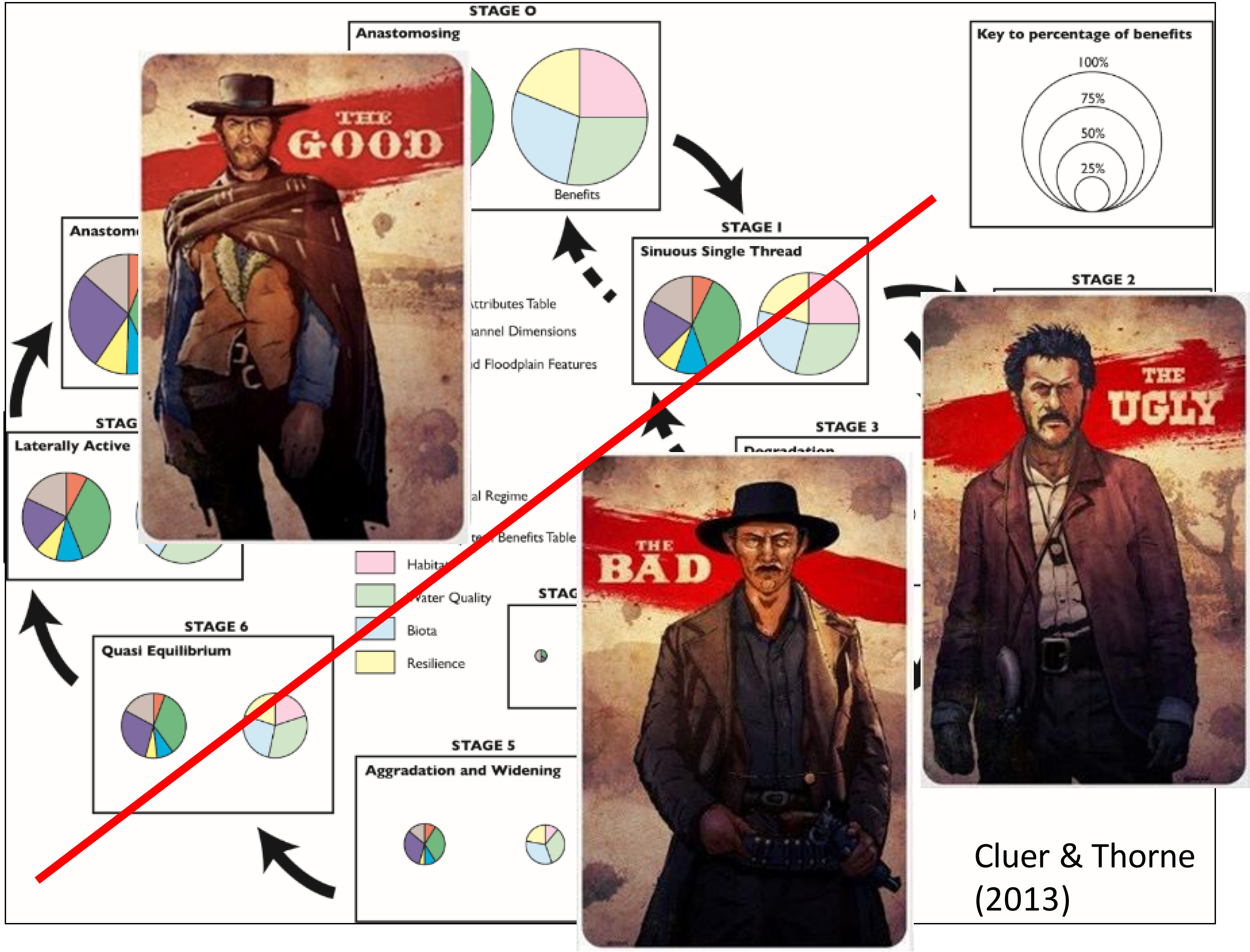
Goals: Re-image Riverscapes

Goals: Re-imagine Riverscapes

Stream Evolution Model



Cluer & Thorne (2013)



Cluer & Thorne (2013)

Goals: Re-imagine Riverscapes

Goals: Re-imagine Riverscapes

Wohl et al. 2021

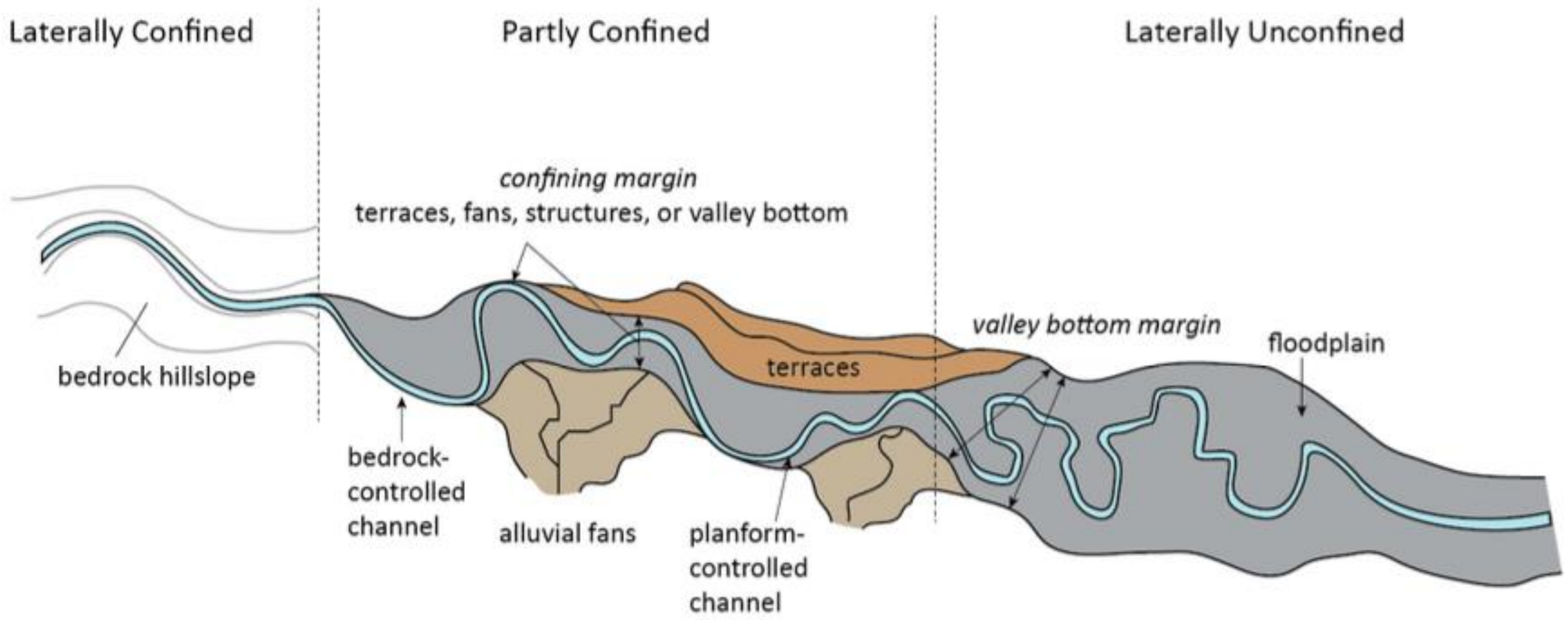
Rivers and Streams 101

Welcome to the DARK ART of Interpretation in (fluvial) geomorphology.

