Restoration in Dynamic Rivers

The Importance of Process-based and Multi-benefit Approaches Throughout Design and Construction

Stillwater Sciences

Flywater

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Dynamic Rivers

What is a dynamic river and how do you know when you've got one?

Dynamic, literally:

Not static.

What is a dynamic river and how do you know when you’ve got one?

dynamic

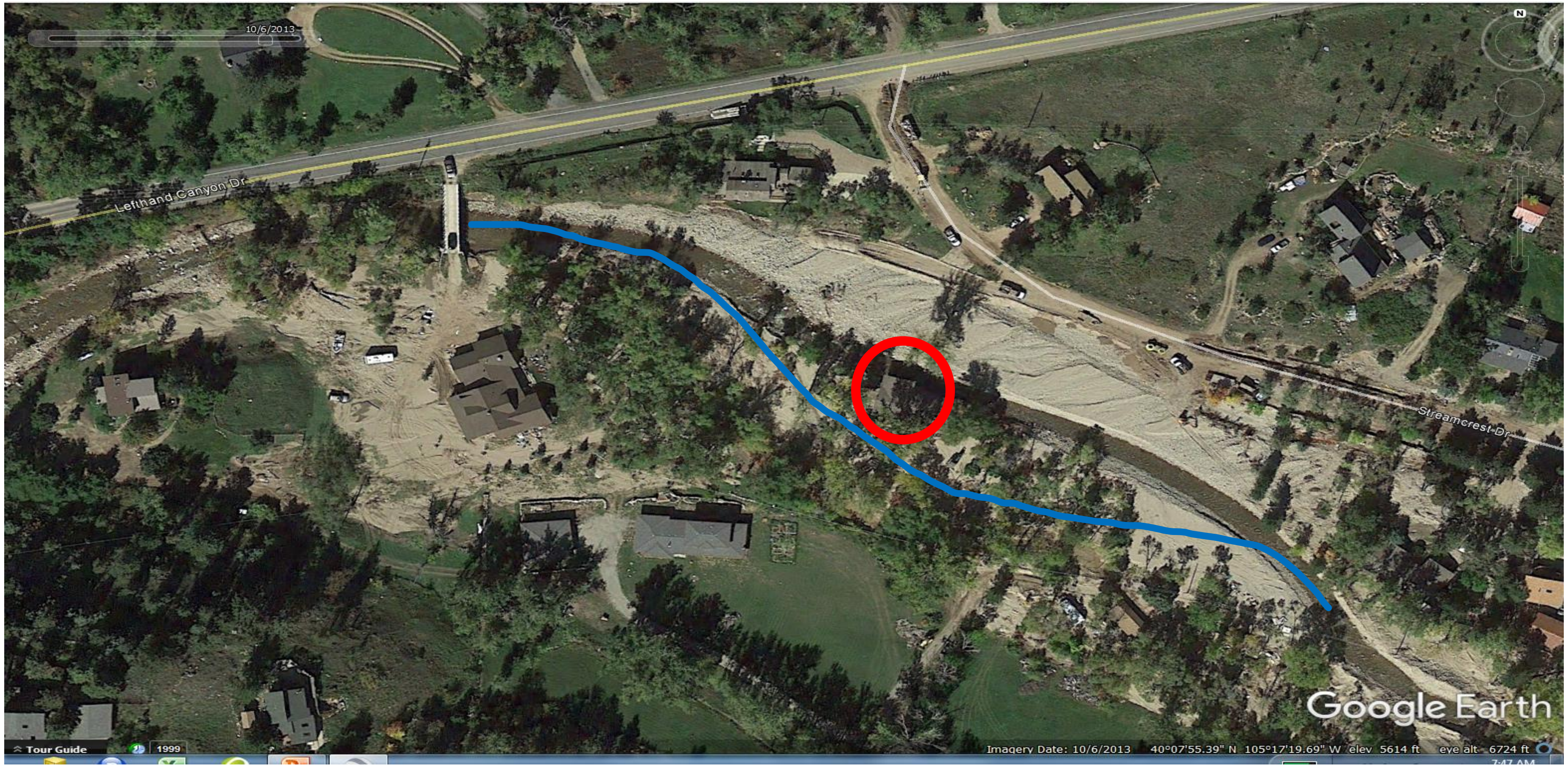
[dīˈnamik]

ADJECTIVE

(of a process or system) characterized by constant change, activity, or progress.

What is a dynamic river?

How do you know when you've got one?



Dynamic stream systems are streams capable of adjustments to channel and bed form, maintaining quasi-equilibrium, in response to expected and normal seasonal and inter-annual variation in sediment and hydrologic inputs over engineering timescales of approximately 50 years *(sensu Cluer and Thorne, 2014; Holling, 1973; Wohl, 2016)*

