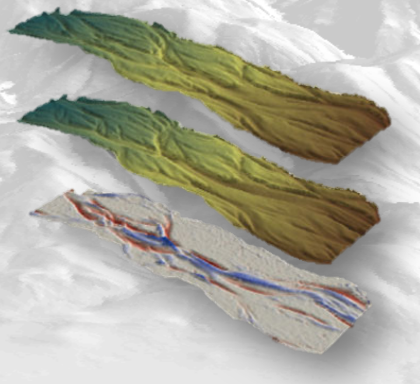
INTEGRATION ACROSS DISCIPLINES

TRENDS AND CHALLENGES IN ANALYSIS OF HIGH RESOLUTION TOPOGRAPHY

Joe Wheaton



A^2HRT Workshop

Boulder, CO

August 21-23, 2018

WHAT CAPTURED OUR IMAGINATION IN HRT?

- For first time, the data, looked just like what we saw in field

- Raw data was every bit as complicated as the real world!

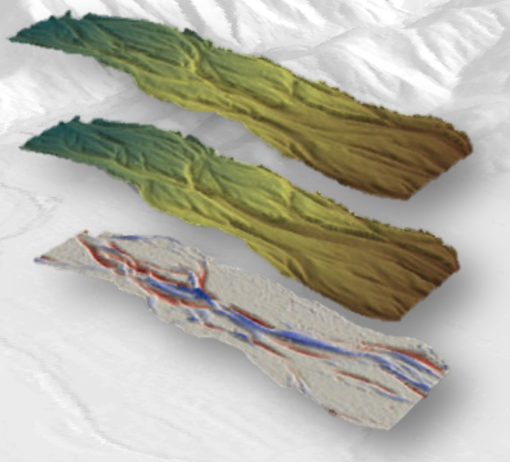
OLD & OUTDATED

From a scan back in 2004

Brasington et al., 2012; Rychkov et al., 2012

PURPOSE OF TALK

- Share with you my perspectives & impressions of high resolution topography (w/o many pictures of HRT) & how to transcend disciplines with it

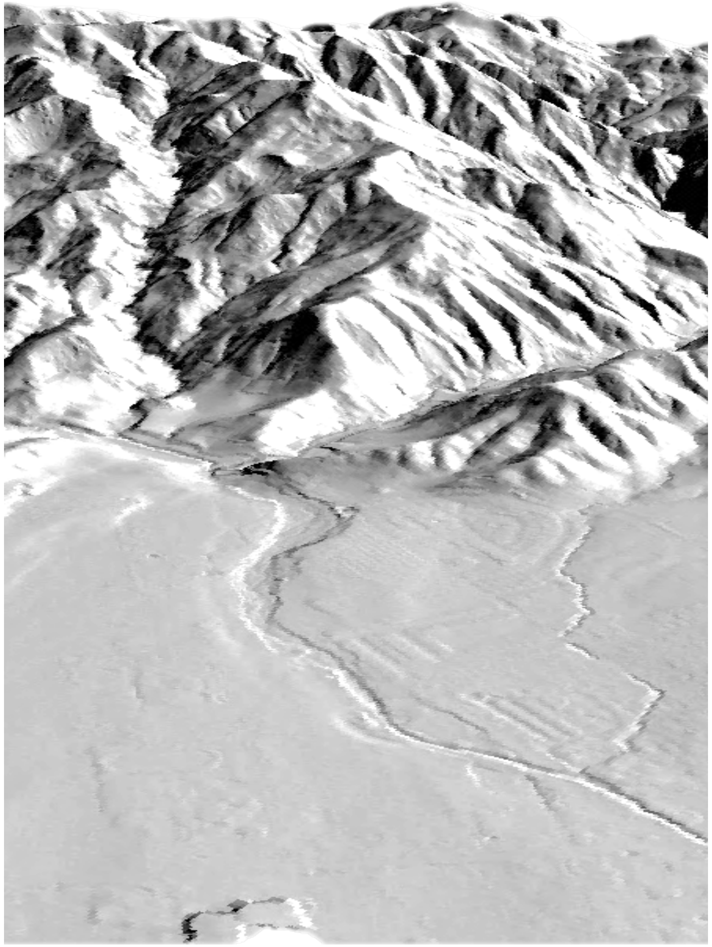


$\frac{\partial z}{\partial t}$

Convince you its time we moved past the pretty pictures & past the methods…

OVER-FOCUS ON 'DO IT BECAUSE WE CAN'

- Why?
- Because we can see in data, what we see on the ground.
- Is method driving our science or are we?
- Let's not fool ourselves... We are not advancing these technologies…

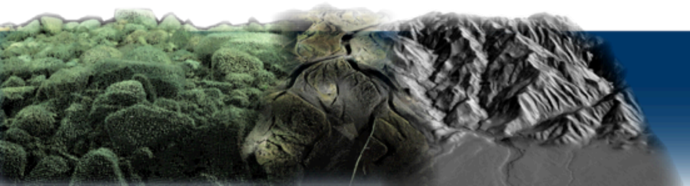


WHAT ARE THE TRENDS?

- Explosion of topographic survey methods
- Cheer-leading for certain technologies
- Same mistakes keep being made!
- Appreciation of role of uncertainty… yet continued use of unsophisticated methods for coping with it
- Wow… look at my point cloud
- Hey, I've got two surveys. That should be publishable…

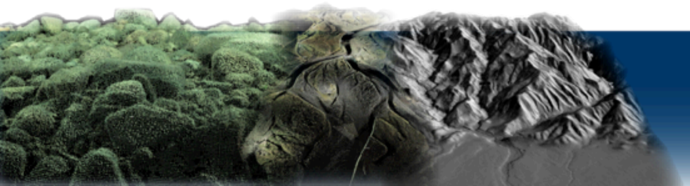
WHAT ARE THE RECENT DEVELOPMENTS?

- Consolidation of topographic survey methods
- Emergence of ‘hybrid’ data collection techniques
- Better error models
- Emergence of more standardized methods for raster-based change detection
- Point-cloud processing (ironically -> decimation focused)
- Cloud-to-Cloud change detection
- Large scale applications
- Novel monitoring applications



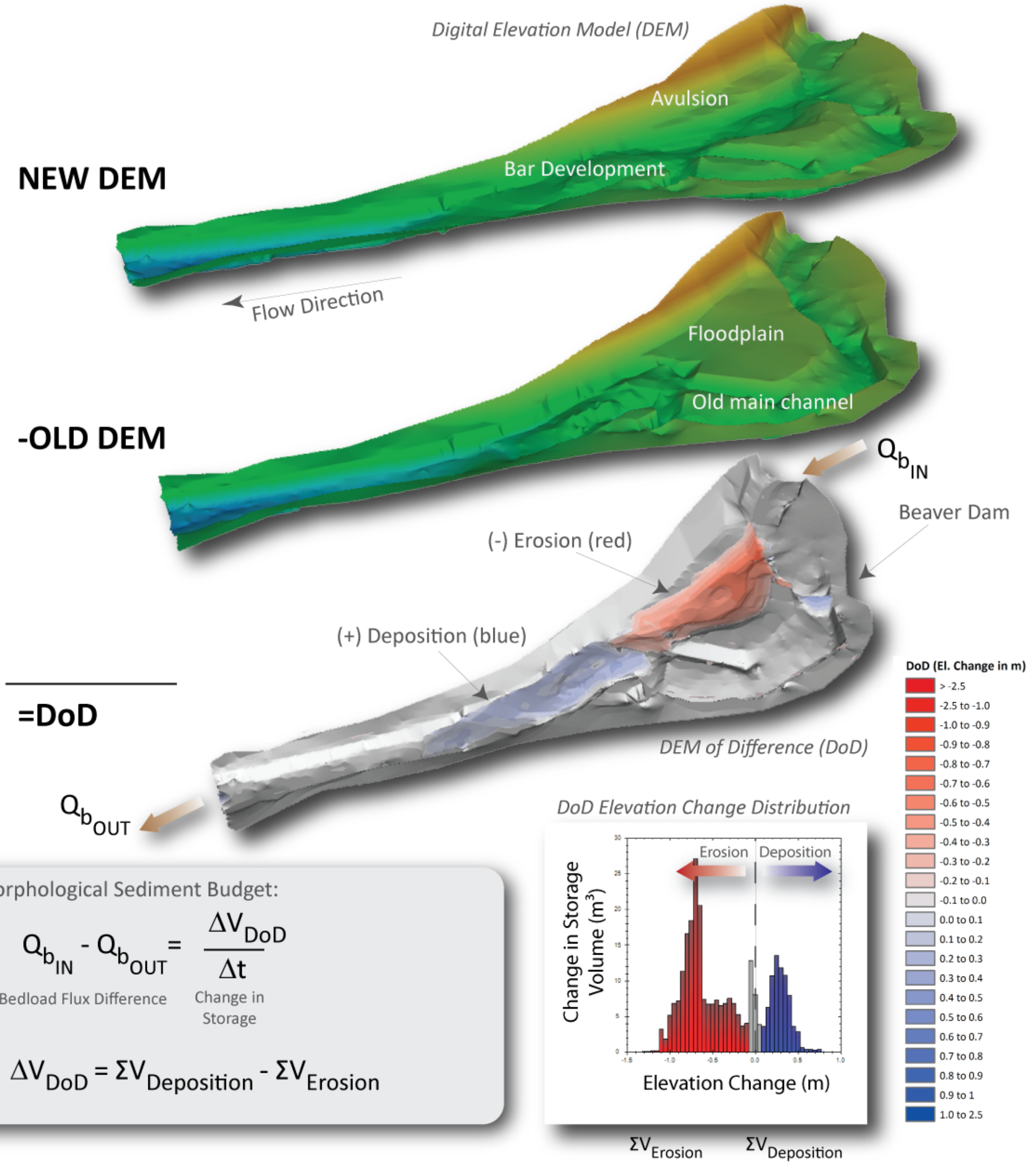
CONCLUSIONS

- We focus too much on methodological tangents
  - Too often these include things that *are known*:
    - How to acquire topographic data for surfaces of interest
    - Lost in signal to noise: uncertainty and error modelling
- We are not driving the technology… we're following it – Oh… look … something shiny
- Is more always better? What do I really need?
  - While HRT acquisition and processing is getting quicker – we quickly find black holes of processing
- What are the questions I really care about?
- What can HRT tell me that I didn't already know?



GCD… SO WHAT?

- What can we do with that repeat topography?
- Develop a direct measure of fluvial erosion and deposition
- Estimate change in storage terms of sediment budgets



Morphological Sediment Budget:

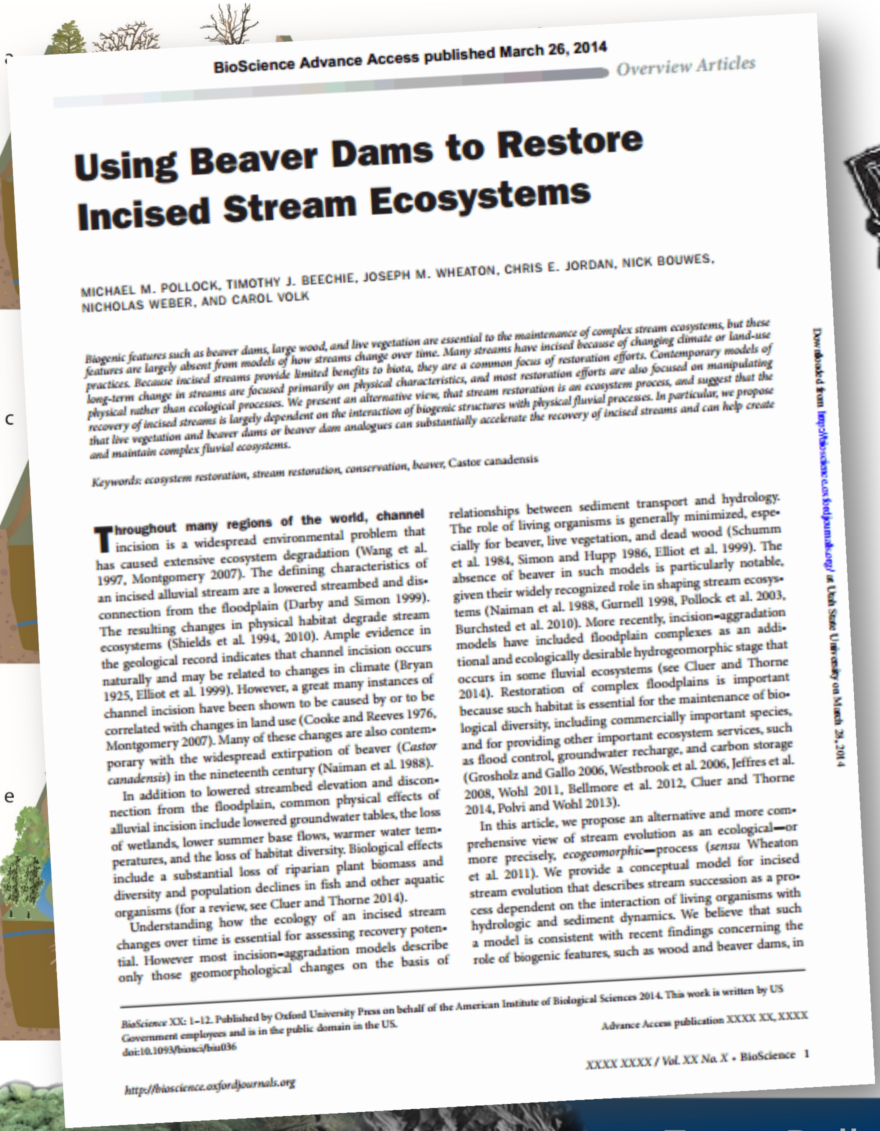
$$\underbrace{Q_{b_{IN}} - Q_{b_{OUT}}}_{\text{Bedload Flux Difference}} = \underbrace{\frac{\Delta V_{DoD}}{\Delta t}}_{\text{Change in Storage}}$$

$$\Delta V_{DoD} = \Sigma V_{Deposition} - \Sigma V_{Erosion}$$

BRIDGE CREEK….

Little incision problem…

USING BEAVER TO RESTORE INCISED STREAMS



BioScience Advance Access published March 26, 2014

Overview Articles

Using Beaver Dams to Restore Incised Stream Ecosystems

MICHAEL M. POLLOCK, TIMOTHY J. BEECHIE, JOSEPH M. WHEATON, CHRIS E. JORDAN, NICK BOUWES,
NICHOLAS WEBER, AND CAROL VOLK

Biogenic features such as beaver dams, large wood, and live vegetation are essential to the maintenance of complex stream ecosystems, but these features are largely absent from models of how streams change over time. Many streams have incised because of changing climate or land-use practices. Because incised streams provide limited benefits to biota, they are a common focus of restoration efforts. Contemporary models of long-term change in streams are focused primarily on physical characteristics, and most restoration efforts are also focused on manipulating physical rather than ecological processes. We present an alternative view, that stream restoration is an ecosystem process, and suggest that the recovery of incised streams is largely dependent on the interaction of biogenic structures with physical fluvial processes. In particular, we propose that live vegetation and beaver dams or beaver dam analogues can substantially accelerate the recovery of incised streams and can help create and maintain complex fluvial ecosystems.