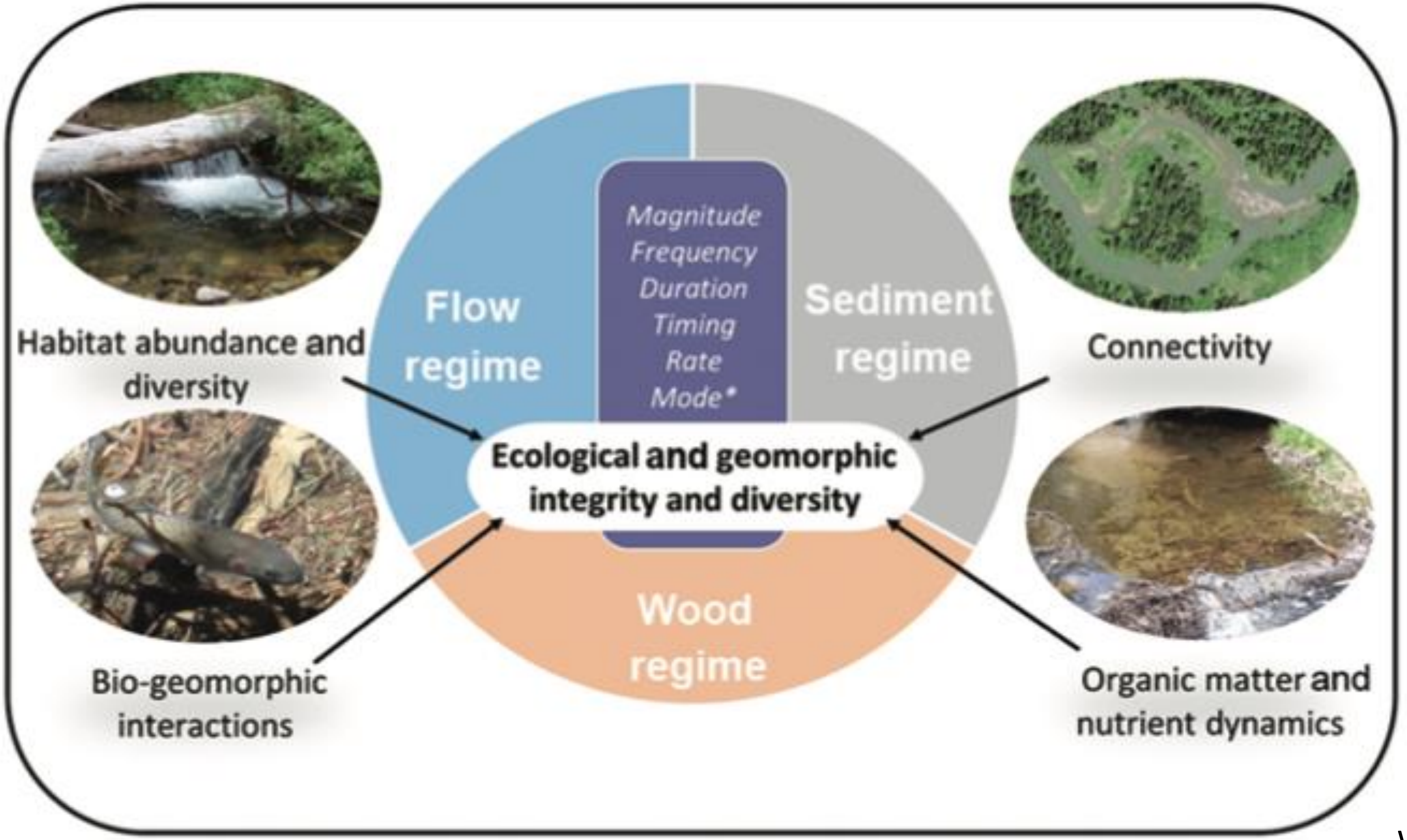
- The study of river processes and forms. How rivers shape the earth.
- River form and function are based on their valley setting (how wide is your valley?), position in the watershed and interactions between streamflow, sediment, and wood.

Brierley et al. (2021)

Rivers and Streams 101



Rivers and Streams 101



Wohl et al. (2019)

From rivers to 'riverscapes' – getting out of the channel

Valley bottom aka River Corridor – channel(s) and active floodplain

- The area re-worked by contemporary fluvial processes
- The maximum area that can be influenced by restoration

What processes are important for maintaining healthy riverscapes?

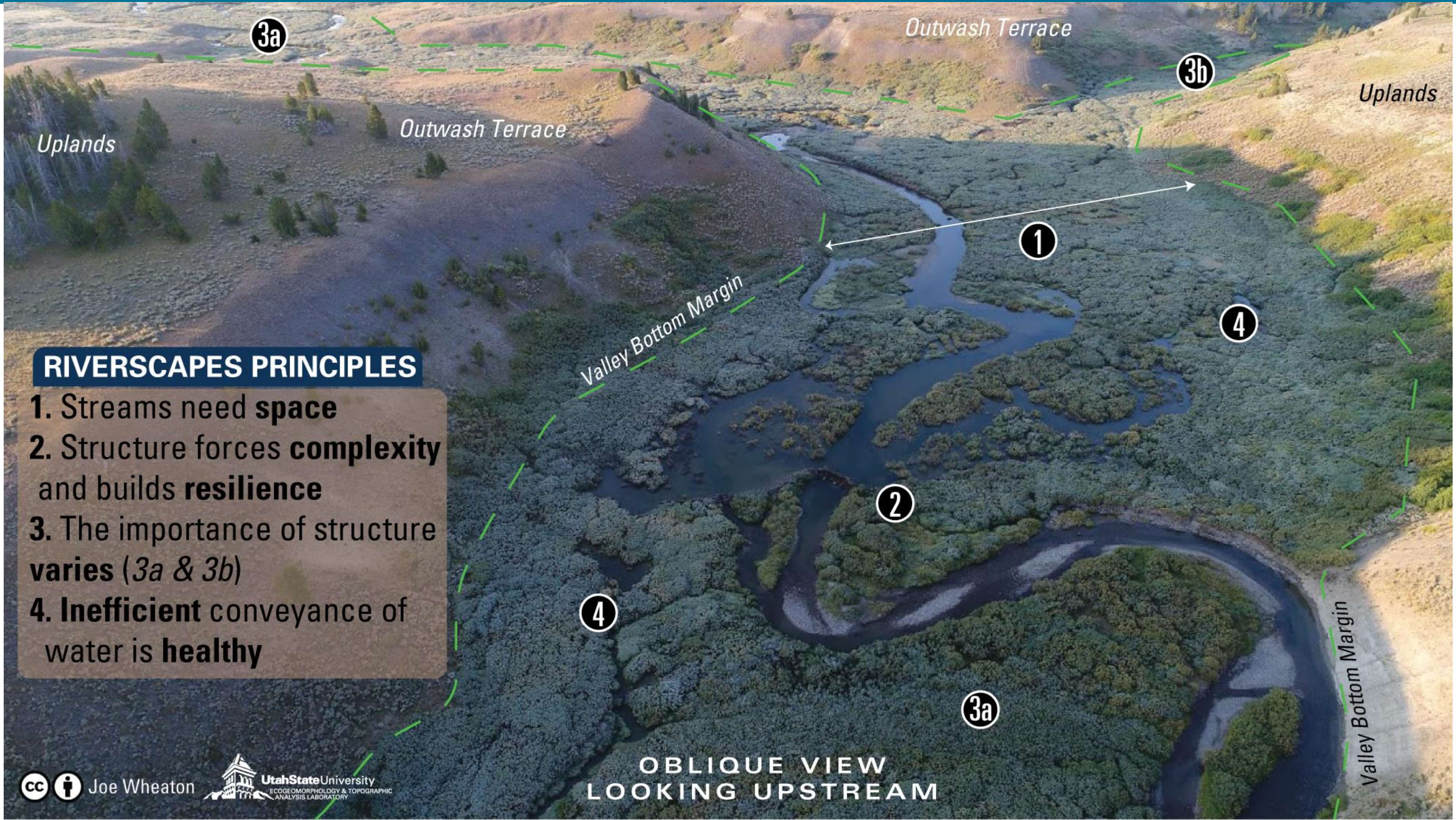
- Overbank flow
- Groundwater recharge
- Erosion and deposition
- Plant growth
- Beaver dam building
- Wood recruitment, transport, and storage
- Etc.