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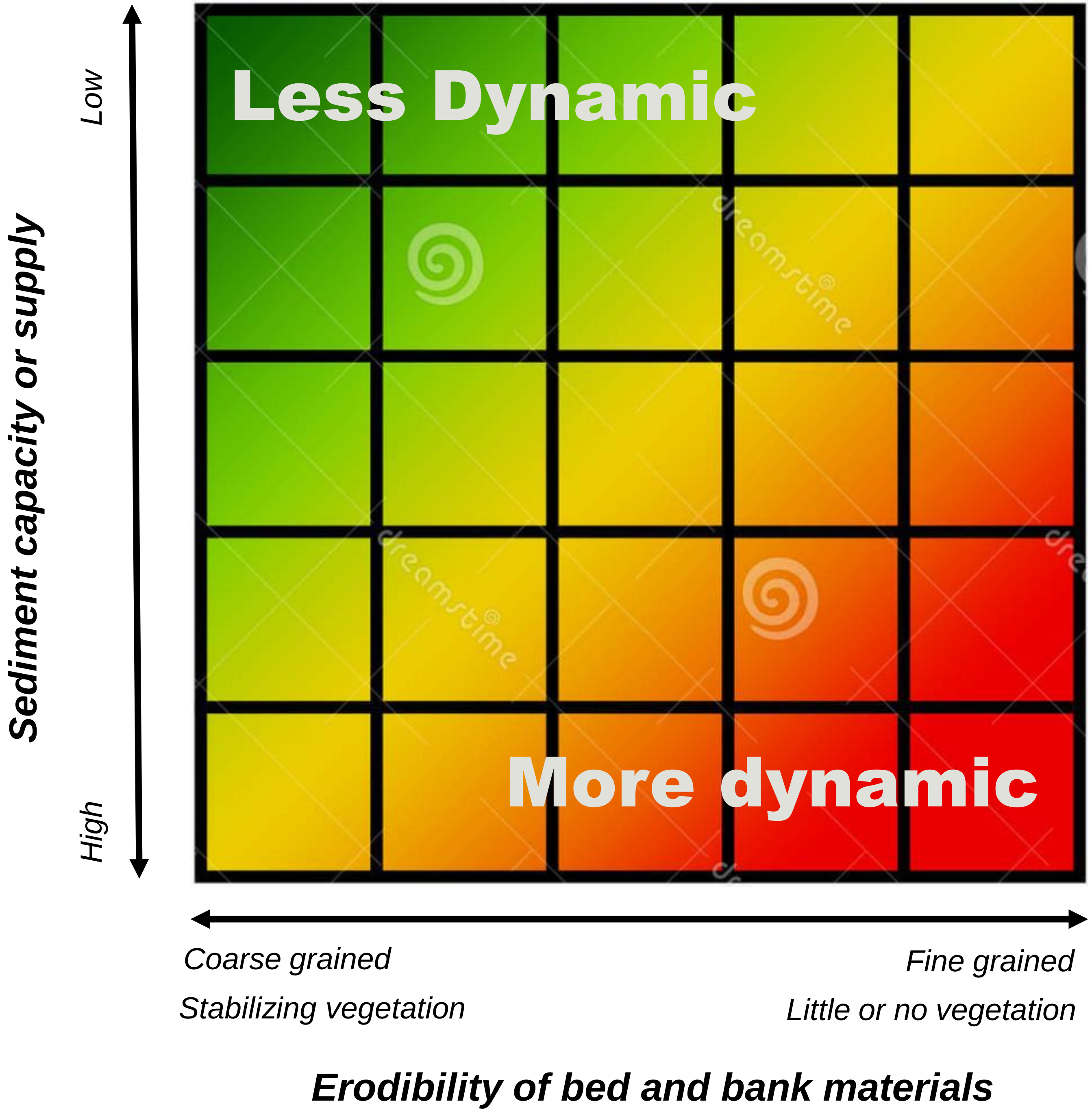
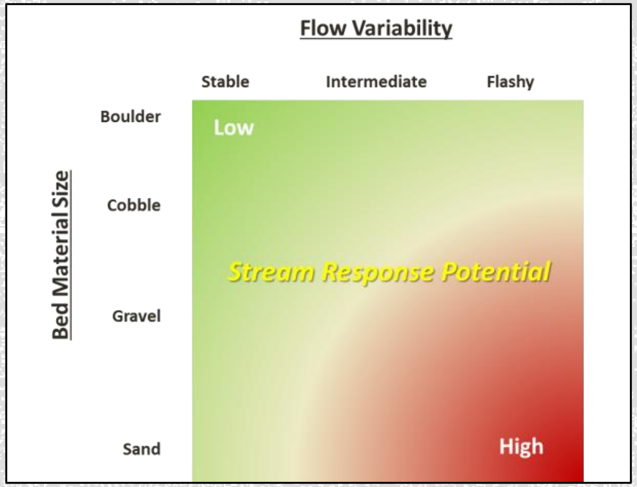


Highly dynamic stream system

Characterized by:

- Easily eroded bed and bank materials;
- High sediment transport capacity; and/or
- Large sediment supply