Keywords: ecosystem restoration, stream restoration, conservation, beaver, Castor canadensis

Throughout many regions of the world, channel incision is a widespread environmental problem that has caused extensive ecosystem degradation (Wang et al. 1997, Montgomery 2007). The defining characteristics of an incised alluvial stream are a lowered streambed and disconnection from the floodplain (Darby and Simon 1999). The resulting changes in physical habitat degrade stream ecosystems (Shields et al. 1994, 2010). Ample evidence in the geological record indicates that channel incision occurs naturally and may be related to changes in climate (Bryan 1925, Elliot et al. 1999). However, a great many instances of channel incision have been shown to be caused by or to be correlated with changes in land use (Cooke and Reeves 1976, Montgomery 2007). Many of these changes are also contemporary with the widespread extirpation of beaver (*Castor canadensis*) in the nineteenth century (Naiman et al. 1988).

In addition to lowered streambed elevation and disconnection from the floodplain, common physical effects of alluvial incision include lowered groundwater tables, the loss of wetlands, lower summer base flows, warmer water temperatures, and the loss of habitat diversity. Biological effects include a substantial loss of riparian plant biomass and diversity and population declines in fish and other aquatic organisms (for a review, see Cluer and Thorne 2014).

Understanding how the ecology of an incised stream changes over time is essential for assessing recovery potential. However most incision–aggradation models describe only those geomorphological changes on the basis of relationships between sediment transport and hydrology. The role of living organisms is generally minimized, especially for beaver, live vegetation, and dead wood (Schumm et al. 1984, Simon and Hupp 1986, Elliot et al. 1999). The absence of beaver in such models is particularly notable, given their widely recognized role in shaping stream ecosystems (Naiman et al. 1988, Gurnell 1998, Pollock et al. 2003, Burchsted et al. 2010). More recently, incision–aggradation models have included floodplain complexes as an additional and ecologically desirable hydrogeomorphic stage that occurs in some fluvial ecosystems (see Cluer and Thorne 2014). Restoration of complex floodplains is important because such habitat is essential for the maintenance of biological diversity, including commercially important species, and for providing other important ecosystem services, such as flood control, groundwater recharge, and carbon storage (Grosholz and Gallo 2006, Westbrook et al. 2006, Jeffres et al. 2008, Wohl 2011, Bellmore et al. 2012, Cluer and Thorne 2014, Polvi and Wohl 2013).

In this article, we propose an alternative and more comprehensive view of stream evolution as an ecological—or more precisely, *ecogeomorphic*—process (*sensu* Wheaton et al. 2011). We provide a conceptual model for incised stream evolution that describes stream succession as a process dependent on the interaction of living organisms with hydrologic and sediment dynamics. We believe that such a model is consistent with recent findings concerning the role of biogenic features, such as wood and beaver dams, in

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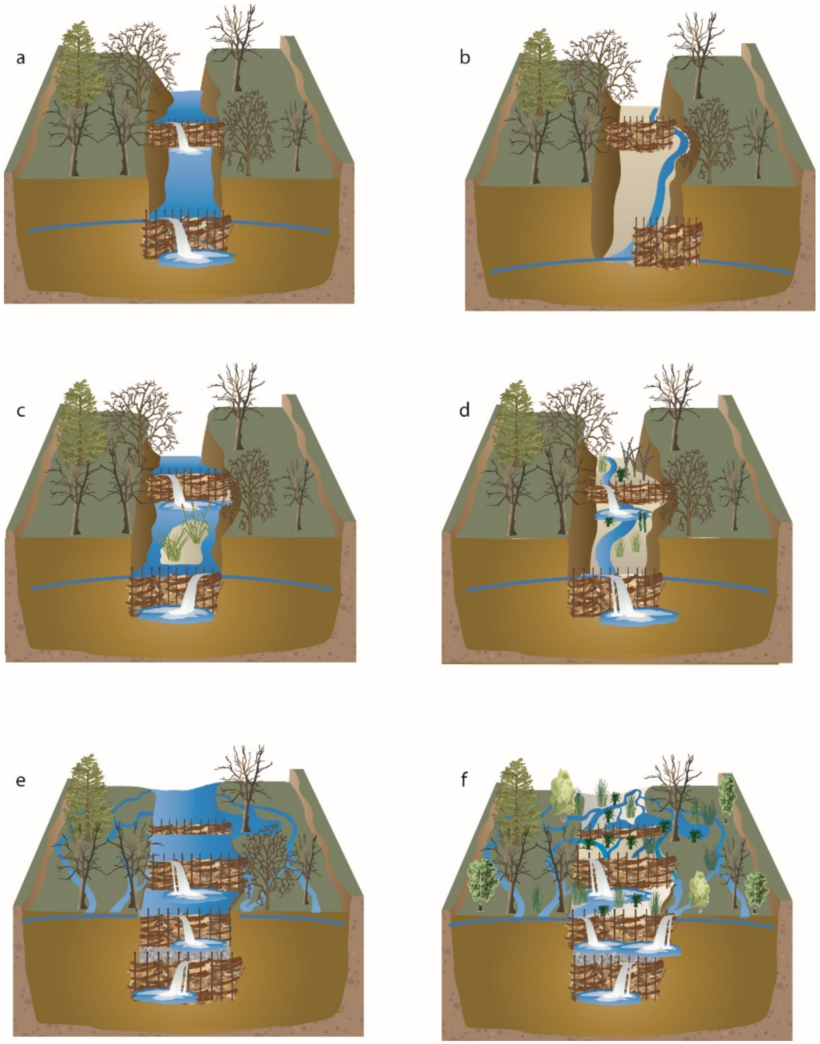
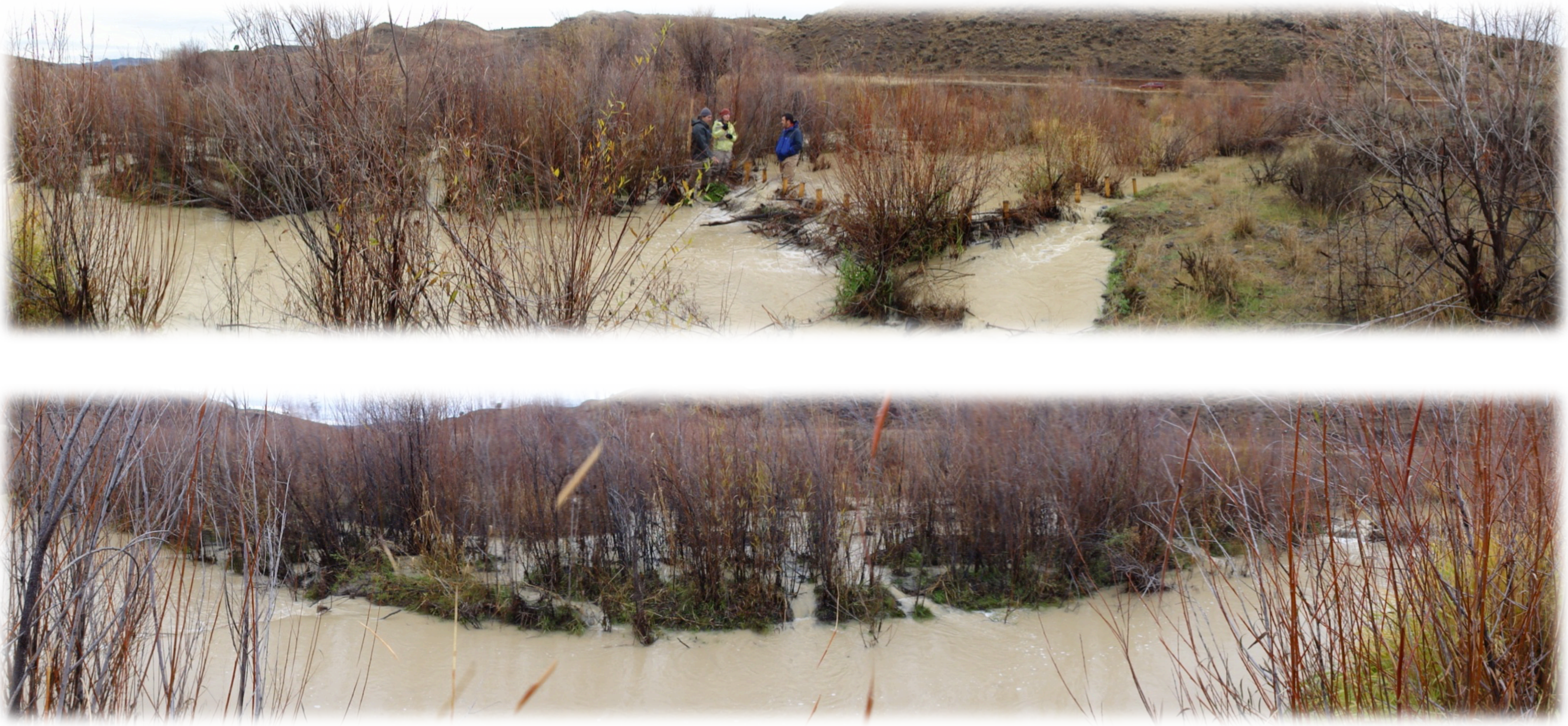
Advance Access publication XXXX XX, XXXX

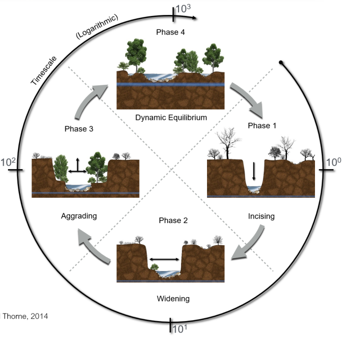


From Pollock et al. (2014) –
Bioscience

STARTER DAM OCCUPIED…



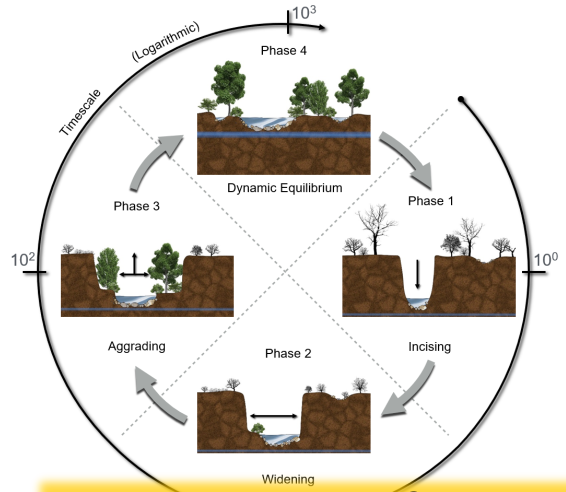
Installed September 2009, Occupied by November 2009



Cluer and Thorne, 2014

WHAT DID WE LEARN?

- Can’t aggrade without eroding!!!
- Speeding up morphodynamic evolution builds both more habitat and more complex fish habitat!

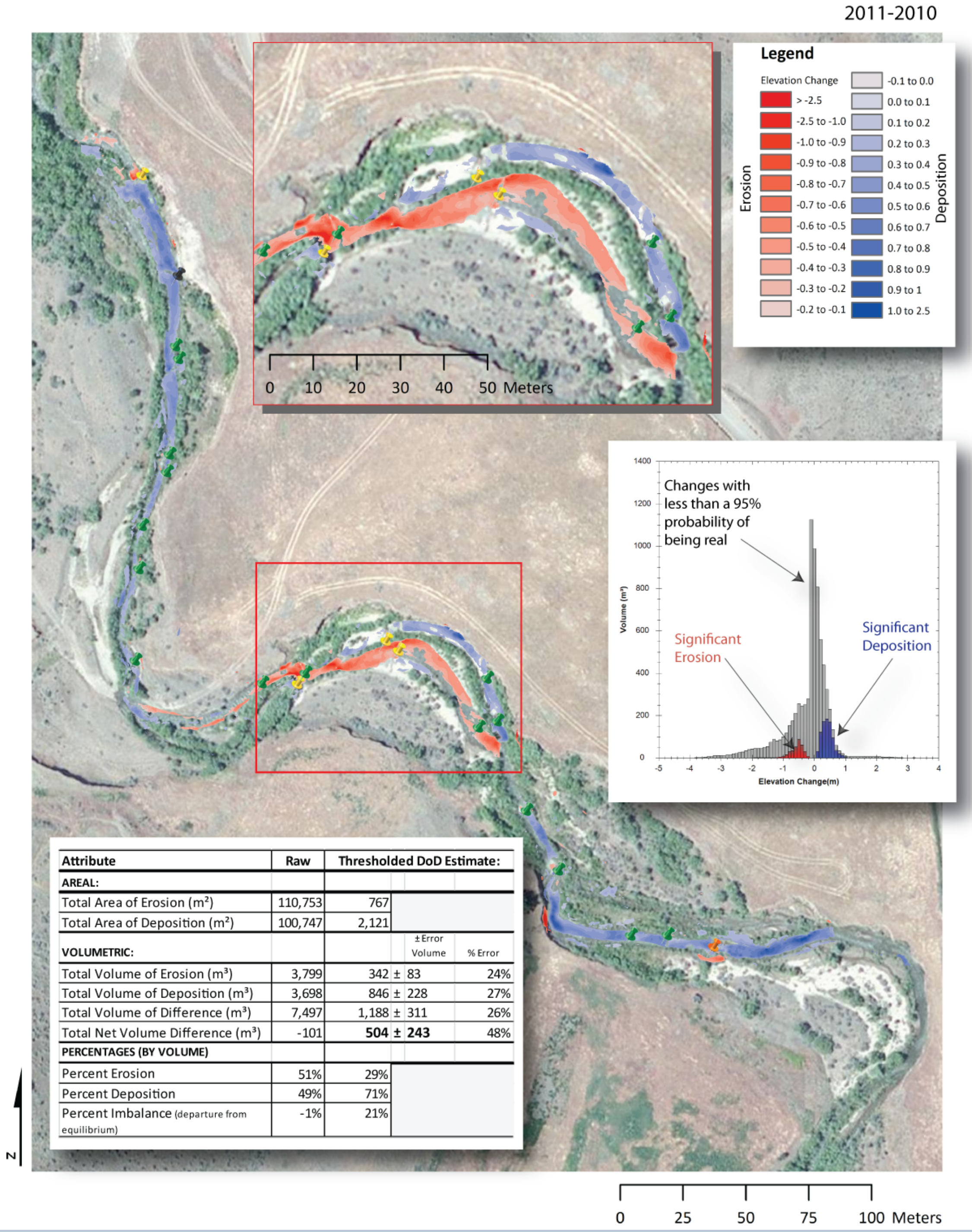


Cluer and Thorne 201

Erosion: 342 m^3 +/- 83

Deposition: 846 m^3 +/- 228

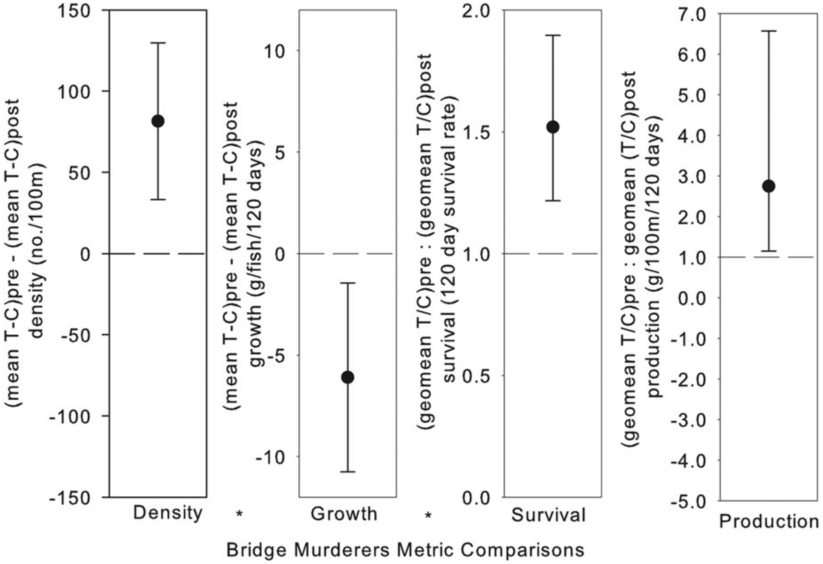
NET: + 504 m^3 (+/- 243)