Table 1. Examples of watershed-scale and reach-scale processes that control riverine ecosystem dynamics.

Ecosystem feature	Driving processes
Watershed scale	
Sediment	Sediment delivered to river systems through landsliding, surface erosion, and soil creep.
Hydrology	Runoff delivered to streams through surface and subsurface flow paths.
Organic matter	Tree fall, leaf litter fall.
Light and heat	Solar insolation and advective heat transfer to the water column.
Nutrients	Delivery of dissolved nutrients via groundwater flow.
Chemicals	Delivery of contaminants, pesticides from agricultural or industrial sites through surface runoff or shallow subsurface flow.
Biota	Migration of aquatic organisms, seed transport.
Reach scale	
Channel morphology and habitat structure	Channel migration, bank erosion, bar formation, and floodplain sediment deposition create a dynamic mosaic of main-channel, secondary-channel, and floodplain environments. Wood recruitment results in part from bank erosion and channel migration, and wood accumulations reduce bank erosion rates or enhance island formation. Sediment and wood transport and storage processes drive channel cross-section shape, formation of pools, and locations of sediment accumulation. Bank reinforcement by roots reduces bank erosion rates and may force narrowing and deepening of channels. Animals such as beaver physically modify the environment and create new habitats.
Thermal regime	Local stream shading and exchange of water between surface and hyporheic flows regulates stream temperature at the scale of habitat units and reaches.
Water chemistry	Delivery of dissolved nutrients through groundwater and hyporheic exchange; uptake of nutrients by aquatic and riparian plants. Delivery of pesticides and other pollutants at point sources damage health and survival of biota.
Riparian species assemblages	Seedling establishment, tree growth, succession drive reach-scale riparian plant assemblages.
Aquatic species assemblages	Photosynthesis drives primary production of algae and aquatic plants. Leaf-litter inputs drive detritus-based food web strands. Habitat selection, predation, feeding, growth, and competition drive species composition of invertebrate, amphibian, and fish assemblages.

Beechie et al. (2010)

What constitutes a healthy riverscape?



Streams need space

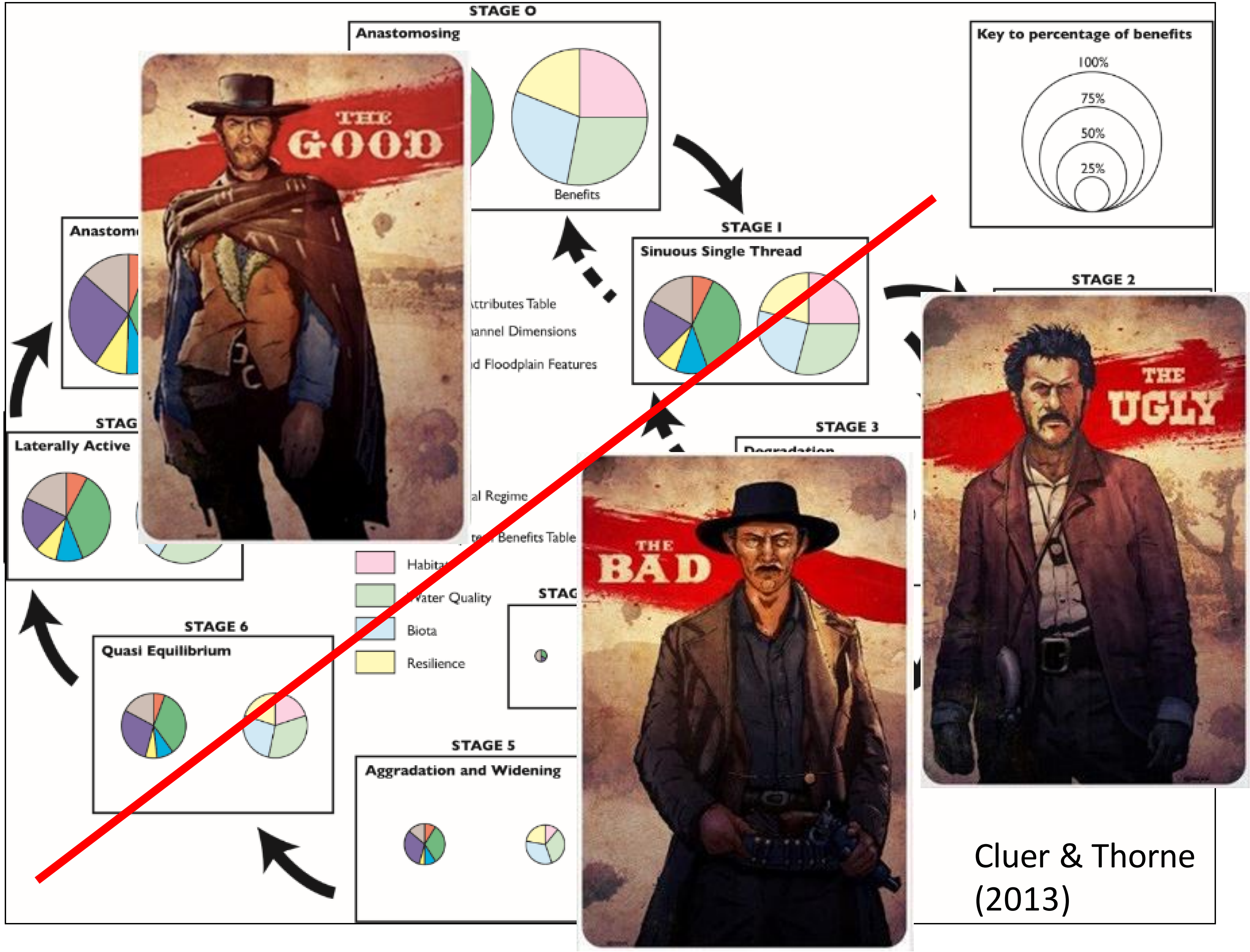
Streams need natural flow, sediment, and wood regimes

Water
(streamflow)

Dirt
(sediment)

Wood

Structure forces complexity



Cluer & Thorne (2013)

The restoration continuum – from high-tech to low-tech, and just getting out of the way

Just Stop Hurting it and get out of the way!