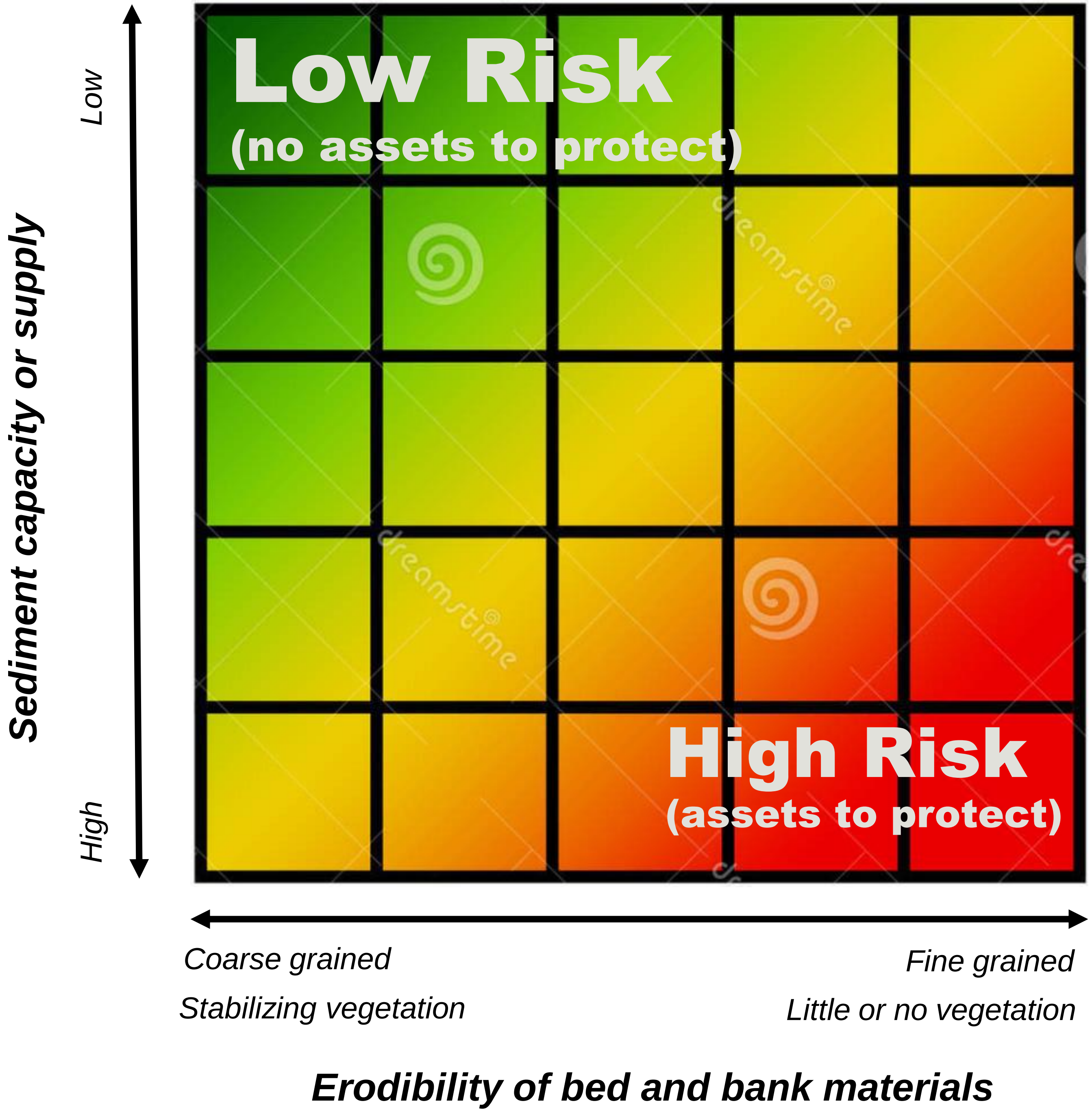


- No stream is actually static
- Every stream is a dynamic system continually altered by the changing character of its watershed
- Some systems are more dynamic than others
- Focus here on large scale adjustments

  This is what causes problems for static restoration approaches

- Colorado has its share of highly dynamic systems

Design in Dynamic Rivers



Effect of higher dynamism on design and construction

Increased project risk:

R = P x C

Higher dynamism means increased probability of:

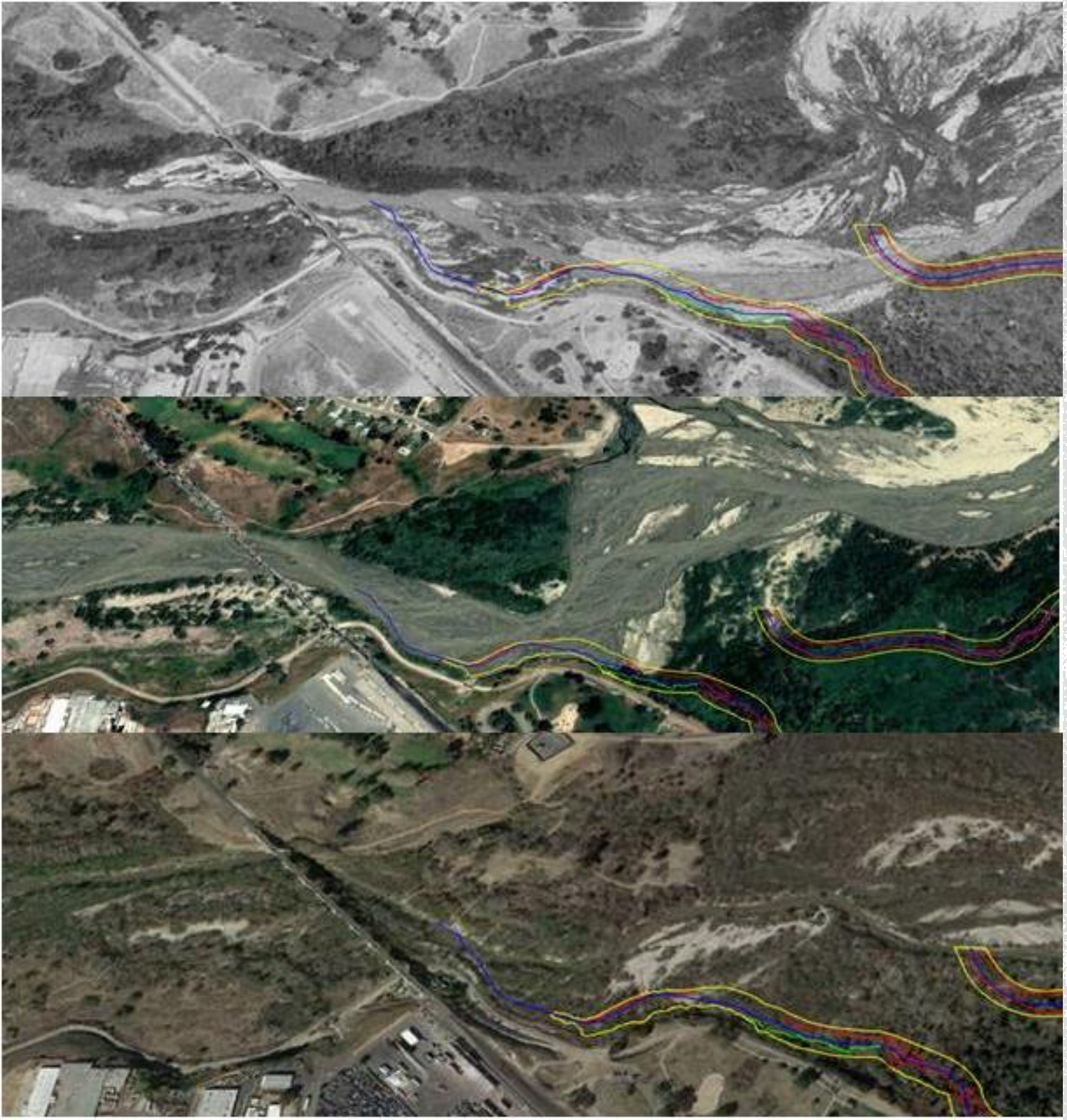
- adjustment
- damage to assets
- especially "static" assets

Most assets have no choice but to be "static"

But do our river restoration investments have to be?