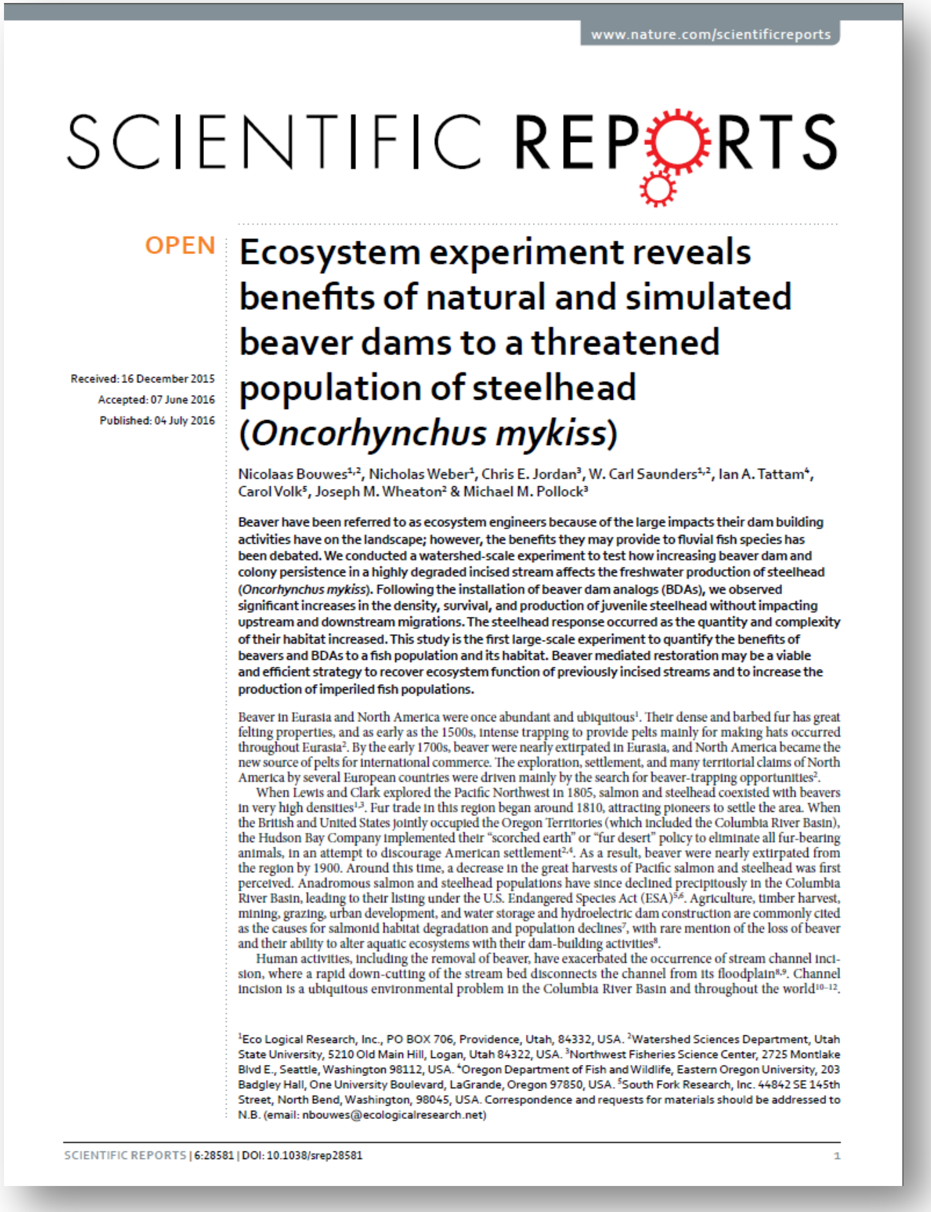


Attribute	Raw	Thresholded DoD Estimate:			
AREAL:					
Total Area of Erosion (m²)	110,753	767			
Total Area of Deposition (m²)	100,747	2,121			
VOLUMETRIC:				± Error Volume	% Error
Total Volume of Erosion (m³)	3,799	342	±	83	24%
Total Volume of Deposition (m³)	3,698	846	±	228	27%
Total Volume of Difference (m³)	7,497	1,188	±	311	26%
Total Net Volume Difference (m³)	-101	**504**	±	**243**	48%
PERCENTAGES (BY VOLUME)					
Percent Erosion	51%	29%			
Percent Deposition	49%	71%			
Percent Imbalance (departure from equilibrium)	-1%	21%			

HRT MAKING A SPLASH….

- Restoration using beaver as restoration agent actually produced a population level increase in density, survival and production of ESA listed salmon




www.nature.com/scientificreports

SCIENTIFIC REPORTS

OPEN

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Ecosystem experiment reveals benefits of natural and simulated beaver dams to a threatened population of steelhead (*Oncorhynchus mykiss*)

Nicolaas Bouwes[1,2], Nicholas Weber[1], Chris E. Jordan[3], W. Carl Saunders[1,2], Ian A. Tattam[4], Carol Volk[5], Joseph M. Wheaton[2] & Michael M. Pollock[3]

Beaver have been referred to as ecosystem engineers because of the large impacts their dam building activities have on the landscape; however, the benefits they may provide to fluvial fish species has been debated. We conducted a watershed-scale experiment to test how increasing beaver dam and colony persistence in a highly degraded incised stream affects the freshwater production of steelhead (*Oncorhynchus mykiss*). Following the installation of beaver dam analogs (BDAs), we observed significant increases in the density, survival, and production of juvenile steelhead without impacting upstream and downstream migrations. The steelhead response occurred as the quantity and complexity of their habitat increased. This study is the first large-scale experiment to quantify the benefits of beavers and BDAs to a fish population and its habitat. Beaver mediated restoration may be a viable and efficient strategy to recover ecosystem function of previously incised streams and to increase the production of imperiled fish populations.

Beaver in Eurasia and North America were once abundant and ubiquitous[1]. Their dense and barbed fur has great felting properties, and as early as the 1500s, intense trapping to provide pelts mainly for making hats occurred throughout Eurasia[2]. By the early 1700s, beaver were nearly extirpated in Eurasia, and North America became the new source of pelts for international commerce. The exploration, settlement, and many territorial claims of North America by several European countries were driven mainly by the search for beaver-trapping opportunities[2].

When Lewis and Clark explored the Pacific Northwest in 1805, salmon and steelhead coexisted with beavers in very high densities[1,3]. Fur trade in this region began around 1810, attracting pioneers to settle the area. When the British and United States jointly occupied the Oregon Territories (which included the Columbia River Basin), the Hudson Bay Company implemented their “scorched earth” or “fur desert” policy to eliminate all fur-bearing animals, in an attempt to discourage American settlement[2,4]. As a result, beaver were nearly extirpated from the region by 1900. Around this time, a decrease in the great harvests of Pacific salmon and steelhead was first perceived. Anadromous salmon and steelhead populations have since declined precipitously in the Columbia River Basin, leading to their listing under the U.S. Endangered Species Act (ESA)[5,6]. Agriculture, timber harvest, mining, grazing, urban development, and water storage and hydroelectric dam construction are commonly cited as the causes for salmonid habitat degradation and population declines[7], with rare mention of the loss of beaver and their ability to alter aquatic ecosystems with their dam-building activities[8].

Human activities, including the removal of beaver, have exacerbated the occurrence of stream channel incision, where a rapid down-cutting of the stream bed disconnects the channel from its floodplain[8,9]. Channel incision is a ubiquitous environmental problem in the Columbia River Basin and throughout the world[10–12].

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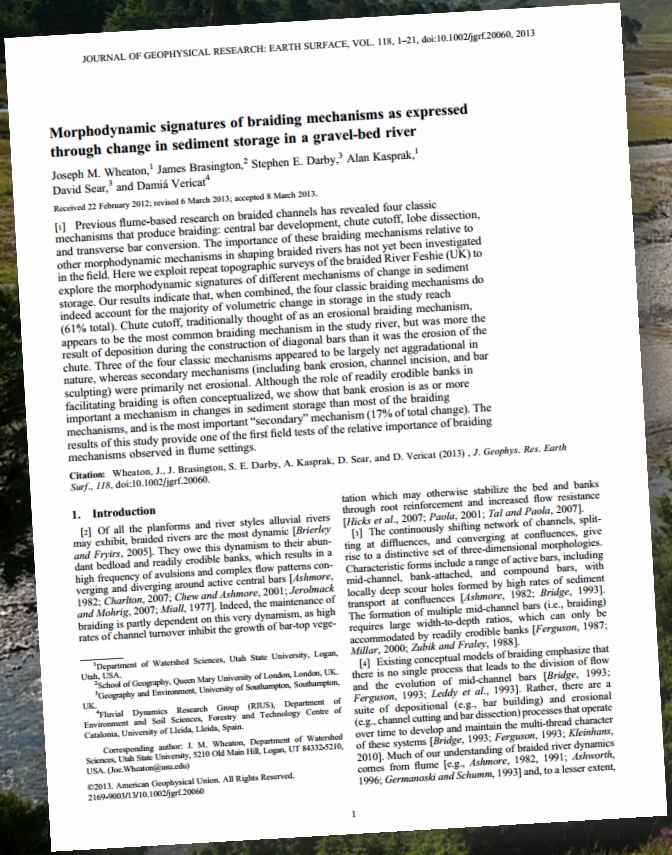
WHAT IS ALL THAT RED AND BLUE?

- How important are braiding mechanisms at explaining change in storage?



JOURNAL OF GEOPHYSICAL RESEARCH: EARTH SURFACE, VOL. 118, 1–21, doi:10.1002/jgrf.20060, 2013

Morphodynamic signatures of braiding mechanisms as expressed through change in sediment storage in a gravel-bed river

Joseph M. Wheaton,[1] James Brasington,[2] Stephen E. Darby,[3] Alan Kasprak,[1] David Sear,[3] and Damiá Vericat[4]

Received 22 February 2012; revised 6 March 2013; accepted 8 March 2013.

[1] Previous flume-based research on braided channels has revealed four classic mechanisms that produce braiding: central bar development, chute cutoff, lobe dissection, and transverse bar conversion. The importance of these braiding mechanisms relative to other morphodynamic mechanisms in shaping braided rivers has not yet been investigated in the field. Here we exploit repeat topographic surveys of the braided River Feshie (UK) to explore the morphodynamic signatures of different mechanisms of change in sediment storage. Our results indicate that, when combined, the four classic braiding mechanisms do indeed account for the majority of volumetric change in storage in the study reach (61% total). Chute cutoff, traditionally thought of as an erosional braiding mechanism, appears to be the most common braiding mechanism in the study river, but was more the result of deposition during the construction of diagonal bars than it was the erosion of the chute. Three of the four classic mechanisms appeared to be largely net aggradational in nature, whereas secondary mechanisms (including bank erosion, channel incision, and bar sculpting) were primarily net erosional. Although the role of readily erodible banks in facilitating braiding is often conceptualized, we show that bank erosion is as or more important a mechanism in changes in sediment storage than most of the braiding mechanisms, and is the most important "secondary" mechanism (17% of total change). The results of this study provide one of the first field tests of the relative importance of braiding mechanisms observed in flume settings.

Citation: Wheaton, J., J. Brasington, S. E. Darby, A. Kasprak, D. Sear, and D. Vericat (2013) , *J. Geophys. Res. Earth Surf.*, *118*, doi:10.1002/jgrf.20060.

1. Introduction

[2] Of all the planforms and river styles alluvial rivers may exhibit, braided rivers are the most dynamic [*Brierley and Fryirs*, 2005]. They owe this dynamism to their abundant bedload and readily erodible banks, which results in a high frequency of avulsions and complex flow patterns converging and diverging around active central bars [*Ashmore*, 1982; *Charlton*, 2007; *Chew and Ashmore*, 2001; *Jerolmack and Mohrig*, 2007; *Miall*, 1977]. Indeed, the maintenance of braiding is partly dependent on this very dynamism, as high rates of channel turnover inhibit the growth of bar-top vegetation which may otherwise stabilize the bed and banks through root reinforcement and increased flow resistance [*Hicks et al.*, 2007; *Paola*, 2001; *Tal and Paola*, 2007].

[3] The continuously shifting network of channels, splitting at diffluences, and converging at confluences, give rise to a distinctive set of three-dimensional morphologies. Characteristic forms include a range of active bars, including mid-channel, bank-attached, and compound bars, with locally deep scour holes formed by high rates of sediment transport at confluences [*Ashmore*, 1982; *Bridge*, 1993]. The formation of multiple mid-channel bars (i.e., braiding) requires large width-to-depth ratios, which can only be accommodated by readily erodible banks [*Ferguson*, 1987; *Millar*, 2000; *Zubik and Fraley*, 1988].