Process-based Restoration

Big Yellow Machines – Form based

Low — High

Amount of Effort

"Your restoration project will be more successful if you picture rivers as movies, rather than photos." – P. Wilcock

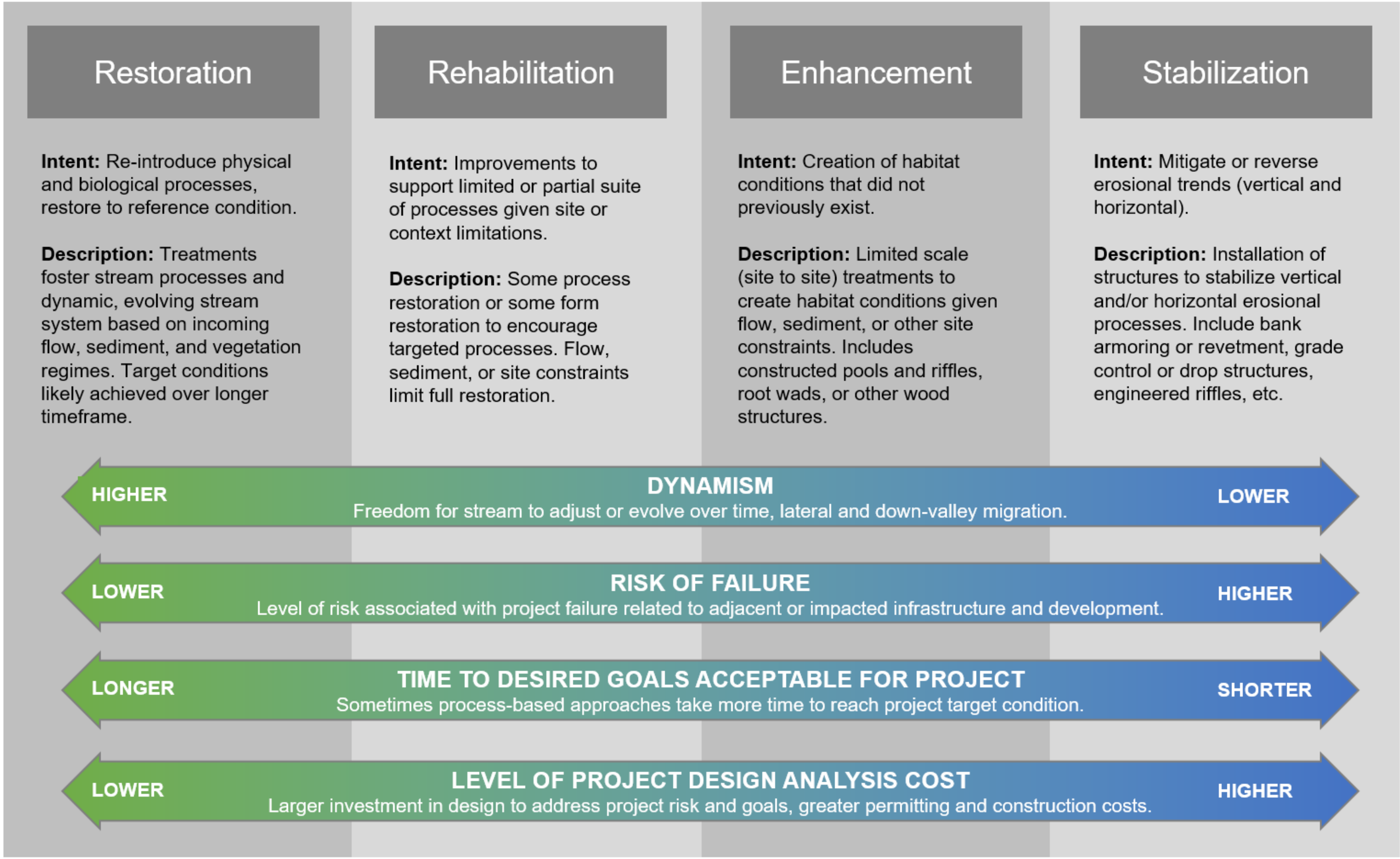
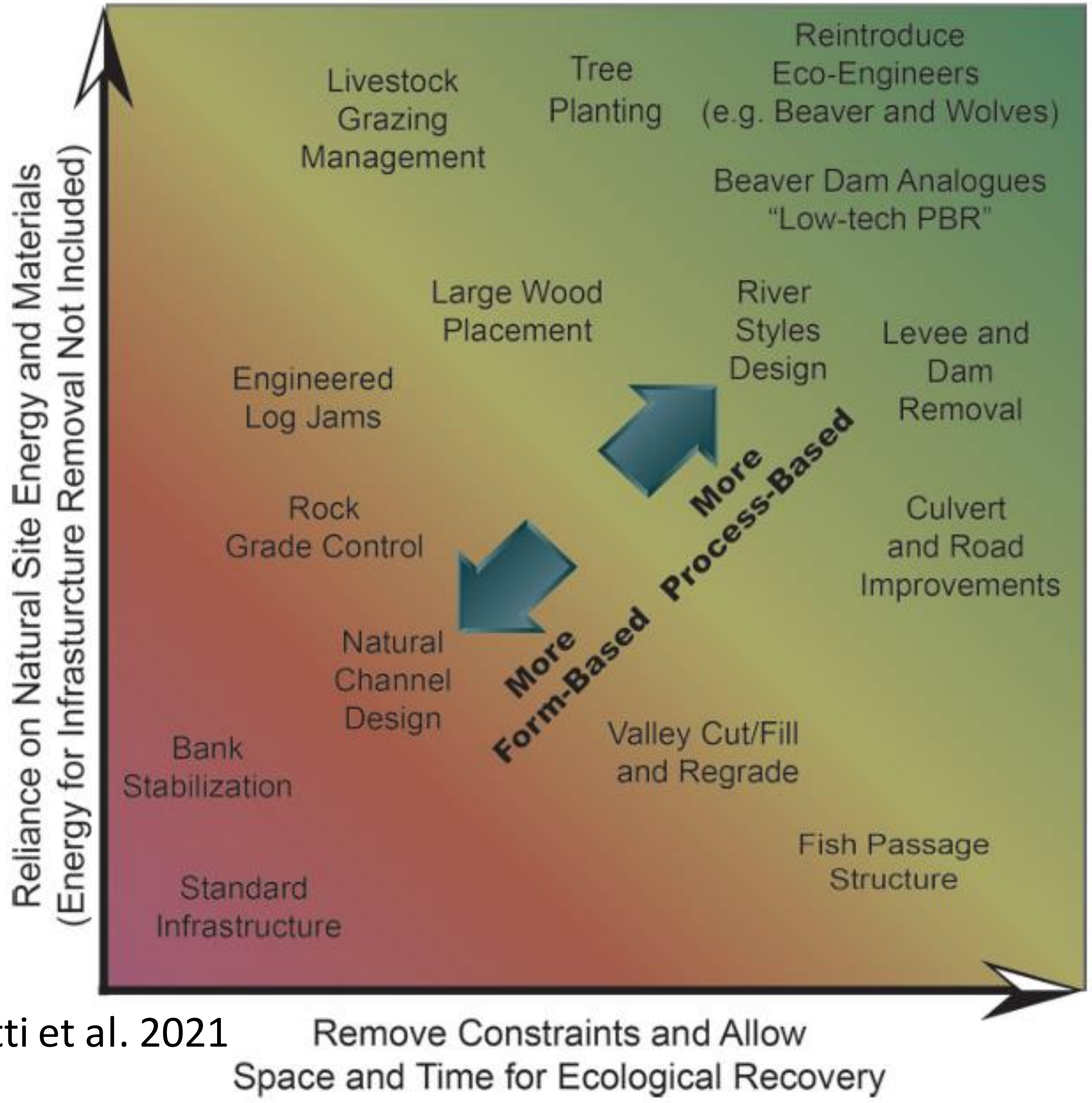
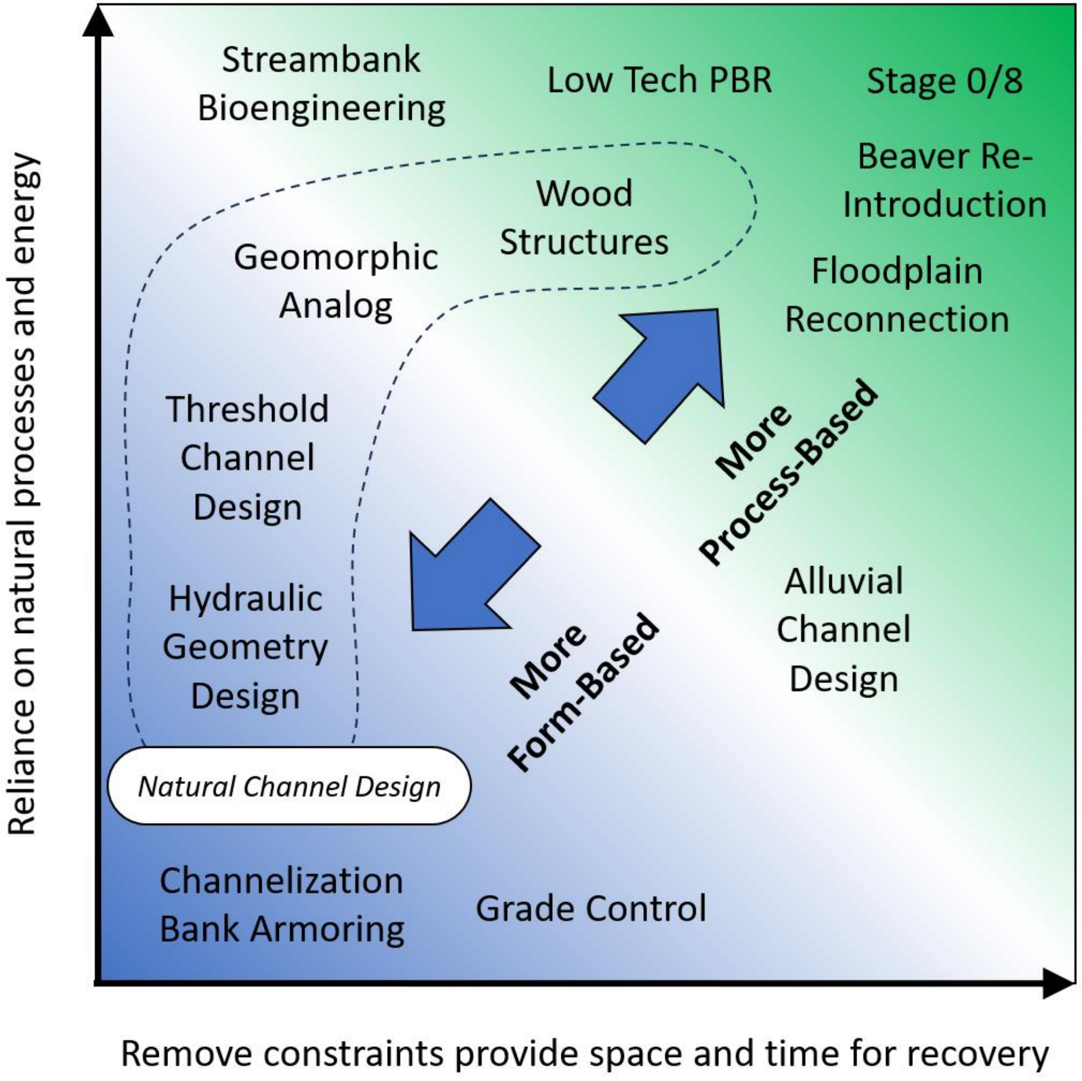