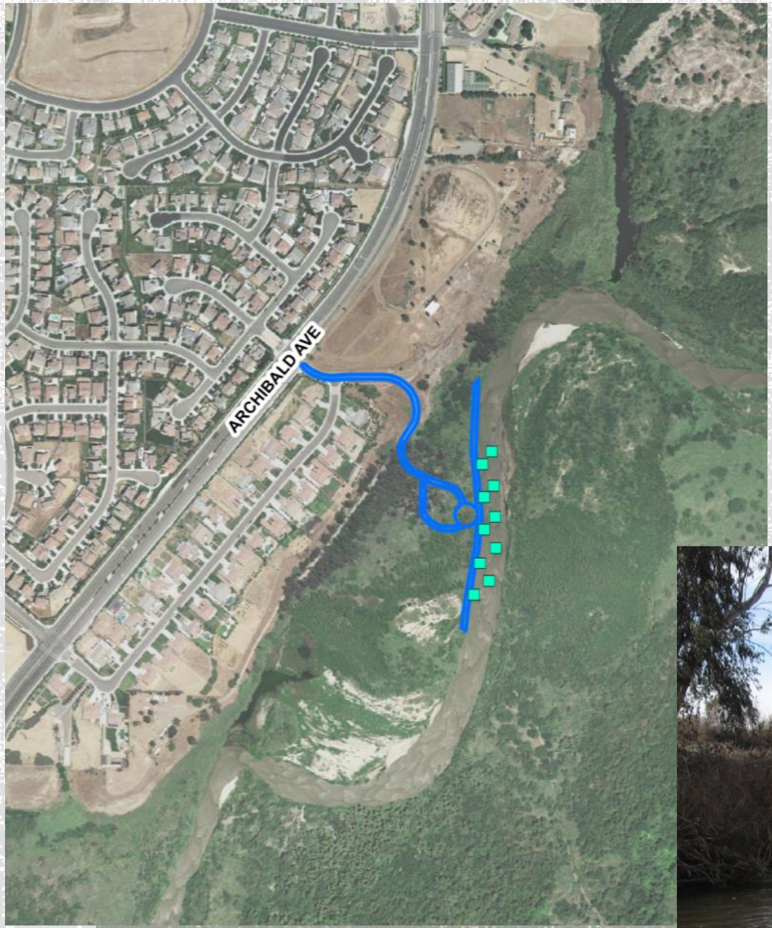
When is that not ok?

When we really pay for it…



Santa Ana River is a sandy braided floodplain system, draining the largest watershed of California's South Coast region

- Static restoration approaches target one state of equilibrium
- Cannot accommodate large adjustments
- Large adjustments are common in highly dynamic systems
- Require costly maintenance and/or replacement over time



Rock gabion 9 months after installation

When we really pay for it…

Project Title: Santa Ana Sucker Habitat Restoration Project

Project Description: The construction of 10 below grade and 10 above grade rock gabion structures along the Santa Ana River

How do you know when you've got one?