[4] Existing conceptual models of braiding emphasize that there is no single process that leads to the division of flow and the evolution of mid-channel bars [*Bridge*, 1993; *Ferguson*, 1993; *Leddy et al.*, 1993]. Rather, there are a suite of depositional (e.g., bar building) and erosional (e.g., channel cutting and bar dissection) processes that operate over time to develop and maintain the multi-thread character of these systems [*Bridge*, 1993; *Ferguson*, 1993; *Kleinhans*, 2010]. Much of our understanding of braided river dynamics comes from flume [e.g., *Ashmore*, 1982, 1991; *Ashworth*, 1996; *Germanoski and Schumm*, 1993] and, to a lesser extent,

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2169-9003/13/10.1002/jgrf.20060

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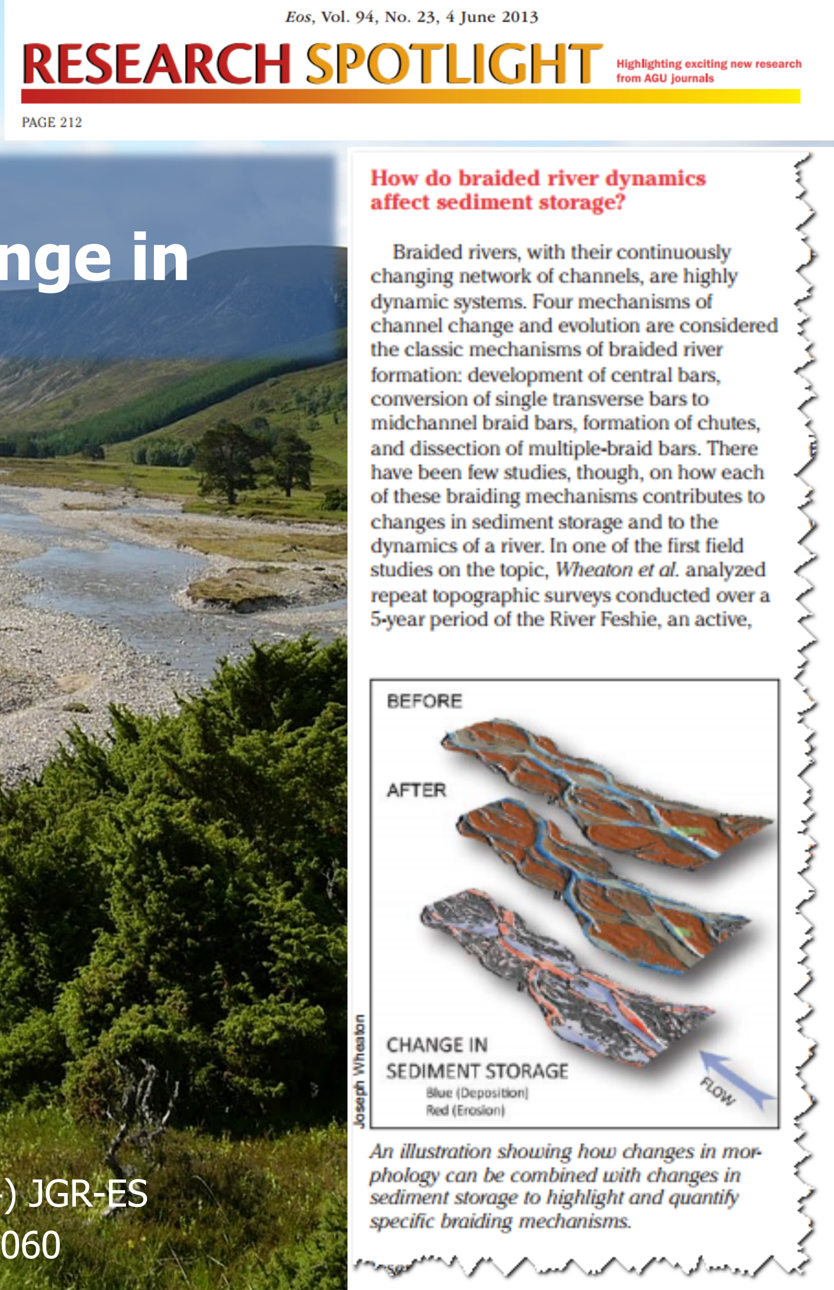
Wheaton et al. (2014) JGR-ES
DOI: 10.1002/jgrf.20060



Eos, Vol. 94, No. 23, 4 June 2013

RESEARCH SPOTLIGHT Highlighting exciting new research from AGU journals

PAGE 212

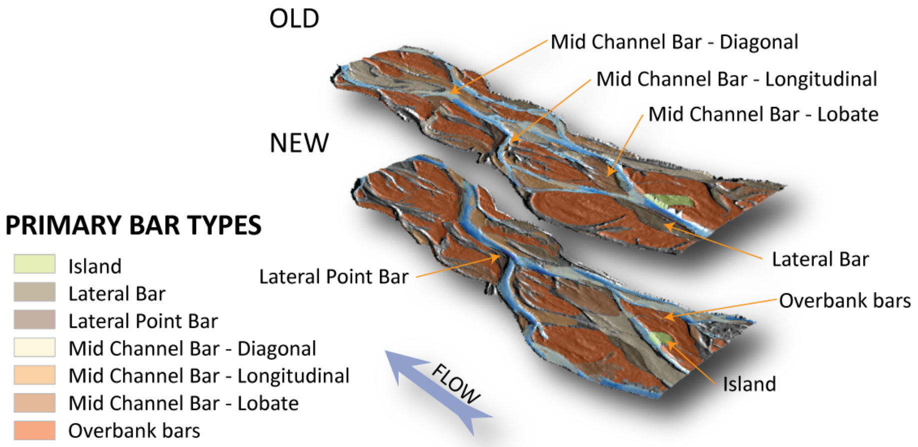
How do braided river dynamics affect sediment storage?

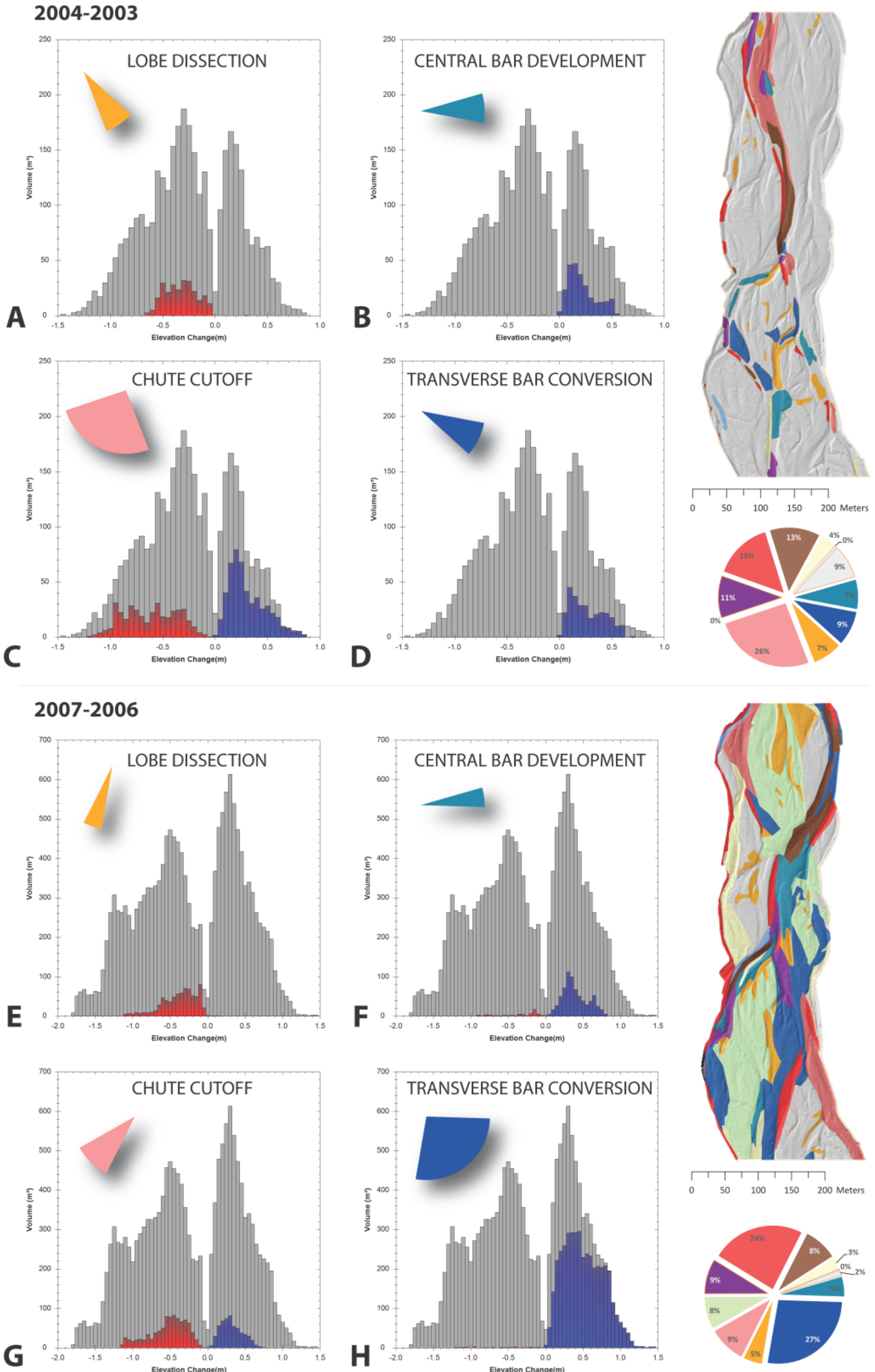
Braided rivers, with their continuously changing network of channels, are highly dynamic systems. Four mechanisms of channel change and evolution are considered the classic mechanisms of braided river formation: development of central bars, conversion of single transverse bars to midchannel braid bars, formation of chutes, and dissection of multiple-braid bars. There have been few studies, though, on how each of these braiding mechanisms contributes to changes in sediment storage and to the dynamics of a river. In one of the first field studies on the topic, *Wheaton et al.* analyzed repeat topographic surveys conducted over a 5-year period of the River Feshie, an active,

An illustration showing how changes in morphology can be combined with changes in sediment storage to highlight and quantify specific braiding mechanisms.

BRAIDING MECHANISMS

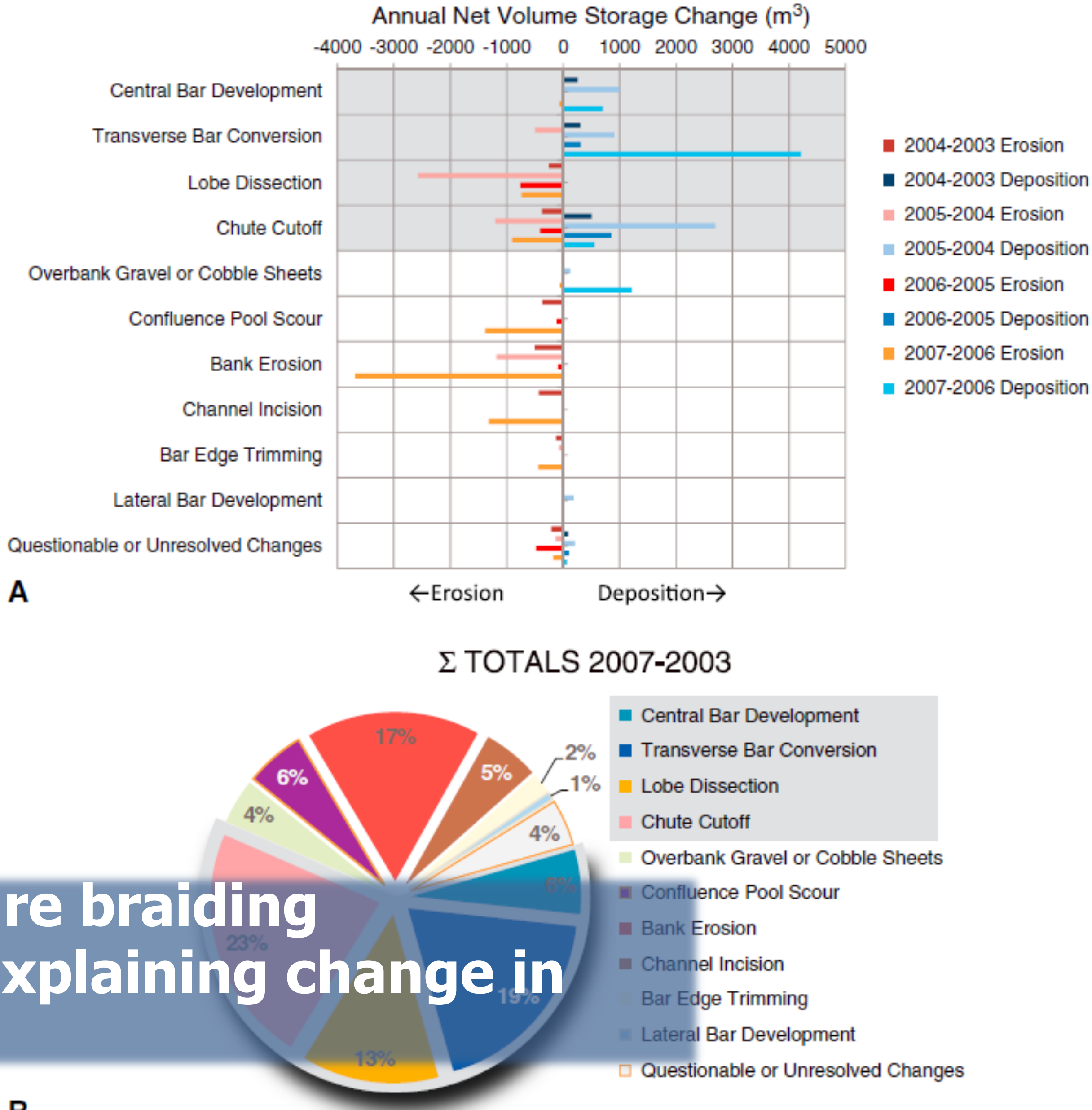
- Four ‘presumed’ key mechanisms from flume studies
- No empirical field tests of their importance
- Under appreciation of importance of bank erosion





ABOUT THOSE BRAIDING MECHANISMS

- Bar building environment not just about deposition!
- Critical importance of erosion to produce local supply!



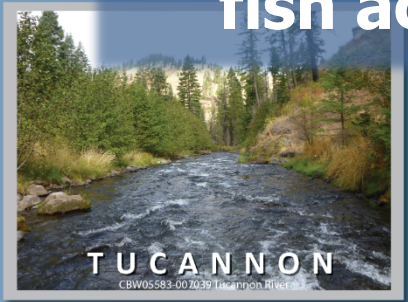
- **How important are braiding mechanisms at explaining change in storage?**