Figure 1. *The channel restoration-stabilization spectrum. Projects commonly referred to as restoration projects in fact span a spectrum of project goals and effective outcomes from the restoration of natural processes to the stabilization and constraint of natural processes. In between these endpoints are rehabilitation and enhancements, both of which may be limited in the extent to which they restore stream processes. (Adapted from Gillilan Associates Inc. in Skidmore et al. 2011 and Headwaters Magazine 2023)*

The restoration continuum – from high-tech to low-tech, and just getting out of the way



Ciotti et al. 2021



Goals: Re-imagine Riverscapes

What is process-based restoration?

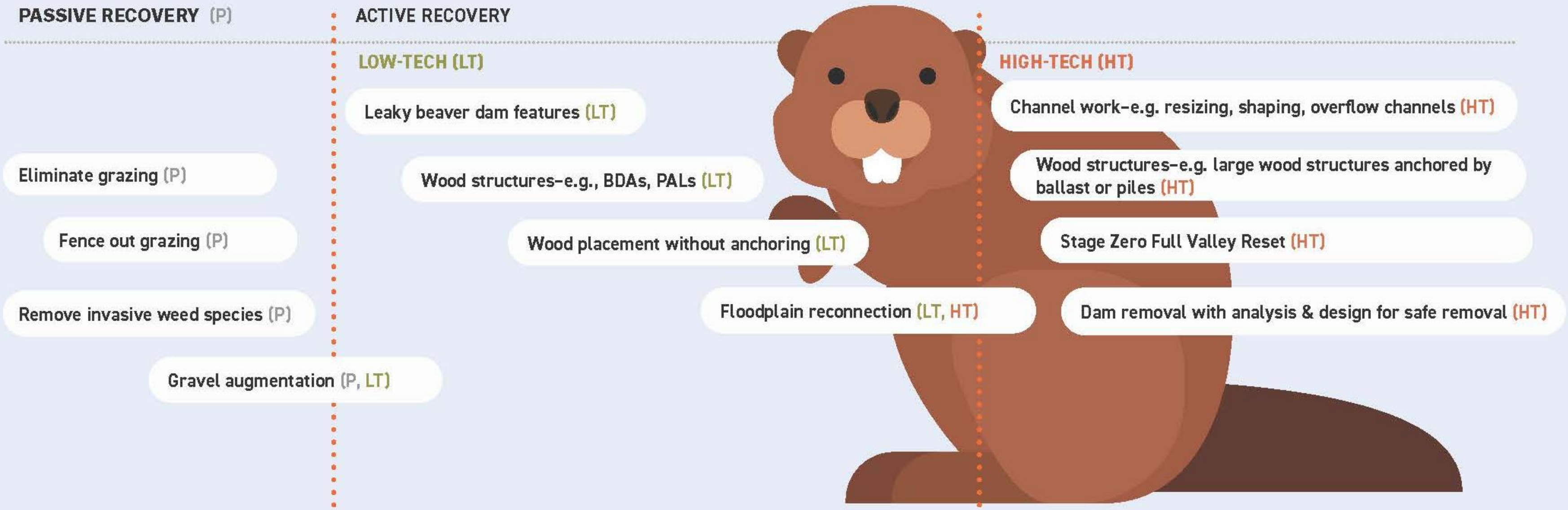
- Process-based restoration – Restoration that initiates or accelerates natural hydrologic, geomorphic, and biological processes leading to improved stream and floodplain conditions

- Low-tech – Simple, hand built, non-engineered e.g., beaver dam analogues

DETAILS & APPLICABILITY FOR PBR APPROACHES:

Approach:	Developed for or applicable to:	Limitations:	Common level of design analysis required:
Passive Recovery (P)	■ Any system	■ Not helpful when causative stressor (cause of degradation) cannot be removed (e.g., a dam or diversion structure)	■ No design required for system recovery ■ Design for safe removal of the causative stressor may be required
LTPBR & other beaver mimicry (LT), including Beaver Dam Analogs (BDAs), Post-Assisted Log Structures (PALs), Simulated Beaver Structures (SBS)	■ Wadeable streams (aka low-order, often headwaters streams) ■ Systems where degradation is caused by structural starvation of wood and beaver dams ■ Targeted where beavers existed historically ■ Typically requires adaptive management	■ Not intended for non-wadeable, higher order systems where causative stressor is other than loss of wood and beaver dams ■ If beaver can't be expected to move in to the restored area, beaver mimicry structures may be built	■ Engineering design analysis not required ■ LTPBR Manual 2019 provides "guidelines for implementing a subset of low-tech tools (i.e., BDAs and PALs in riverscapes lacking wood and beaver dams"
Stage Zero Design (LT or HT) Stage Zero falls between LT & HT in required analysis and construction cost. Smaller Stage Zero efforts may have LT characteristics, but a larger project such as work covering a full valley, is closer to HT.	■ Most successful in depositional areas with wide valleys and mild slopes to promote deposition ■ Often in small, incised streams in wet meadows headwaters, but can be up-scaled to larger rivers ■ Promote processes that will nudge the system back toward a Stage Zero condition ■ May need sediment supply from upstream to fill incised channels over time ■ Works best with adaptive management, but not required	■ Typically low risk areas with low or no infrastructure adjacency to accommodate floods covering full width of the valley bottom ■ Access to full floodplain may currently be impractical due to anthropogenic constraints—Stage Eight might work well instead with restoration to an extent rather than the full floodplain width	■ Engineering design analysis varies, typically falling between LTPBR and HTPBR ■ Analysis required to determine target slopes at minimum ■ Full valley reset approach requires significant analysis
HTPBR (HT)	■ Detailed analysis allows PBR application on a case-by-case basis to any system ■ Works best with adaptive management	■ Applies to most systems and causative stressors because customized detailed analysis addresses site-specific constraints ■ Higher cost of analysis and often construction as well	■ Heavier engineering design analysis required compared to other approaches, but varies greatly across specific projects

EXAMPLES OF TREATMENTS (NOTING OVERLAP ACROSS RESTORATION APPROACH):



From pages 3-4 of Pocket Guide; Wheaton et al. (2019)

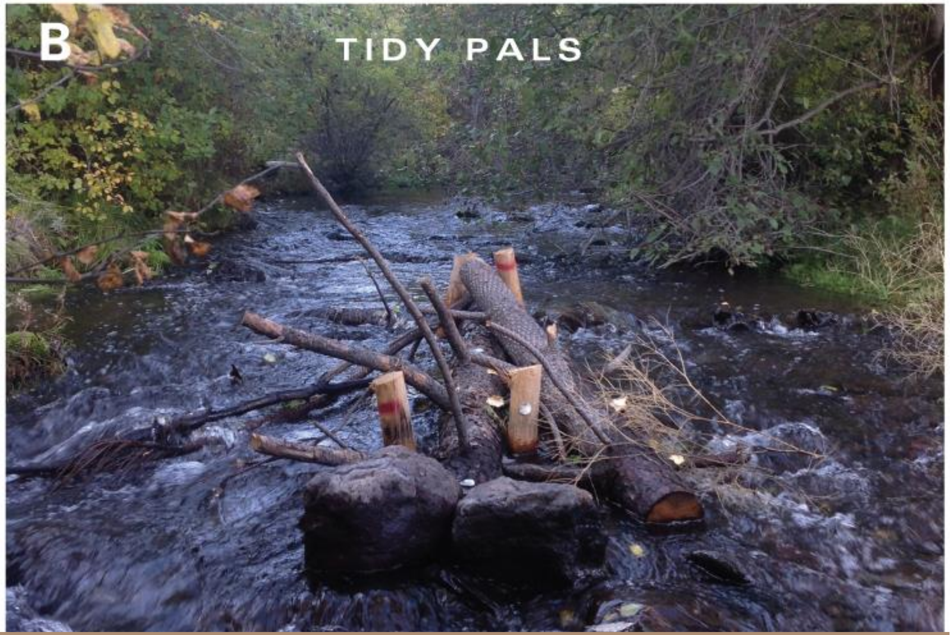
DOI: 10.13140/RG.2.2.28222.13123/1

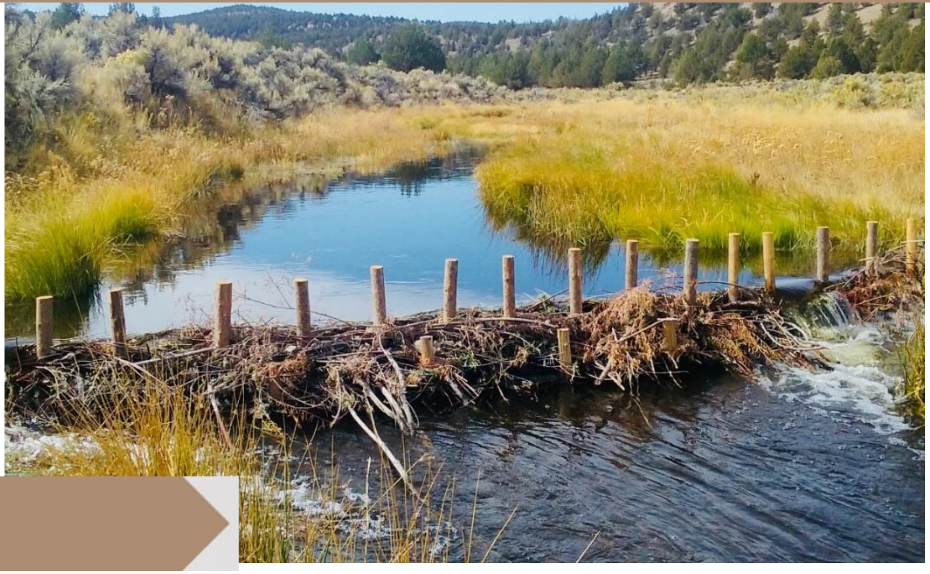
See Wheaton et al. (2019, p 72)