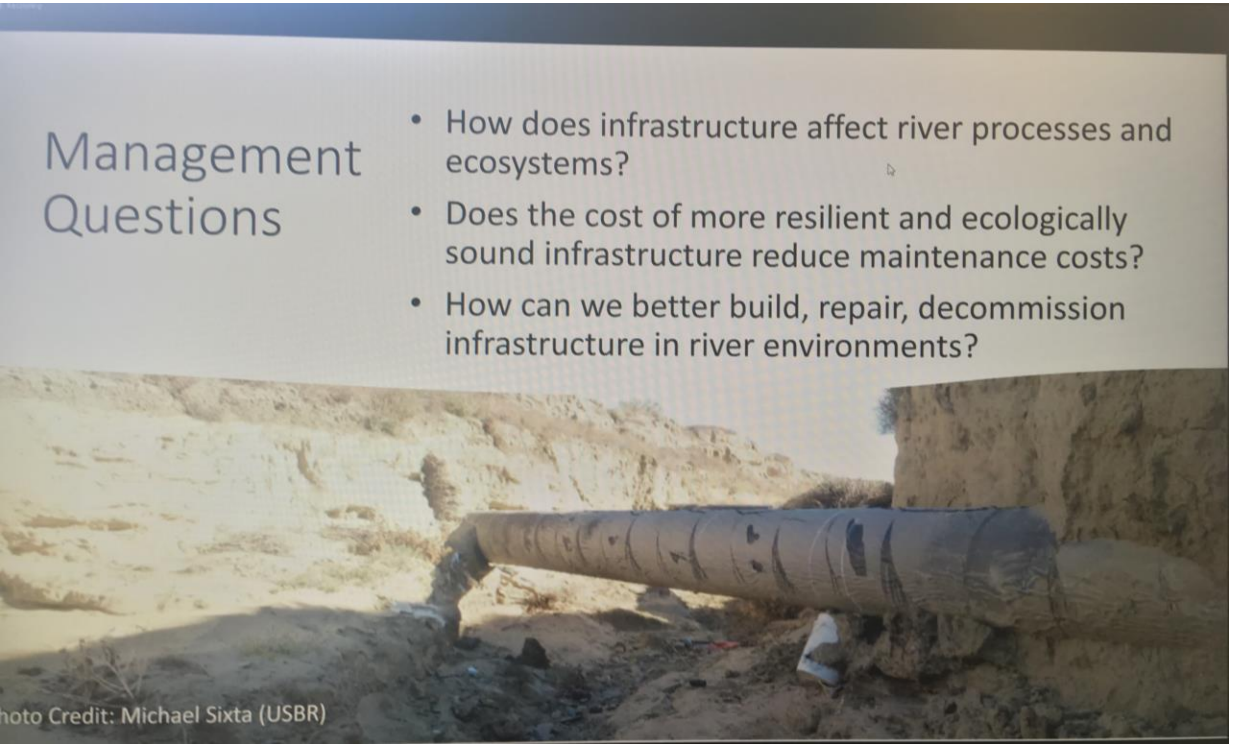
Colorado examples

- Fountain Creek system in Colorado Springs
- Many channels are steep and sandy with extensive development in close proximity
- No room for the river
- Actively responding to hydrodynamic changes
- Large adjustments are frequent

"The Engineer Graveyard"

Quick aside…

- Larger scale solutions are required in addition to improved design and construction at the project level
- Like Abby said yesterday, engage political partners too
- Long-range planning needs to change and be informed by understanding of river processes



2018: Managing Infrastructure in the Stream Environment

JOURNAL OF THE AMERICAN WATER RESOURCES ASSOCIATION
AMERICAN WATER RESOURCES ASSOCIATION

Managing Infrastructure in the Stream Environment

Joel S. Sholtes, Caroline Ubing, Timothy J. Randle, Jon Fripp, Daniel Cenderelli, and Drew C. Baird

Research Impact Statement: We present a framework for infrastructure designers and managers to build and manage riverine infrastructure in a manner that is both resilient to hazards and more compatible with stream ecosystems.

ABSTRACT: Riverine infrastructure provides essential services for the operation and development of the world's nations and their economies. When much of this infrastructure was built in the United States, fluvial processes and stream ecology were not well understood, putting it in conflict with and at risk from the stream environment. High maintenance costs are often required to keep such infrastructure viable and some of it has led to the degradation of aquatic and riparian ecosystems. This commentary paper lays the foundation for infrastructure designers and managers to build and manage infrastructure in a manner both resilient to riverine hazards and more compatible with aquatic and riparian ecosystem needs. We introduce fundamental fluvial geomorphic and ecosystem concepts and provide a decision-making framework to replace or repair existing infrastructure or build new infrastructure. Common management challenges associated with 11 riverine infrastructure types are discussed and we provide suggestions on how each infrastructure type can be better built and managed within stream corridors. We close with a discussion on managing infrastructure under future hydrologic uncertainty and in response to natural disasters.

(KEYWORDS: rivers; aquatic ecology; riparian zone, sustainability; resiliency; restoration; floods; natural hazards.)

INTRODUCTION

Government agencies, along with private citizens, have worked to construct and manage a vast network of infrastructure within stream corridors. This riverine infrastructure and associated activities includes channel and floodplain works (channelization, large wood management, and floodplain encroachment), streamside infrastructure (roads, pipelines, levees, streambank protection), and stream crossing infrastructure (bridges and culverts, pipelines, grade control structures, dams, reservoirs, and surface water diversion structures). We define riverine infrastructure broadly herein to include a spectrum of human activities in the stream corridor that fall under the umbrella of public works, stream engineering, and stream management. Riverine infrastructure provides vital services but is frequently detrimental to stream ecosystems and can pose a liability in terms of public safety and maintenance costs (Doyle et al. 2003; Nilsson et al. 2005; TRB and NRC 2005).

A large proportion of the infrastructure in the United States (U.S.) was built in the early and middle 20th Century and is nearing the end of its