COLUMBIA HABITAT MONITORING PROGRAM
MONITORING SITE LOCATIONS, COLUMBIA RIVER WATERSHED

CHaMP Columbia Habitat Monitoring Program

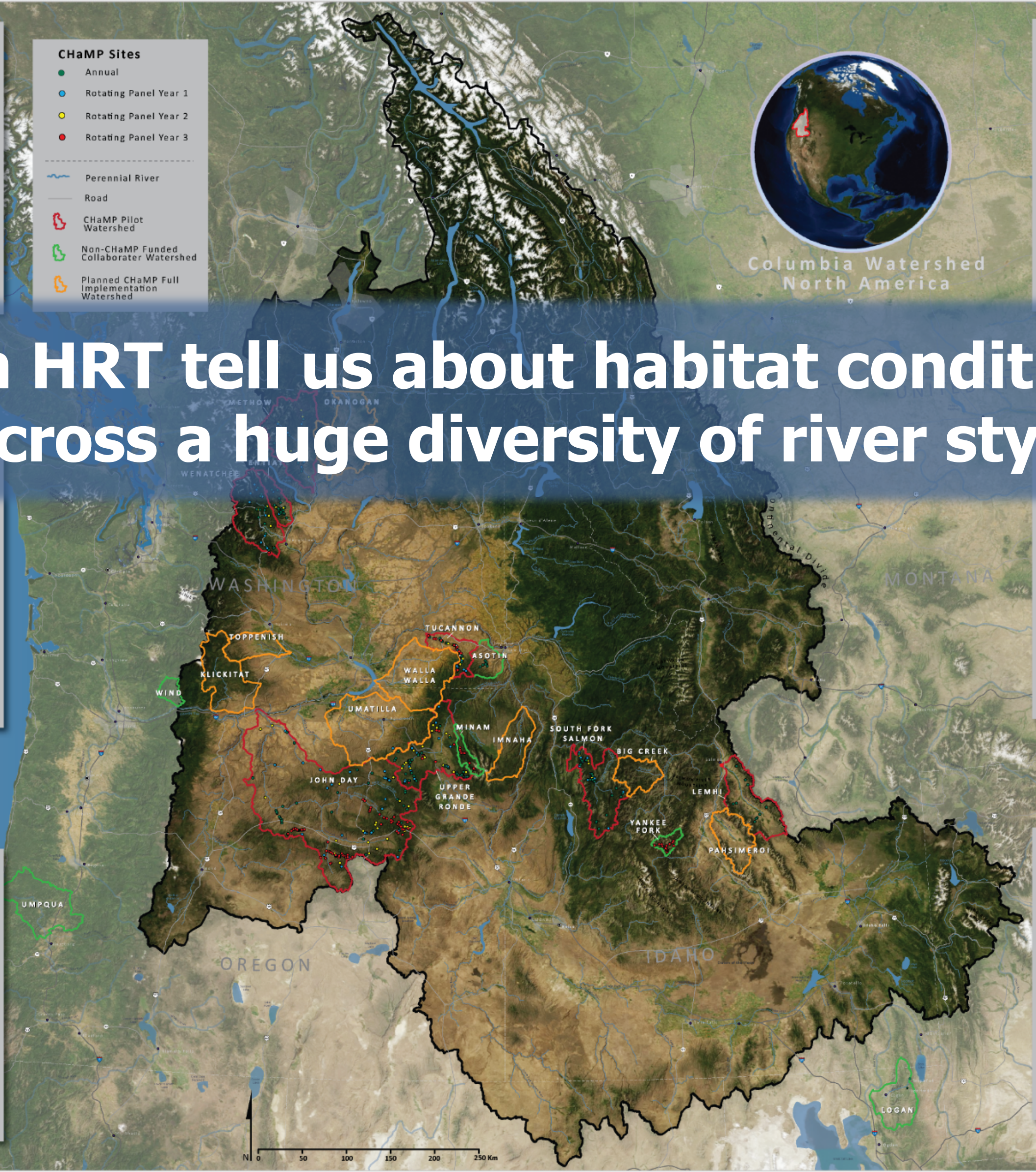
Funding Entities

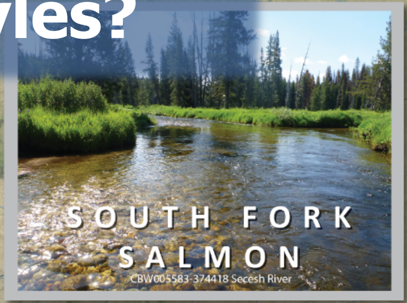
What can HRT tell us about habitat conditions for fish across a huge diversity of river styles?

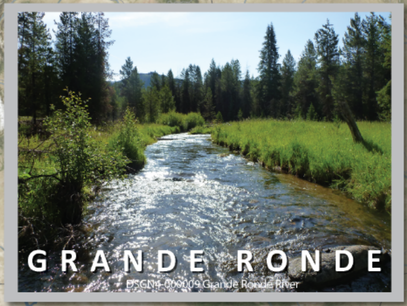


CHaMP Sites

- ● Annual
- ● Rotating Panel Year 1
- ● Rotating Panel Year 2
- ● Rotating Panel Year 3
- Perennial River
- Road
- CHaMP Pilot Watershed
- Non-CHaMP Funded Collaborator Watershed
- Planned CHaMP Full Implementation Watershed







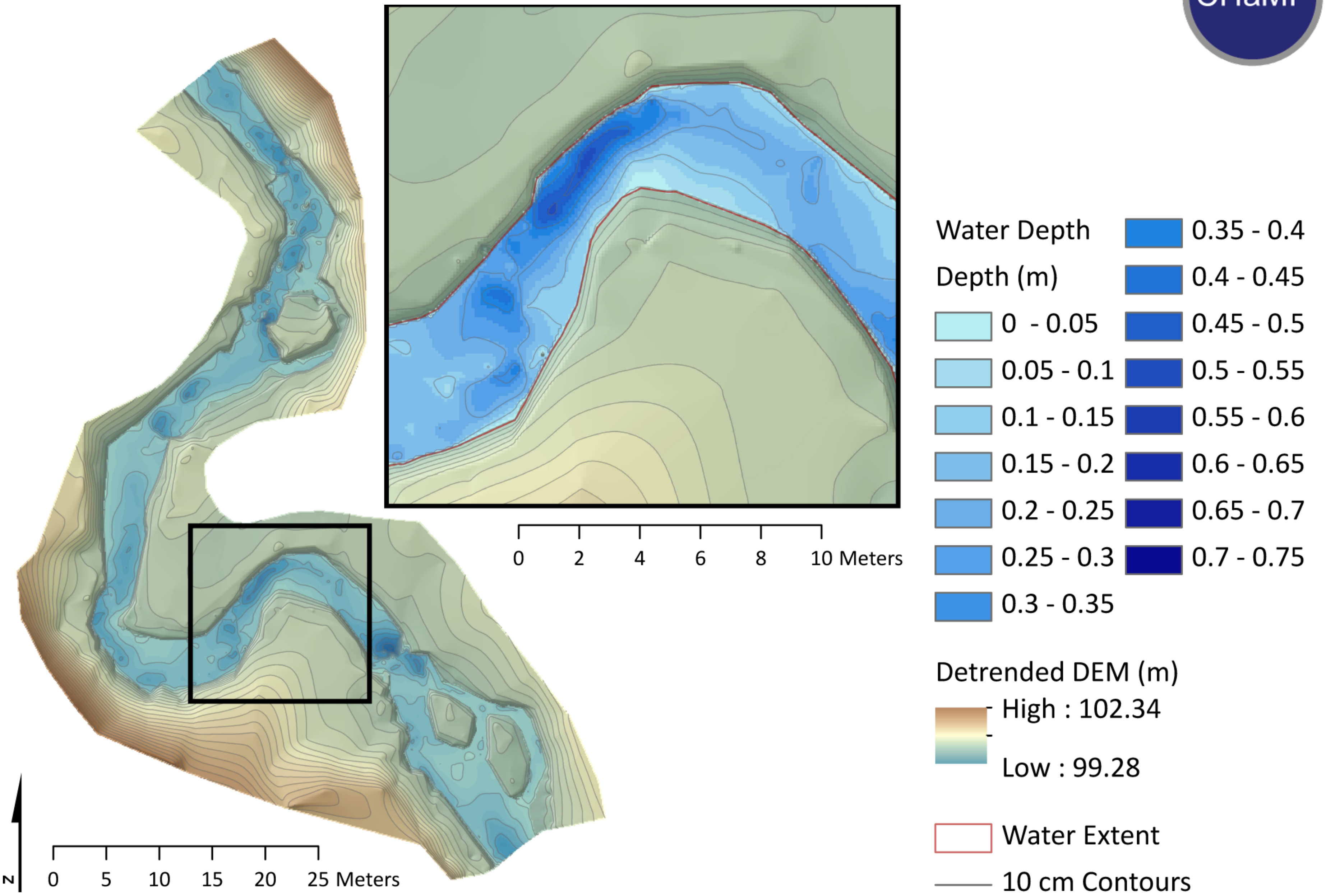
NAD 1927 Albers
Data Sources:
USGS NED 10m Digital Elevation Model
ESRI Imagery
Natural Earth

Development Team: Eco Logical Research, Inc. Utah State University Ecogeomorphology & Topographic Analysis Laboratory FHC The Fluvial Habitats Center QCInc. sitka Watershed Solutions Inc

Other Collaborators: OSU Oregon State

champmonitoring.org
Map created by Martha Jensen, USU ET-AL

A TYPICAL CHaMP TOPO SURVEY



CHaMP TOPO SANDBOX

CHaMP Columbia Habitat Monitoring Program

BONNEVILLE POWER ADMINISTRATION

Pilot Phase

- 11 Watersheds throughout the Columbia Basin
- Roughly 45-55 sites in each basin (10-15 annual): 950 Total
- 5500 individual surveys

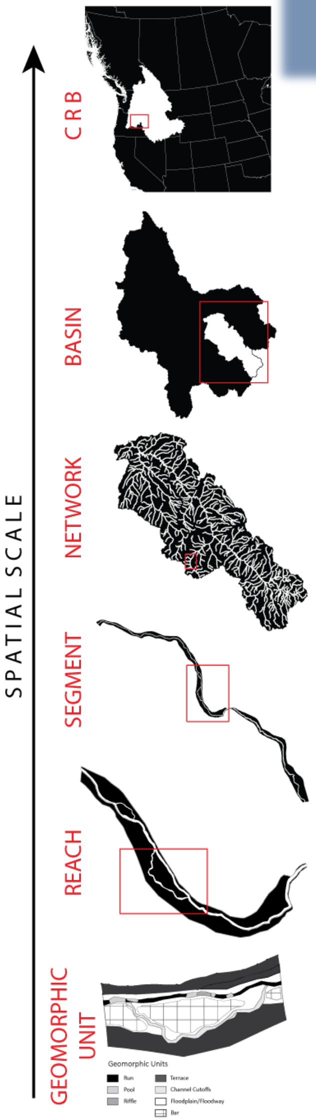
Map by Martha Jensen

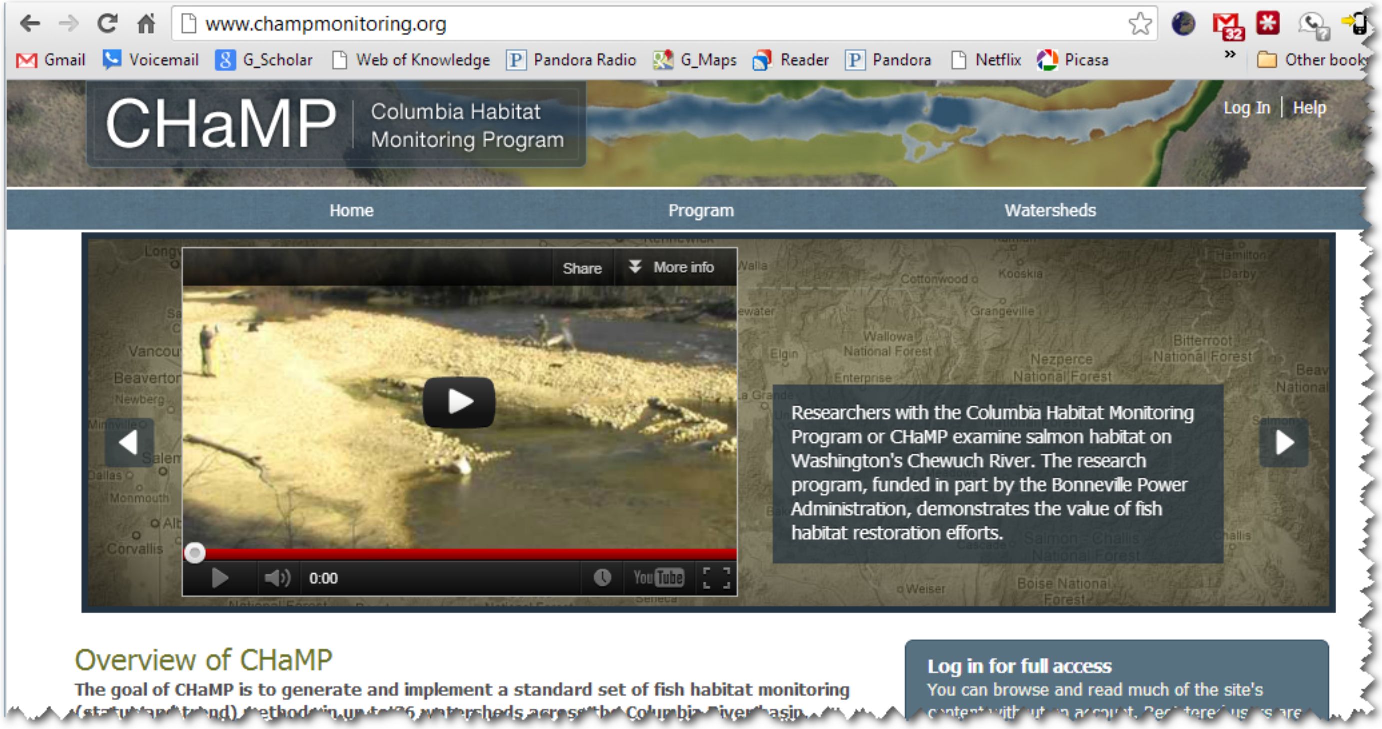
See http://champmonitoring.org

UtahStateUniversity

WHAT WILL GCD x 5000 TELL US WE DID NOT KNOW?

BEST EXPERIMENTAL OPPORTUNITY FOR HYPOTHESIS TESTING ACROSS SCALES YET….





Researchers with the Columbia Habitat Monitoring Program or CHaMP examine salmon habitat on Washington's Chewuch River. The research program, funded in part by the Bonneville Power Administration, demonstrates the value of fish habitat restoration efforts.

Overview of CHaMP

The goal of CHaMP is to generate and implement a standard set of fish habitat monitoring

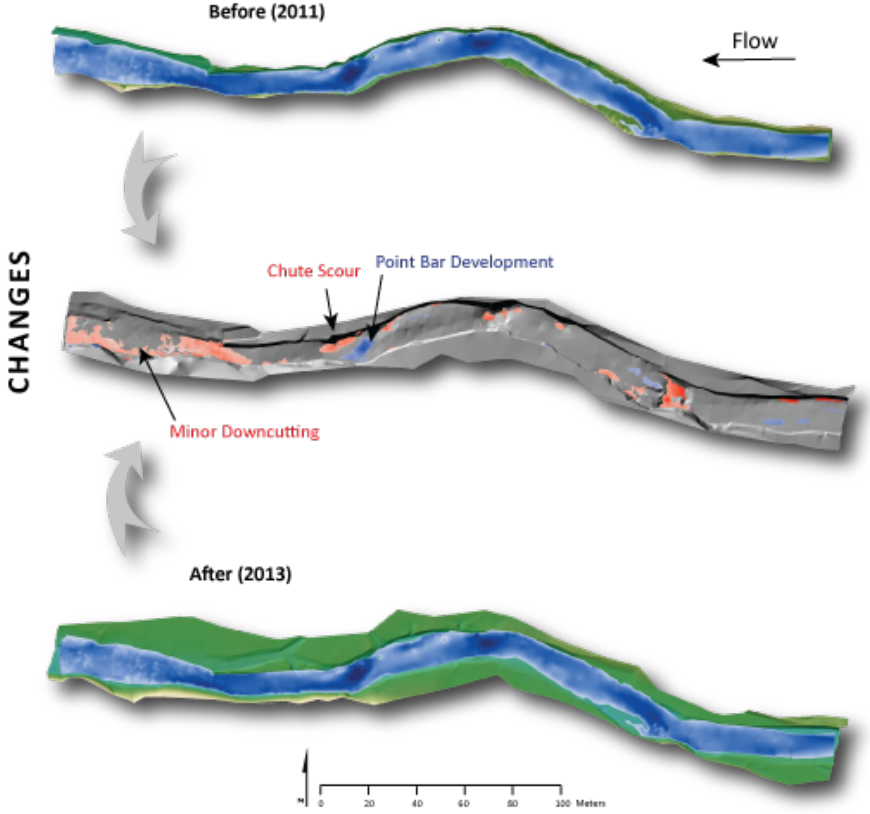
Log in for full access

You can browse and read much of the site's

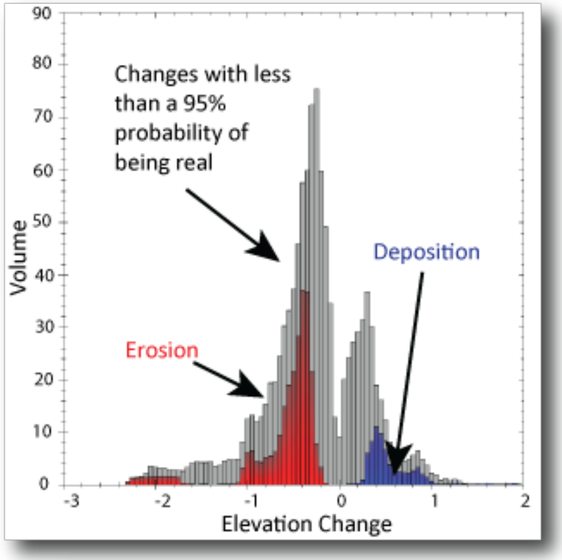
- http://champmonitoring.org
- TS topographic & habitat surveys…