Chapter 2 LTPBR Manual for Principles

DOI: 10.13140/RG.2.2.34270.69447

5. It's okay to be messy

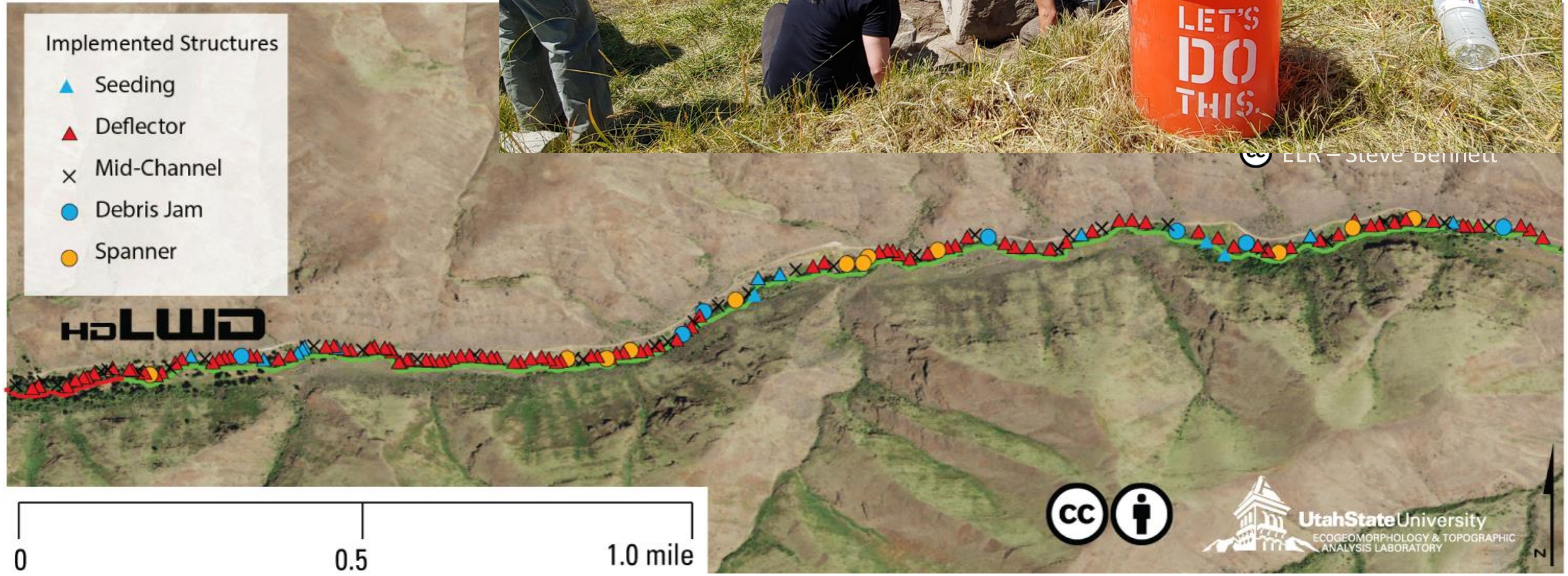




IT'S OKAY TO BE MESSY
RESTORATION PRINCIPLE 5.

6. There is strength in numbers

More IS OFTEN better



Adapted from Figure 2.10 of Wheaton et al. (2019, p 74-75) – Chapter 2 LTPBR Manual. DOI: [10.13140/RG.2.2.34270.69447](https://doi.org/10.13140/RG.2.2.34270.69447)

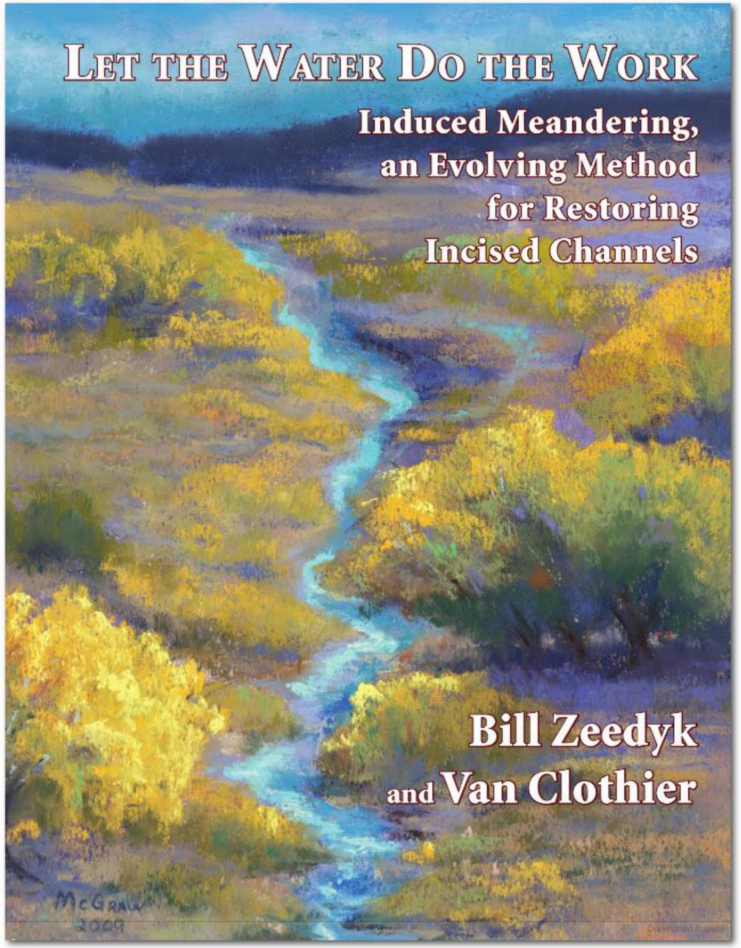
From pages 3-4 of Pocket Guide; Wheaton et al. (2019) DOI: [10.13140/RG.2.2.28222.13123/1](https://doi.org/10.13140/RG.2.2.28222.13123/1)

7. Use Natural Building Materials

- Reduces costs

- Consistent with local landscape

8. Let the system do the work



> ***"What if restoration was about stream power doing the work, not diesel power?"***
>
> *— Jared McKee (USFWS)*

9. Defer Decision Making to System

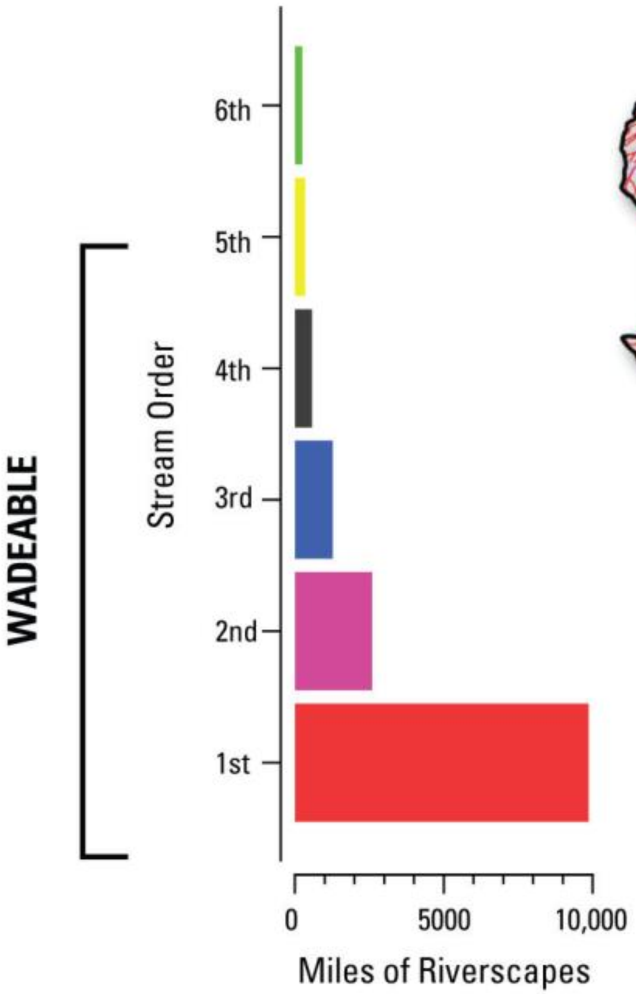
- How far to erode bank?
- Channel width
- Slope
- Planform
- Capacity of channel

10. Self-Sustaining systems the goal

Q: Where do you use (LT)PBR?

A: In wadeable streams

The majority (~80%) of total stream miles in any watershed are wadeable streams



Q: Where do you use (LT)PBR?