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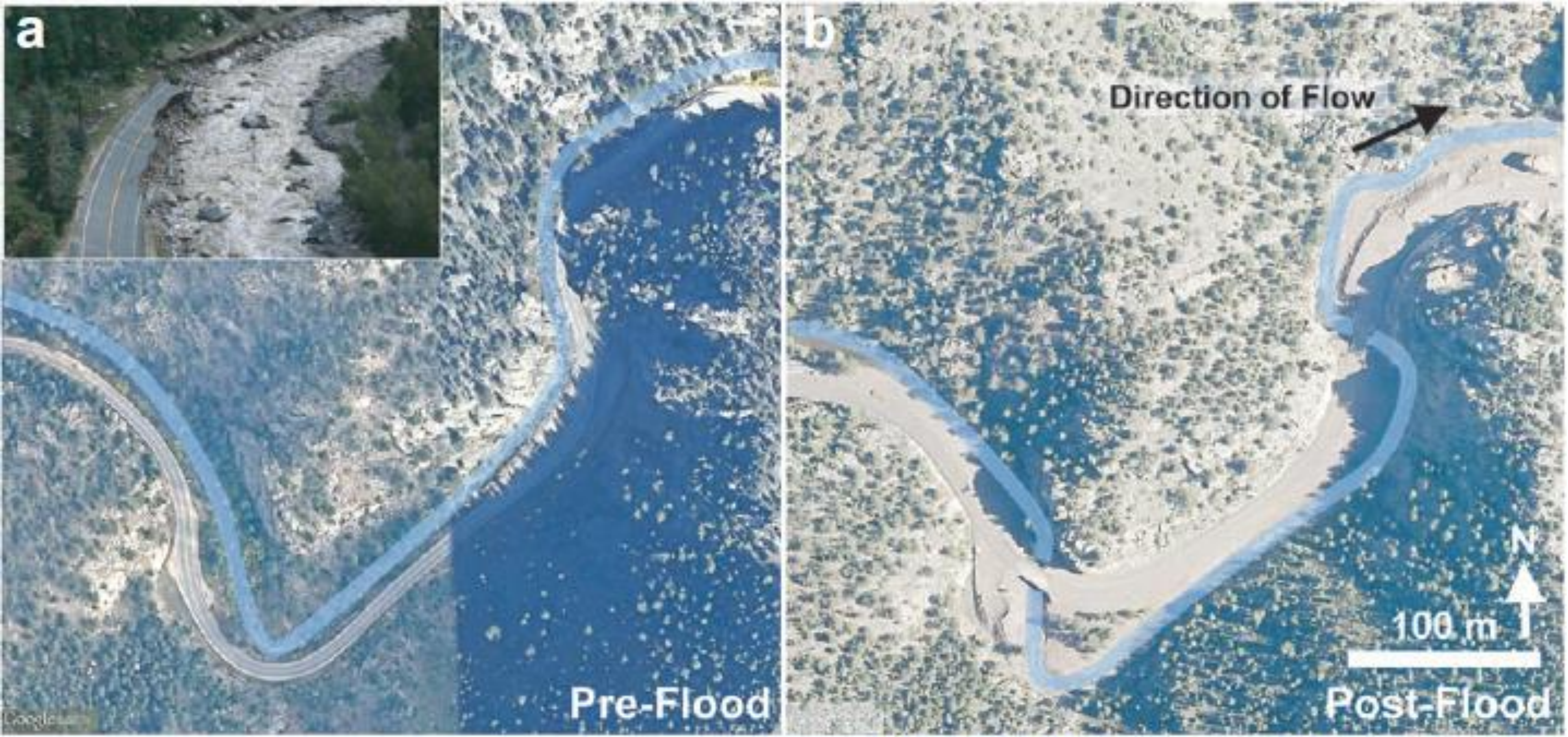
Sedimentation and River Hydraulics Group (Sholtes, Ubing, Randle, Baird), Bureau of Reclamation, Denver, Colorado, USA; National Design, Construction, and Soil Mechanics Center (Fripp), Natural Resources Conservation Service, Fort Worth, Texas, USA; and National Stream and Aquatic Ecology Center (Cenderelli), U.S. Forest Service, Fort Collins, Colorado, USA (Correspondence to Sholtes: jsholtes@gmail.com).

Citation: Sholtes, J.S., C. Ubing, T.J. Randle, J. Fripp, D. Cenderelli, and D.C. Baird. 2018. "Managing Infrastructure in the Stream Environment." *Journal of the American Water Resources Association* 1–13. https://doi.org/10.1111/1752-1688.12692.

Colorado examples

"A flood is likely to leave a messy river behind, with newly eroded banks and undermined trees that have fallen into the channel; freshly deposited bars; cutoff or secondary channels; and large wood deposited on the floodplain. This messiness, or newly created physical complexity, rejuvenates the river corridor…" **–Ellen Wohl**



Colorado examples

Process-based, Multiple benefit

- Non-static, resilient solutions:
  - better protect assets
  - maintain desired ecosystem functions
- Maintain natural riverine processes and "work with the river" for better performance long term through flood, fire, and drought cycles
- Adjust to changes in water and sediment delivery, including those associated with hydromodification and climate change

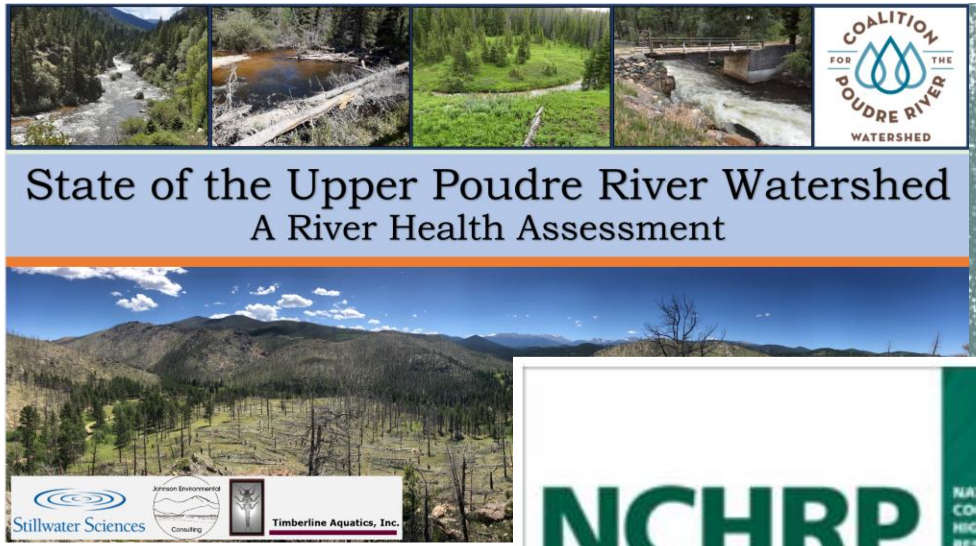
. . .