GCD TO DESCRIBE BEHAVIOR… IN A POOR CONDITION VARIANT

DYNAMIC RIVER BEHAVIOR
CHANGES CAPTURED WITH CHaMP

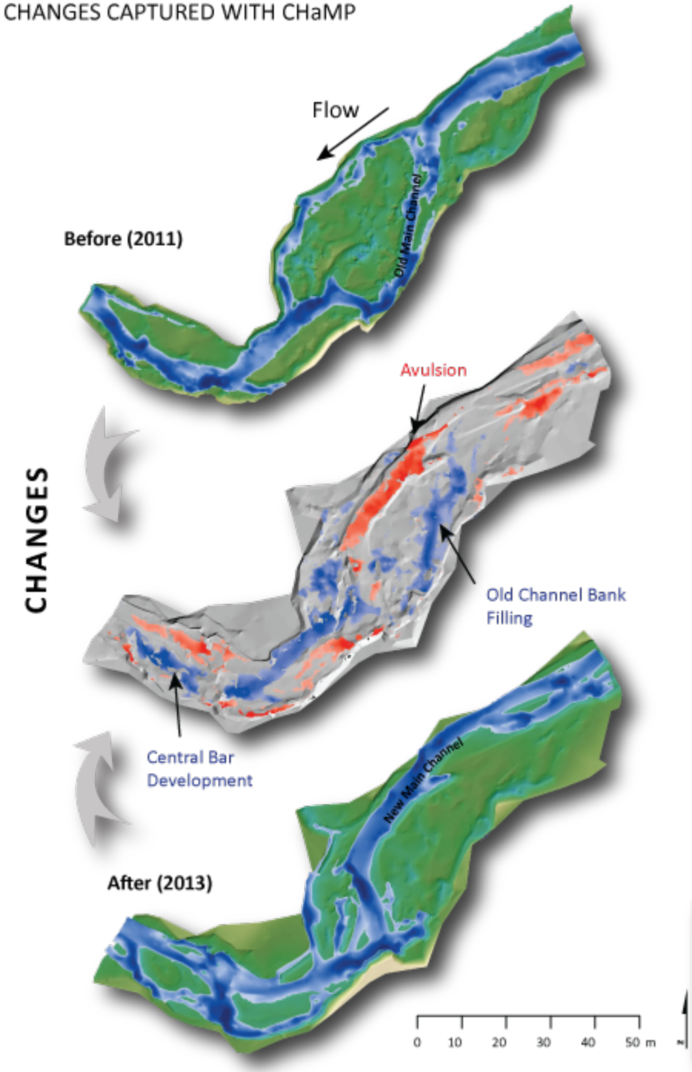


Champ Site: Tucannon River, WA ID: CBW05583-386091

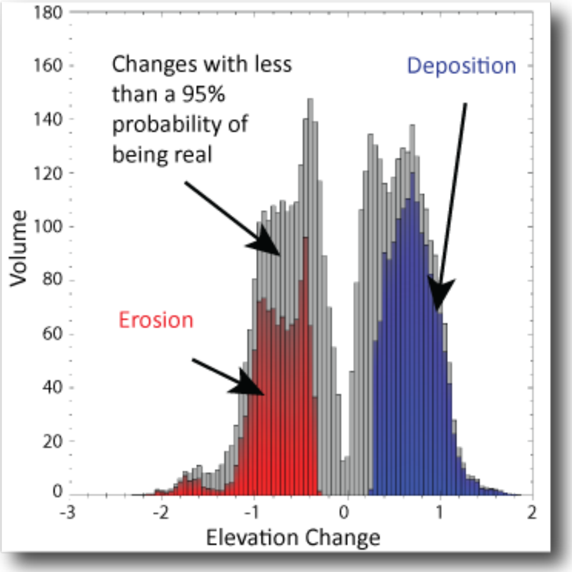


GCD TO DESCRIBE BEHAVIOR… IN A GOOD CONDITION VARIANT

DYNAMIC RIVER BEHAVIOR
CHANGES CAPTURED WITH CHaMP



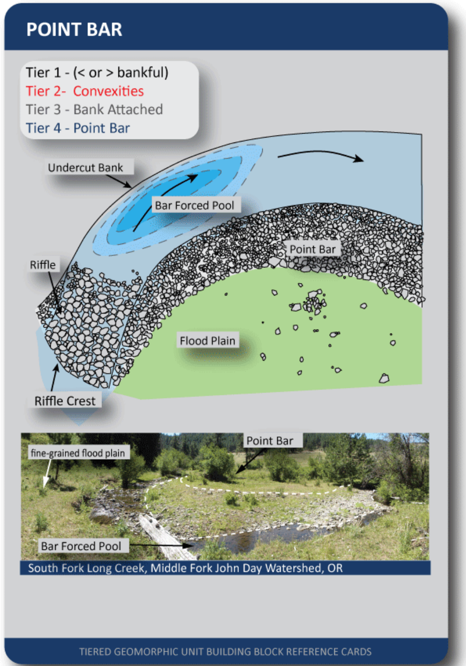
Champ Site: Tucannon River, WA ID: CBW05583-481459



WHAT CAN HRT TELL US ABOUT BUILDING BLOCKS OF RIVERS?

What characteristic assemblages of geomorphic units exist?

What gives rise to heterogeneity versus homogeneity in the building blocks of a riverscape?

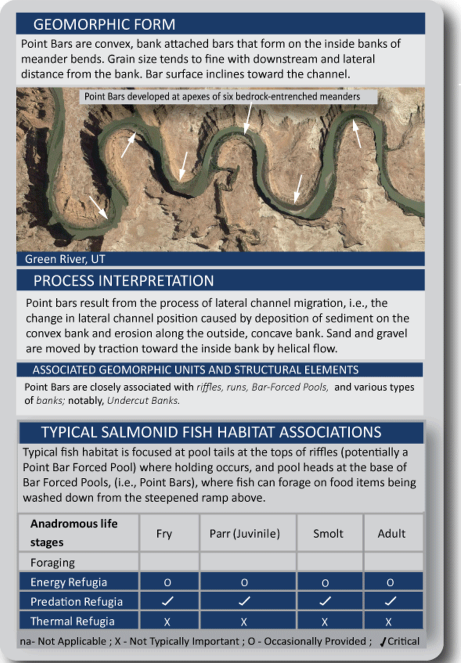


POINT BAR

Tier 1 - (< or > bankful)
Tier 2- Convexities
Tier 3 - Bank Attached
Tier 4 - Point Bar

South Fork Long Creek, Middle Fork John Day Watershed, OR

TIERED GEOMORPHIC UNIT BUILDING BLOCK REFERENCE CARDS



GEOMORPHIC FORM

Point Bars are convex, bank attached bars that form on the inside banks of meander bends. Grain size tends to fine with downstream and lateral distance from the bank. Bar surface inclines toward the channel.

Green River, UT

PROCESS INTERPRETATION

Point bars result from the process of lateral channel migration, i.e., the change in lateral channel position caused by deposition of sediment on the convex bank and erosion along the outside, concave bank. Sand and gravel are moved by traction toward the inside bank by helical flow.

ASSOCIATED GEOMORPHIC UNITS AND STRUCTURAL ELEMENTS

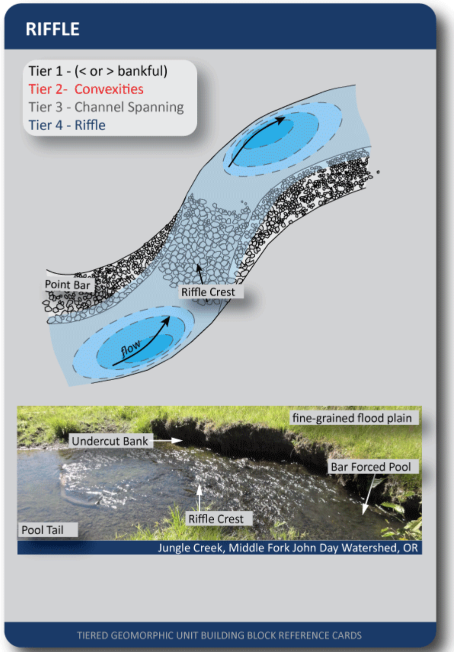
Point Bars are closely associated with *riffles, runs, Bar-Forced Pools,* and various types of *banks;* notably, *Undercut Banks.*

TYPICAL SALMONID FISH HABITAT ASSOCIATIONS

Typical fish habitat is focused at pool tails at the tops of riffles (potentially a Point Bar Forced Pool) where holding occurs, and pool heads at the base of Bar Forced Pools, (i.e., Point Bars), where fish can forage on food items being washed down from the steepened ramp above.

Anadromous life stages	Fry	Parr (Juvinile)	Smolt	Adult
Foraging				
Energy Refugia	O	O	O	O
Predation Refugia	✓	✓	✓	✓
Thermal Refugia	X	X	X	X

na- Not Applicable ; X - Not Typically Important ; O - Occasionally Provided ; ✓Critical

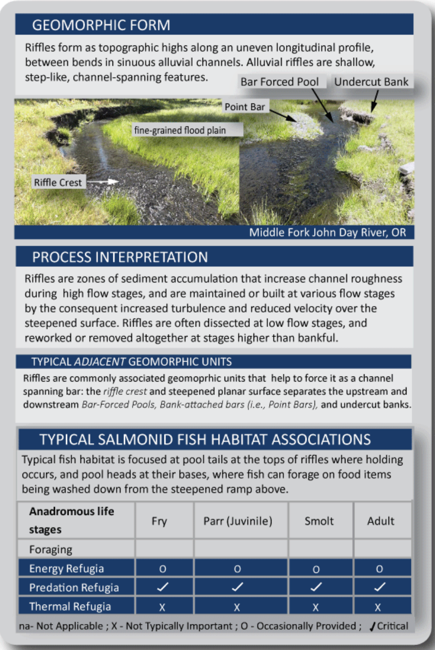


RIFFLE

Tier 1 - (< or > bankful)
Tier 2- Convexities
Tier 3 - Channel Spanning
Tier 4 - Riffle

Jungle Creek, Middle Fork John Day Watershed, OR

TIERED GEOMORPHIC UNIT BUILDING BLOCK REFERENCE CARDS



GEOMORPHIC FORM

Riffles form as topographic highs along an uneven longitudinal profile, between bends in sinuous alluvial channels. Alluvial riffles are shallow, step-like, channel-spanning features.

Middle Fork John Day River, OR

PROCESS INTERPRETATION

Riffles are zones of sediment accumulation that increase channel roughness during high flow stages, and are maintained or built at various flow stages by the consequent increased turbulence and reduced velocity over the steepened surface. Riffles are often dissected at low flow stages, and reworked or removed altogether at stages higher than bankful.

TYPICAL *ADJACENT* GEOMORPHIC UNITS

Riffles are commonly associated geomoprhic units that help to force it as a channel spanning bar: the *riffle crest* and steepened planar surface separates the upstream and downstream *Bar-Forced Pools, Bank-attached bars (i.e., Point Bars),* and undercut banks.

TYPICAL SALMONID FISH HABITAT ASSOCIATIONS

Typical fish habitat is focused at pool tails at the tops of riffles where holding occurs, and pool heads at their bases, where fish can forage on food items being washed down from the steepened ramp above.

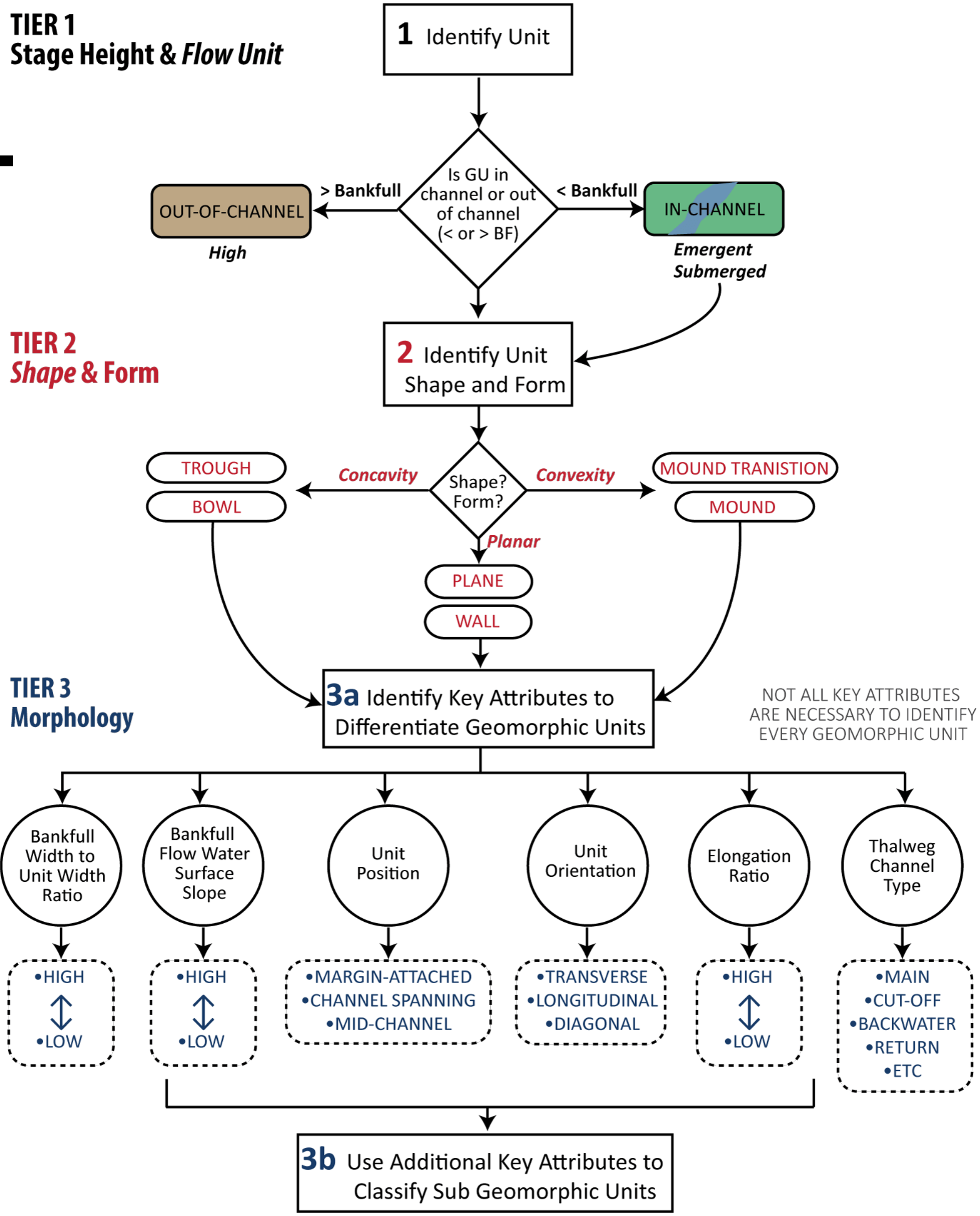
Anadromous life stages	Fry	Parr (Juvinile)	Smolt	Adult
Foraging				
Energy Refugia	O	O	O	O
Predation Refugia	✓	✓	✓	✓
Thermal Refugia	X	X	X	X

na- Not Applicable ; X - Not Typically Important ; O - Occasionally Provided ; ✓Critical

TAXONOMY FOR MAPPING FLUVIAL LANDFORMS

- Four Tiers
  - Stage Height
  - Shape / Form
  - Morphology
  - Roughness/Vegetation
- Over 100 fluvial geomorphic units found in literature, of which 68 are distinctive (3b)
- Clearer, *topographically* based definitions

GUT: Geomorphic Unit Toolkit:
https://riverscapes.github.io/pyGUT/



TIER 1
Stage Height & *Flow Unit*

1 Identify Unit

Is GU in channel or out of channel (< or > BF)

> Bankfull
OUT-OF-CHANNEL
High

< Bankfull
IN-CHANNEL
Emergent
Submerged

TIER 2
***Shape* & Form**

2 Identify Unit Shape and Form

Shape? Form?