Here

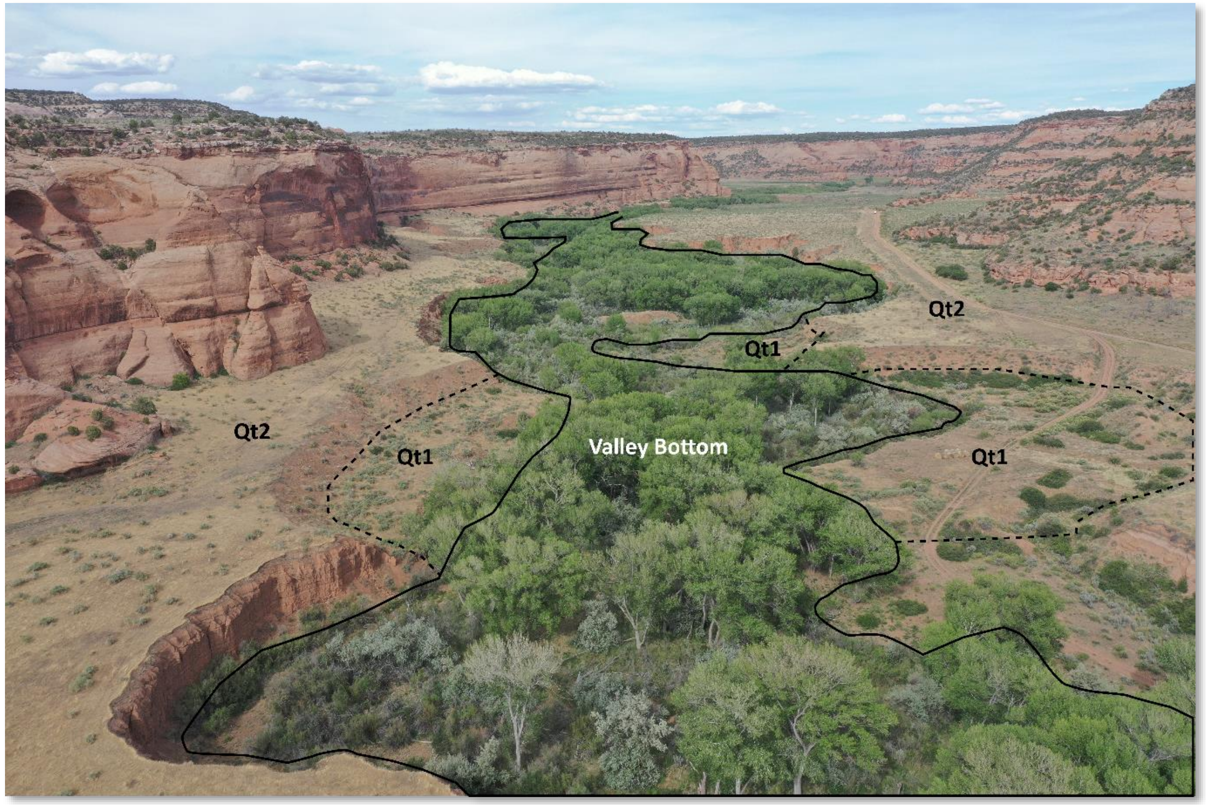
Not Here

Why do we pretend to be beavers? AKA how do beaver dams (and BDAs) promote restoration and conservation?

- Increased groundwater recharge & water tables
- Increase channel-floodplain connectivity
- Restore incised channels
- Create diverse habitat niches for
  - Macroinvertebrates
  - Fish
  - Vegetation

Recovery Potential

- What is possible? (reimagining riverscapes)
- How much space can be recovered?
- What processes can be restored and to what extent?
- Quality vs Quantity



Summary of the four process-based principles

Principle	Description
1. Target root causes of habitat and ecosystem change	Restoration actions that target root causes of degradation rely on assessments of processes that drive habitat conditions, and actions are designed to correct human alterations to those driving processes.
2. Tailor restoration actions to local potential	Each reach in a river network has a relatively narrow range of channel and riparian conditions that match its physiographic and climatic setting, and understanding processes controlling restoration outcomes helps design restoration actions that redirect channel and habitat conditions into that range.
3. Match the scale of restoration to the scale of the problem	When disrupted processes causing degradation are at the reach scale (e.g., channel modification, levees, removal of riparian vegetation), restoration actions at individual sites can effectively address root causes. When causes of degradation are at the watershed scale (e.g., increased erosion, increased runoff due to impervious surfaces), many individual site-scale actions are required to address root causes. Recovery of wide-ranging fishes (e.g., Pacific or Atlantic salmon) requires restoration planning and implementation at the scale of population ranges.
4. Be explicit about expected outcomes	Process-based restoration is a long-term endeavor, and there are often long lag times between implementation and recovery. Ecosystem features will also continuously change through natural dynamics, and biota may not improve dramatically with any single individual action. Hence, quantifying the restoration outcome is critical to setting appropriate expectations for river restoration.

Beechie et al. (2010)

Two assumptions you need to believe, or PBR doesn't make (much) sense

- Process-based restoration will require time and often multiple phases

- You will be coming back and monitoring and (likely) maintaining your restoration project

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Questions/Discussion

ANABRANCH SOLUTIONS

Brian Murphy, PhD, P.E., CFM (bmurphy@rivernetwork.org)
River Network Healthy Rivers Program Director

Beaver Dam Analogues (BDAs)

Post-assisted log structures (PALS)

Mimic natural wood jams

Post-assisted log structures (PALS)

Mimic natural wood jams

The Process-Based Restoration Umbrella—It isn't just about beavers

There's a lot of talk about the benefits of beavers in stream restoration, but Colorado's riparian systems are complex—when it comes to restoring stream systems, there isn't one tool that works in all situations. Rather, there are many tools in the restoration toolbox.

Process-based restoration (PBR) is an important category of restoration work that targets the root causes of ecosystem change and aims to restore a river's natural processes so the area can begin to self heal. But under the PBR umbrella, there is a spectrum of restoration approaches, which includes active and passive recovery (beaver mimicry is considered active). Even with this diversity of approaches, certain characteristics define what fits within the PBR "umbrella."

- **PBR works with the natural processes that drive ecosystem function and dynamics**
- **PBR addresses causes of degradation, rather than symptoms of it**
- **PBR matches the watershed context and human setting of the natural system**

PASSIVE RECOVERY: Typically requires no restoration design in order to remove sources of disturbance or causes of degradation. This removal allows the river to self heal.

LOW-TECH PBR (LTPBR): Uses simple, temporary, low-unit-cost, typically natural structures, often mimicking beavers, to slow a stream's flow and allow it to connect with its natural floodplain.

HIGH-TECH PBR (HTPBR): Typically uses more costly treatments, and requires planning and detailed engineering analysis to design for disturbance, with adjustments made over time.

CONSIDERATIONS WHEN SELECTING RESTORATION APPROACHES AND TREATMENTS

When selecting a restoration approach and treatment, water managers and restoration practitioners weigh the following factors. Passive recovery and low-tech active recovery projects fall toward the left and middle of these spectrums, while high-tech active recovery work is on the right side.

LOWER	PROJECT'S LEVEL OF RISK Risk factors include stream response potential, infrastructure adjacency, public safety, system scale, etc.	HIGHER
HIGHER	UNCERTAINTY ACCEPTABLE FOR PROJECT Project tolerance or "appetite" for uncertainty; often but not always inversely proportional to risk	LOWER
LONGER	TIME TO DESIRED GOALS ACCEPTABLE FOR PROJECT Passive and low-tech approaches sometimes, but not always, require more time to see results	SHORTER
LOWER	LEVEL OF DESIGN ANALYSIS REQUIRED FOR PROJECT Larger investment in design analysis warranted to address risk, uncertainty and/or time to reach goals	HIGHER
LOWER	COST INVESTMENT FOR PROJECT May apply to design, permitting, and/or construction costs; sometimes larger investments decrease time to get results	HIGHER