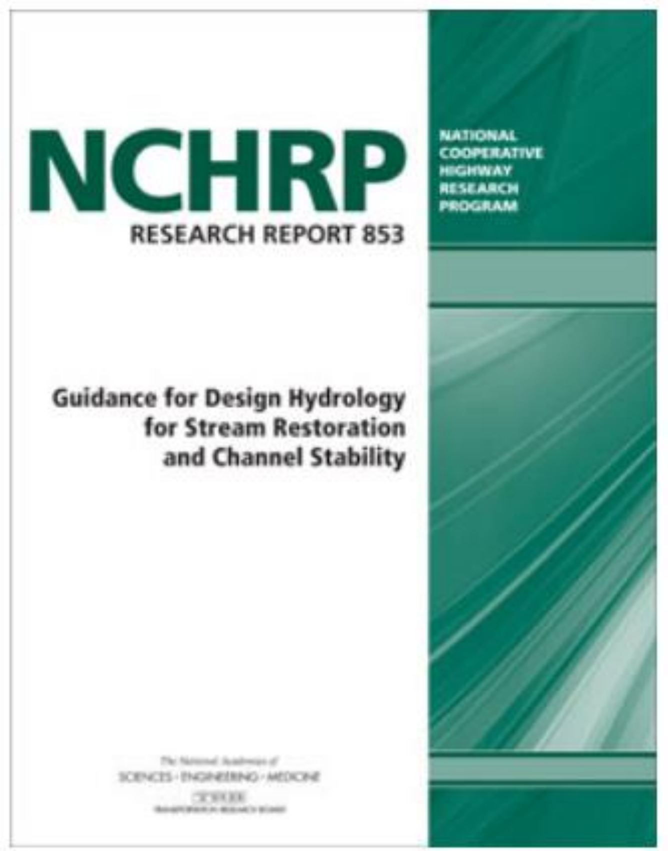
- Design and construction to accommodate adjustment is a challenge
- Designers and contractors must fully understand the process dynamics that drive and shape complex fluvial systems
- Manage expectations placed on restoration investments

Many tools are needed!

Tools

- Understand geomorphic setting and trajectories
- Analyze hydraulics and sediment transport
- Address uncertainty and risk
- Work with river processes

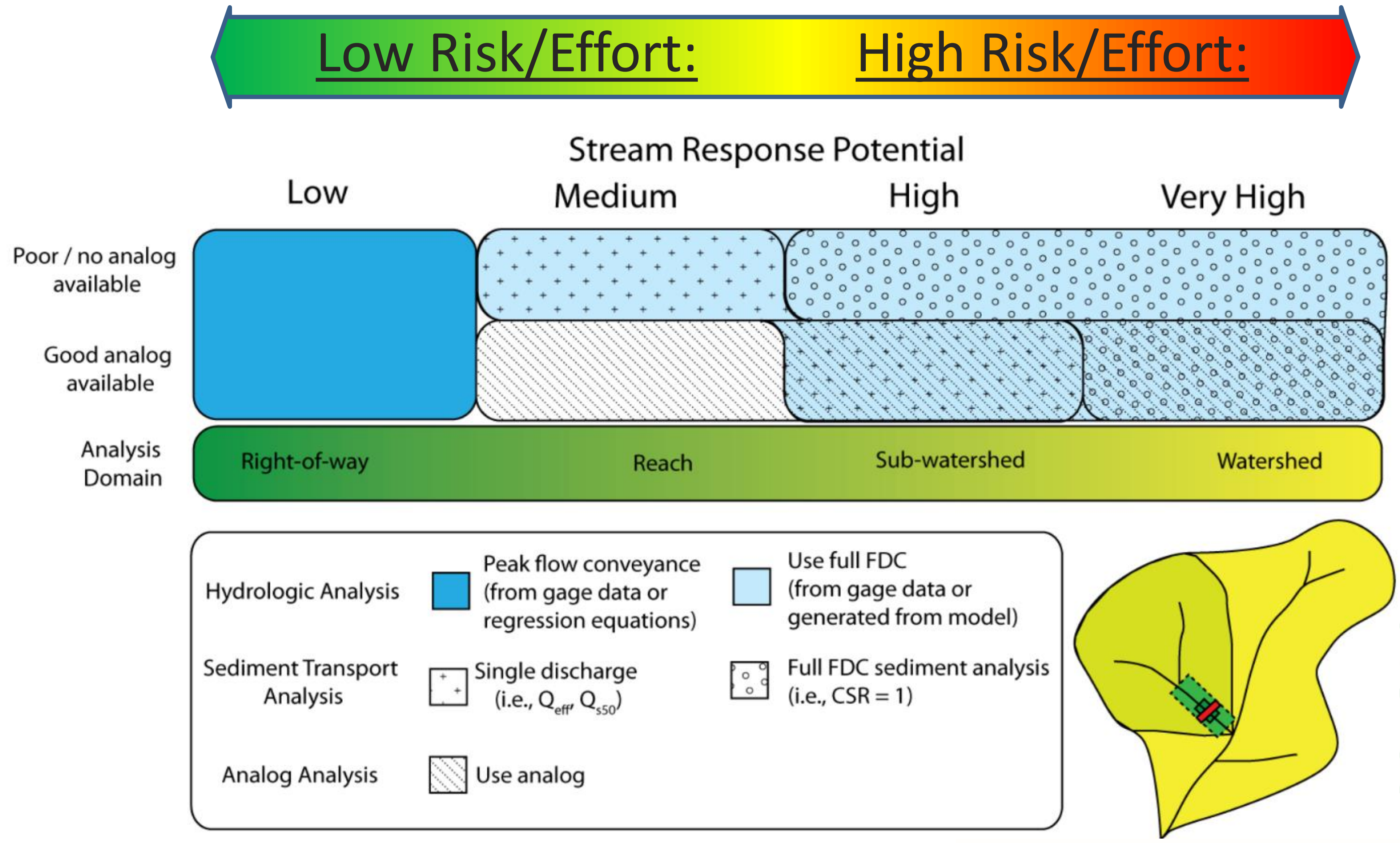




Cache la Poudre River - Downstream of Hatchery	
Flow regime	B
Sediment regime	B+
Water quality	A-
Floodplain connectivity	A
Riparian condition	B
River form	B
Resilience	B
Physical structure	B
Aquatic life	B
Reach condition score	B

System understanding
Geomorphic trajectories

LEVEL OF DESIGN EFFORT BASED ON STREAM RESPONSE POTENTIAL



MORE RISK, MORE LINES OF EVIDENCE

Low Risk/Effort: High Risk/Effort:

Tools!