Concavity
TROUGH
BOWL

Convexity
MOUND TRANISTION
MOUND

Planar
PLANE
WALL

TIER 3
Morphology

3a Identify Key Attributes to Differentiate Geomorphic Units

NOT ALL KEY ATTRIBUTES ARE NECESSARY TO IDENTIFY EVERY GEOMORPHIC UNIT

Bankfull Width to Unit Width Ratio
- •HIGH ↕ •LOW

Bankfull Flow Water Surface Slope
- •HIGH ↕ •LOW

Unit Position
- •MARGIN-ATTACHED
- •CHANNEL SPANNING
- •MID-CHANNEL

Unit Orientation
- •TRANSVERSE
- •LONGITUDINAL
- •DIAGONAL

Elongation Ratio
- •HIGH ↕ •LOW

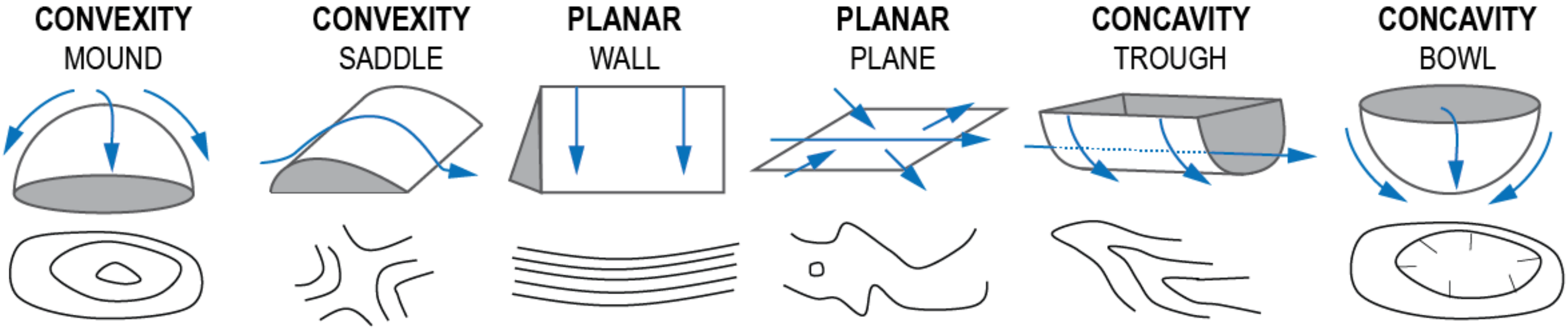
Thalweg Channel Type
- •MAIN
- •CUT-OFF
- •BACKWATER
- •RETURN
- •ETC

3b Use Additional Key Attributes to Classify Sub Geomorphic Units

From: https://riverscapes.github.io/pyGUT/
Wheaton et al. (2015) – Geomorphology; DOI: 10.1016/j.geomorph.2015.07.010

TIER 2 - FORM

- Differentiating shape longitudinally (i.e. stream-wise), vs. laterally (i.e. cross sectional)



Bars

Riffles

Banks/
Avalanche Faces
Edges

Plane
Bed

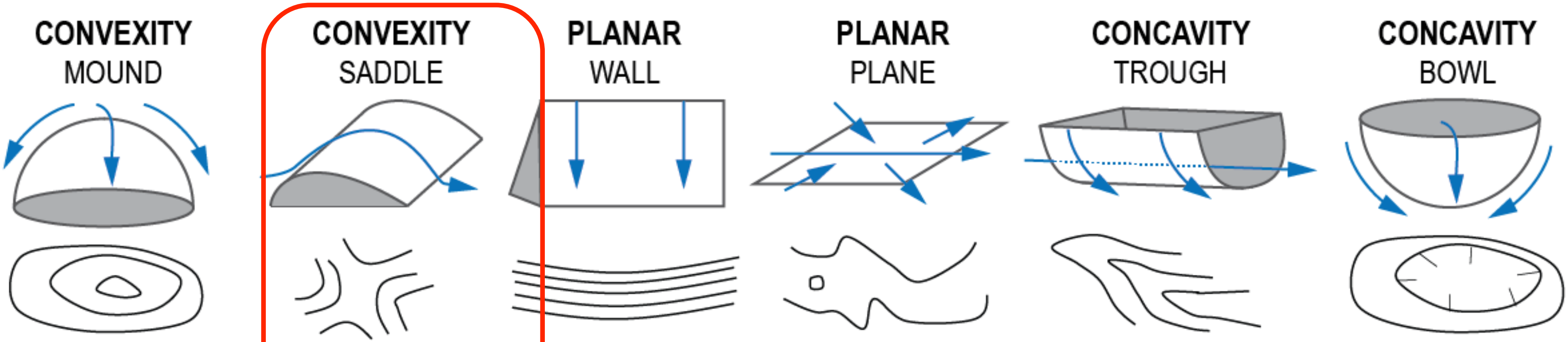
Chutes

Pools

	Mound	Saddle	Wall	Plane	Trough	Bowl
XS	Convex	Concave	NA	Planar	Concave	Concave
LP	Convex	Convex	NA	Planar	Planar	Concave

TIER 2 - FORM

- Key for the riffle… is the thalweg…
- Flow goes up and over (convex), through the thalweg (concave)



Bars

Riffles

Banks/ Avalanche Faces Edges

Plane Bed

Chutes

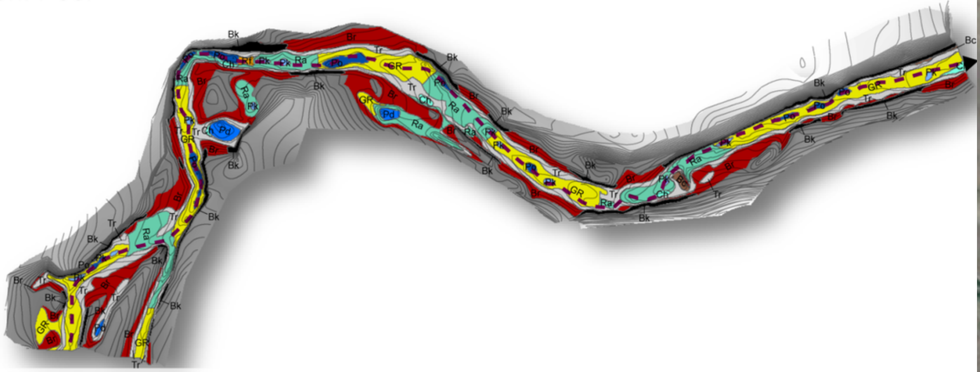
Pools

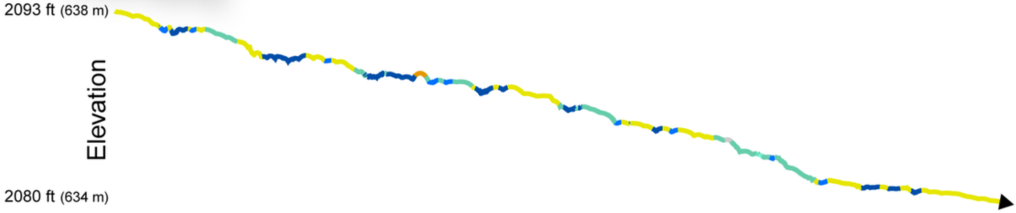
	Mound	Saddle	Wall	Plane	Trough	Bowl
XS	Convex	Concave	NA	Planar	Concave	Concave
LP	Convex	Convex	NA	Planar	Planar	Concave

South Fork Asotin Creek: Planformed Controlled with Discontinuous Floodplain

Latitude: 46.2486
Longitude: -117.2

Condition: Poor





Geomorphic Units - Tier 3

IN-CHANNEL

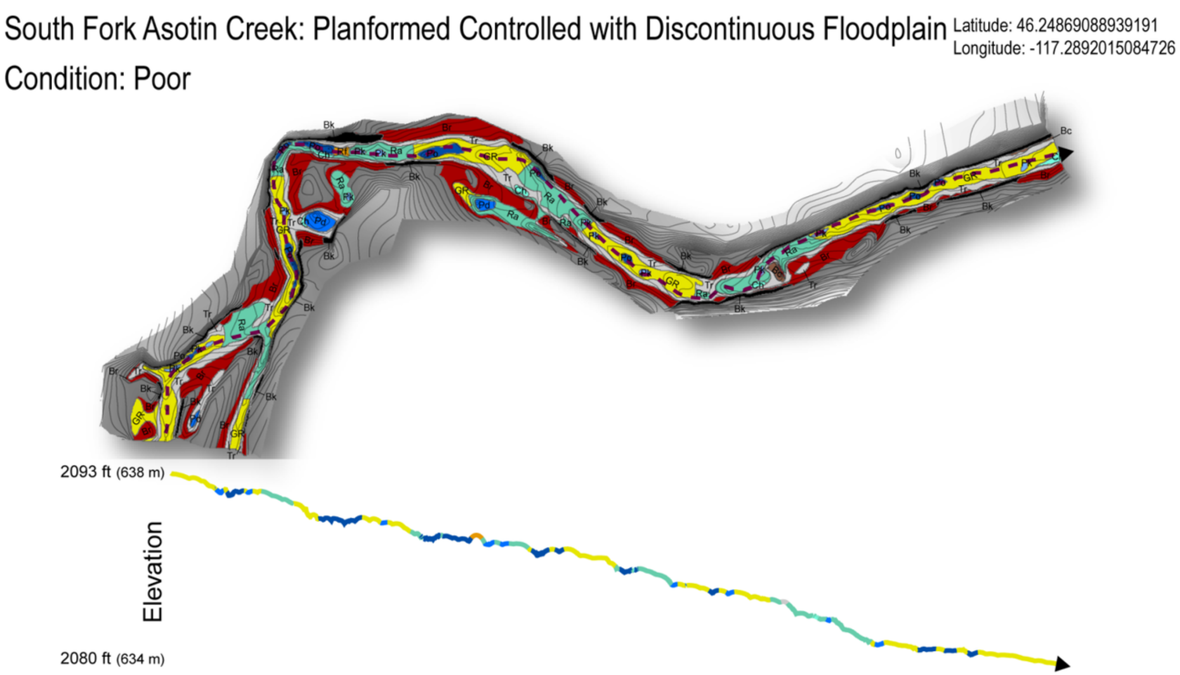
Concavities (e.g. Pools)
- Chute (Ch)
- Pocket Pool (Pk)
- Pond (Pd)
- Pool (Po)

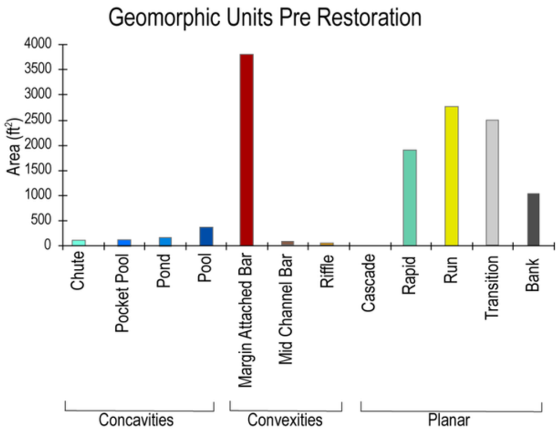
Convexities (e.g. Bars)
- Margin Attached Bar (Br)
- Mid-Channel Bar (Bc)
- Riffle (Rf)

Planar Features
- Cascade (Ca)
- Rapid (Ra)
- Run (GR)
- Transition Zones (Tr)
- Bank (Bk)

Channel Features
- Thalweg
- Old Thalweg

Structural Elements
- LWD





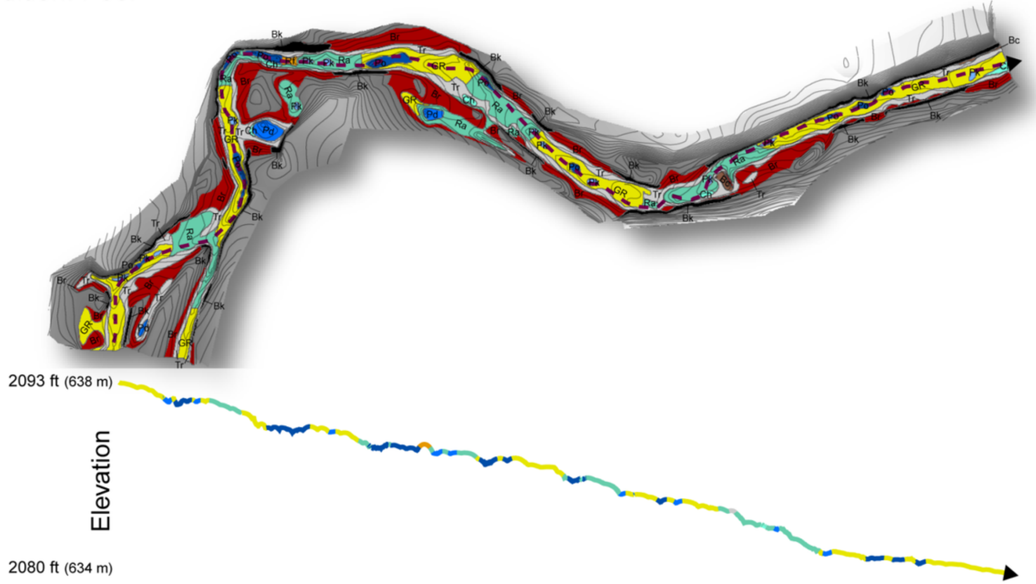
- Plane bed dominated (rapids & runs)
- Starved of wood..
- Limited interaction with floodplain