		Sub-Daily Flow Analysis
		Daily Flow Analysis
	Daily Flow Analysis	Peak Discharge
	Peak Discharge	Capacity/Supply Ratio
Peak Discharge	Sizing Channel for Qs50	Sediment Transport Field Data
Reference Reach	Reference Reach	Reference Reach

Step One

- Ask ourselves "How much room does the river have to move? Can we give it more room?"

Risk and Redundancy

R = P x C

High P - probability of adjustment/damage high in dynamic system

High C – consequence of not protecting the native Santa Ana sucker is high *(conservation status: vulnerable)*

- When risk is high, redundancies are warranted
- Example: predator/bass exclusion issue
- Redundancies being considered:
  - Physical exclusion structure* at confluence with Santa Ana mainstem (aka “wild child”)

    Recommending only minor investment
- Predator removal program *(human dependency)*
- Incorporate habitat that favors sucker over bass

Santa Ana River in California's South Coast region

**Any engineered control, by its nature, will fail under some event. Engineering design picks a design event, beyond which damage or failure is expected.*

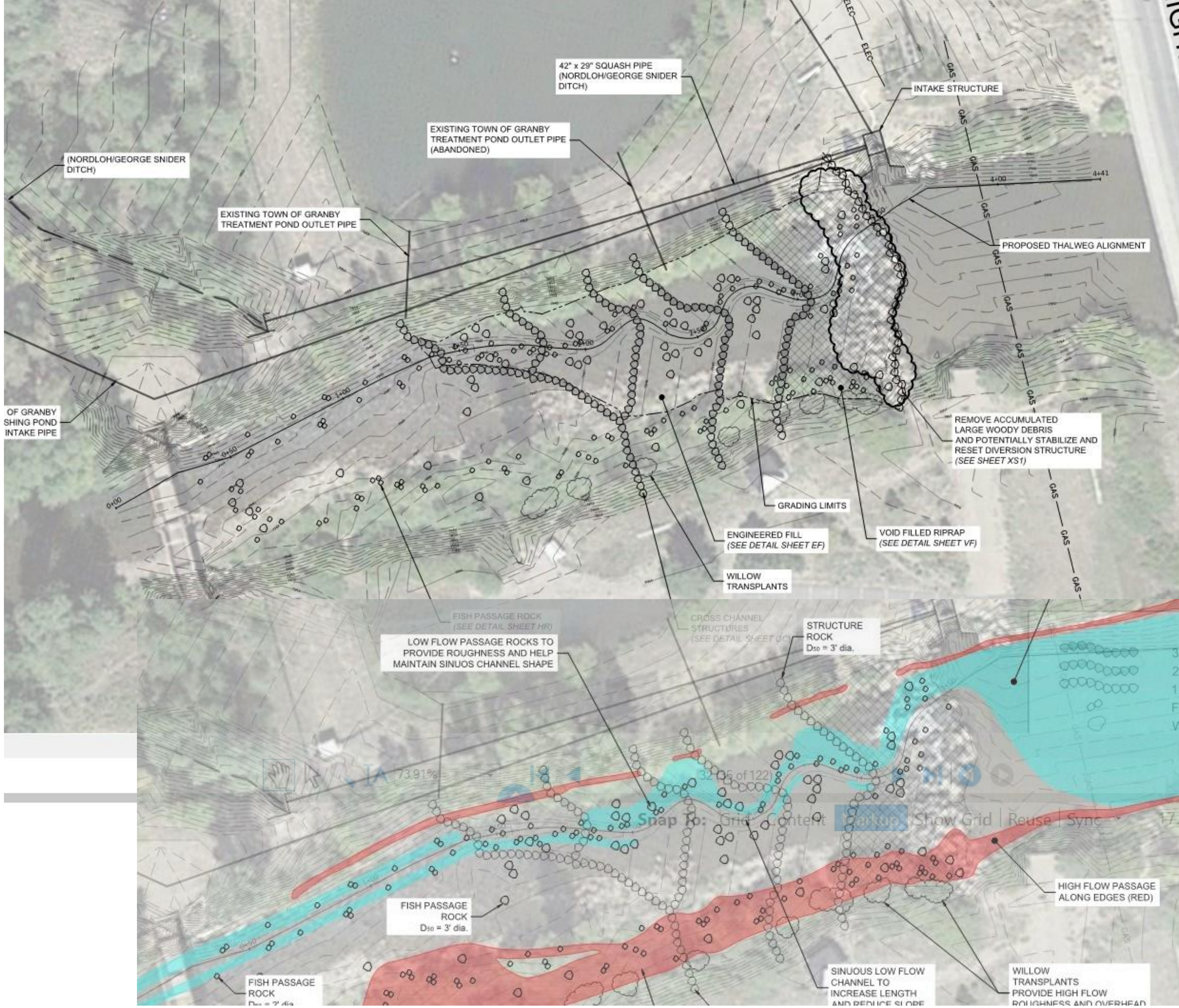
Construction in Dynamic Rivers

Design Understanding

The importance of vision. What is the work intended to accomplish and how is it expected to perform?

Project Bid

- Detail matters
- Approach grounded in the plans and specifications with estimated quantities and production rates
- Regulations
- Risk identification
- Communication and the value of working plans, rollups, and assumptions/exclusions



Implementation

- Safety
- Do no unnecessary harm
- Equipment selection and operation
- Oversight and autonomy, thoughtful decisions regarding existing and proposed conditions

- Balance of heavy and hand work
- Layering and feathering
- Planned randomness
- Material handling and the importance of staging
- BMPs (Best Management Practices)

Monitoring and Maintenance
aka Adaptive Management

We have made a suggestion, now we will see what Mother Nature thinks of it.

Process-based and Multi-benefit Design and Construction in Dynamic River Systems

As we continue designing and implementing process-based and multi-benefit approaches, we will further a new vision of what healthy rivers and protected assets looks like.

Riparian Restoration Conference - RiversEdge West 2020

Many thanks to all who love rivers and the riparian areas that surround them