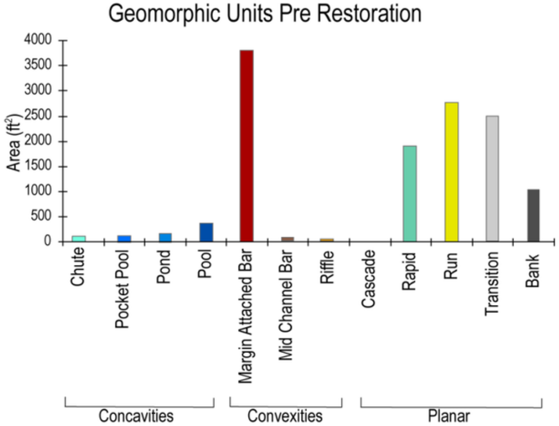
ADDING P.A.L.S. (WOOD)

South Fork Asotin Creek: Planformed Controlled with Discontinuous Floodplain

Latitude: 46.24869088939191
Longitude: -117.2892015084726

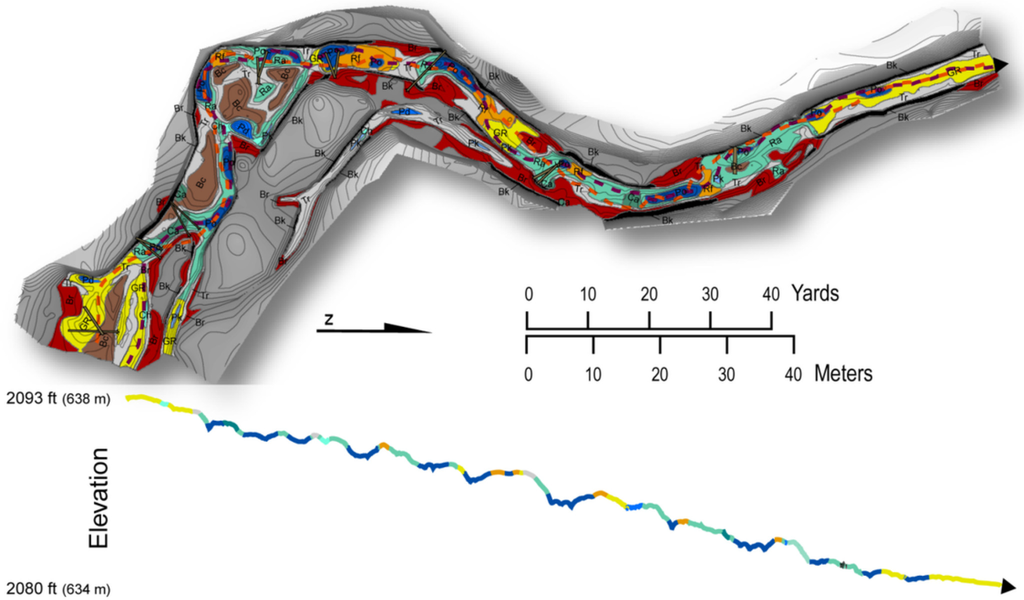
Condition: Poor

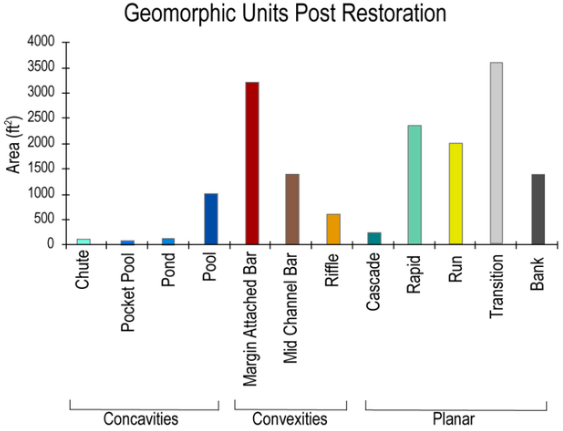



Geomorphic Units Pre Restoration

HDLWD

Condition: Moderate




Geomorphic Units Post Restoration

Geomorphic Units - Tier 3

IN-CHANNEL

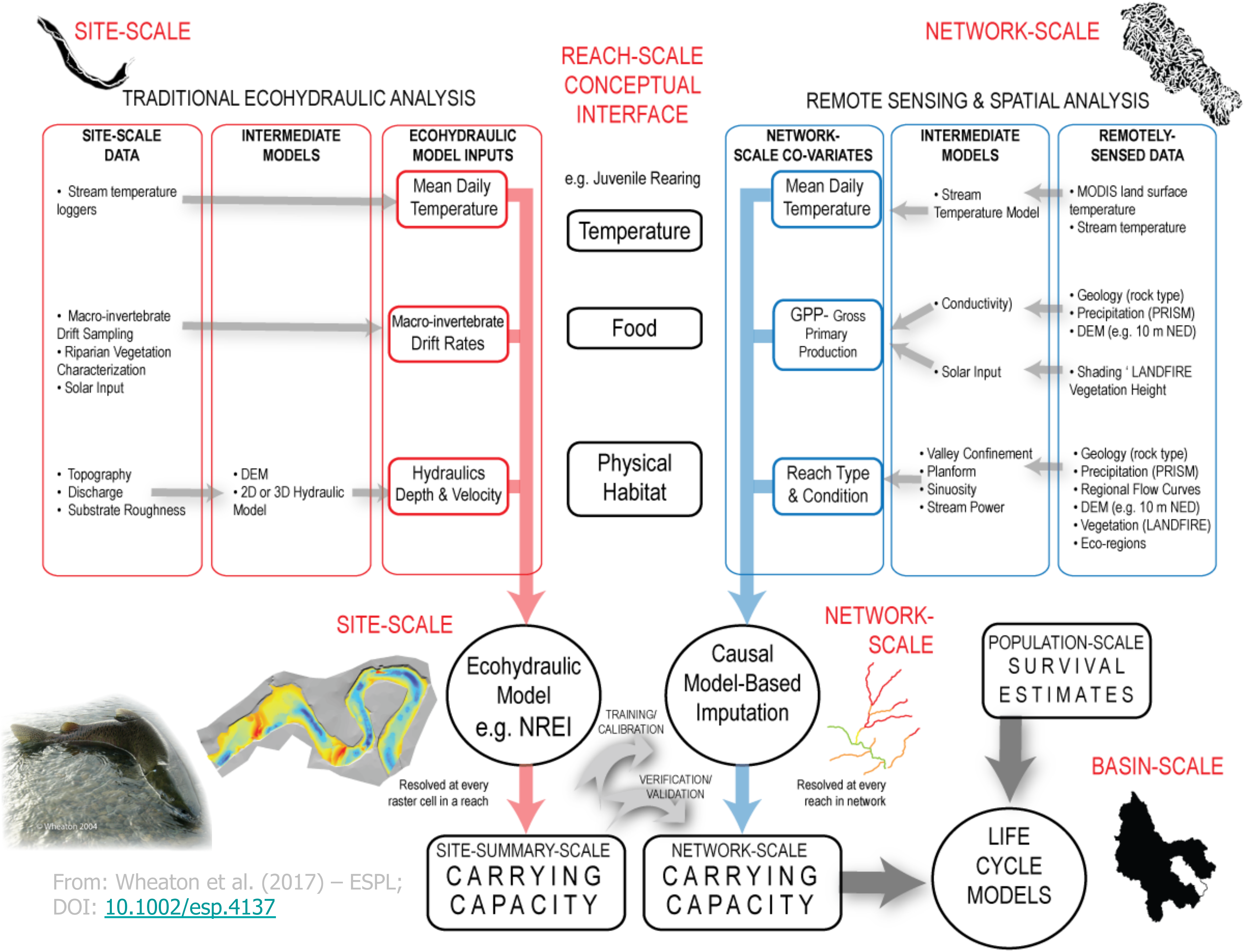
Concavities (e.g. Pools)
- Chute (Ch)
- Pocket Pool (Pk)
- Pond (Pd)
- Pool (Po)

Convexities (e.g. Bars)
- Margin Attached Bar (Br)
- Mid-Channel Bar (Bc)
- Riffle (Rf)

Planar Features
- Cascade (Ca)
- Rapid (Ra)
- Run (GR)
- Transition Zones (Tr)
- Bank (Bk)

Channel Features
- Thalweg
- Old Thalweg

Structural Elements
- LWD



SITE-SCALE

TRADITIONAL ECOHYDRAULIC ANALYSIS

SITE-SCALE DATA

- Stream temperature loggers
- Macro-invertebrate Drift Sampling
- Riparian Vegetation Characterization
- Solar Input
- Topography
- Discharge
- Substrate Roughness

INTERMEDIATE MODELS

- DEM
- 2D or 3D Hydraulic Model

ECOHYDRAULIC MODEL INPUTS

Mean Daily Temperature

Macro-invertebrate Drift Rates

Hydraulics Depth & Velocity

REACH-SCALE CONCEPTUAL INTERFACE

e.g. Juvenile Rearing

Temperature

Food

Physical Habitat

NETWORK-SCALE

REMOTE SENSING & SPATIAL ANALYSIS

NETWORK-SCALE CO-VARIATES

Mean Daily Temperature

GPP- Gross Primary Production

Reach Type & Condition

INTERMEDIATE MODELS

- Stream Temperature Model
- Conductivity)
- Solar Input
- Valley Confinement
- Planform
- Sinuosity
- Stream Power

REMOTELY-SENSED DATA

- MODIS land surface temperature
- Stream temperature
- Geology (rock type)
- Precipitation (PRISM)
- DEM (e.g. 10 m NED)
- Shading ' LANDFIRE Vegetation Height
- Geology (rock type)
- Precipitation (PRISM)
- Regional Flow Curves
- DEM (e.g. 10 m NED)
- Vegetation (LANDFIRE)
- Eco-regions

SITE-SCALE

Ecohydraulic Model e.g. NREI

Resolved at every raster cell in a reach

© Wheaton 2004

TRAINING/ CALIBRATION

VERIFICATION/ VALIDATION

Causal Model-Based Imputation

NETWORK-SCALE

Resolved at every reach in network

POPULATION-SCALE SURVIVAL ESTIMATES

BASIN-SCALE

SITE-SUMMARY-SCALE CARRYING CAPACITY

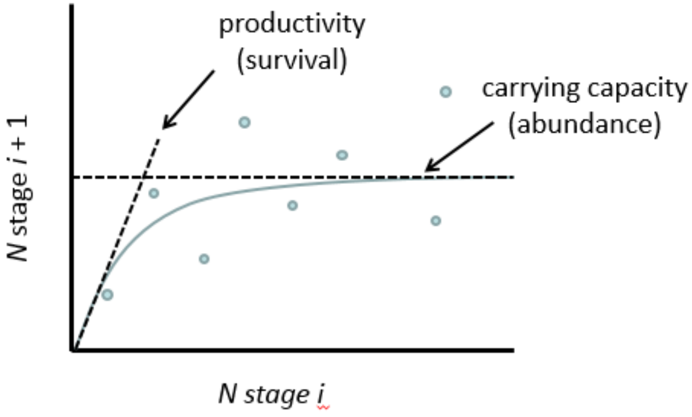
NETWORK-SCALE CARRYING CAPACITY

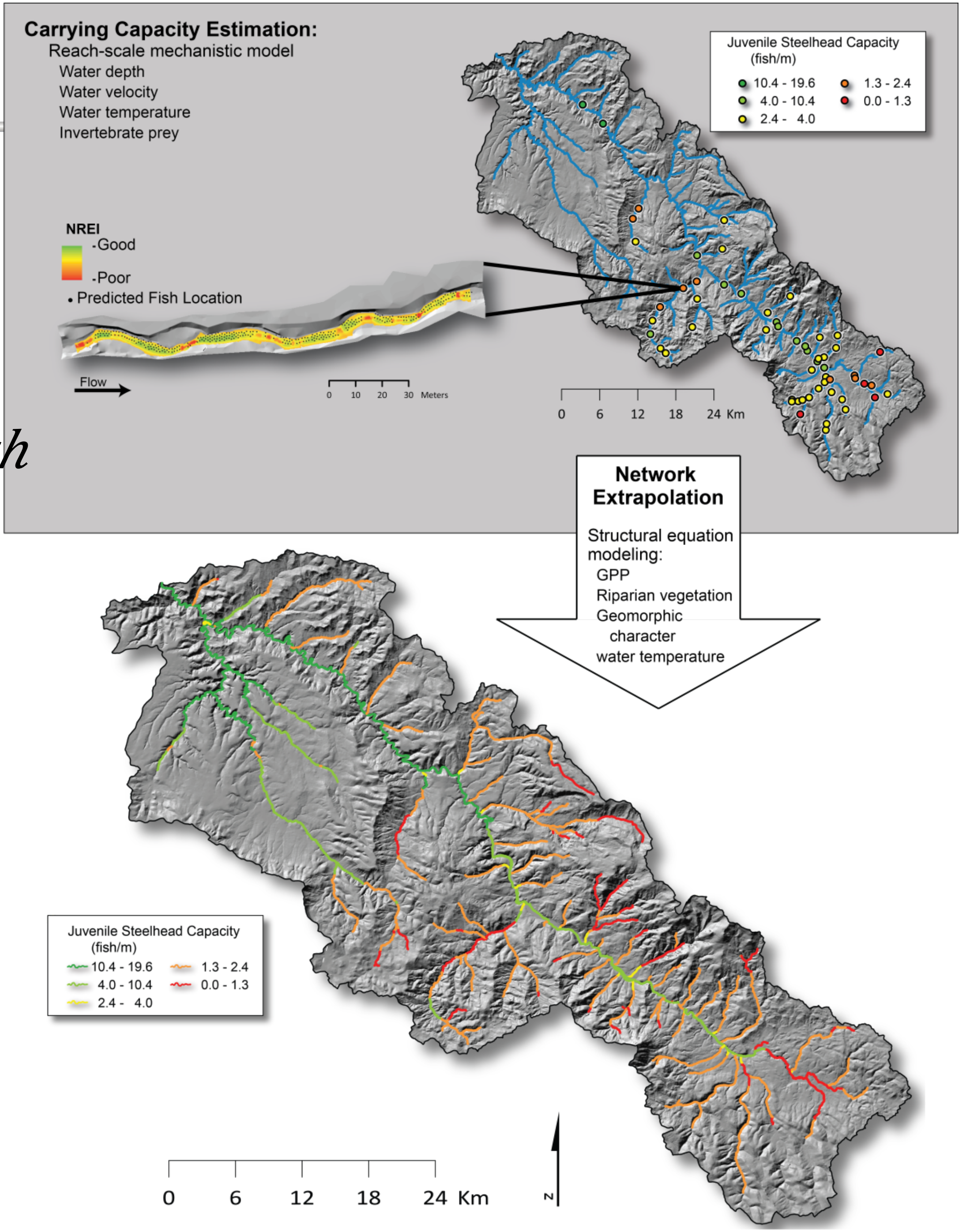
LIFE CYCLE MODELS

From: Wheaton et al. (2017) – ESPL; DOI: 10.1002/esp.4137

NETWORK MODEL OF CARRYING CAPACITY

$$\sum_{\text{Each Reach}} \text{Capacity}$$





Carrying Capacity Estimation:

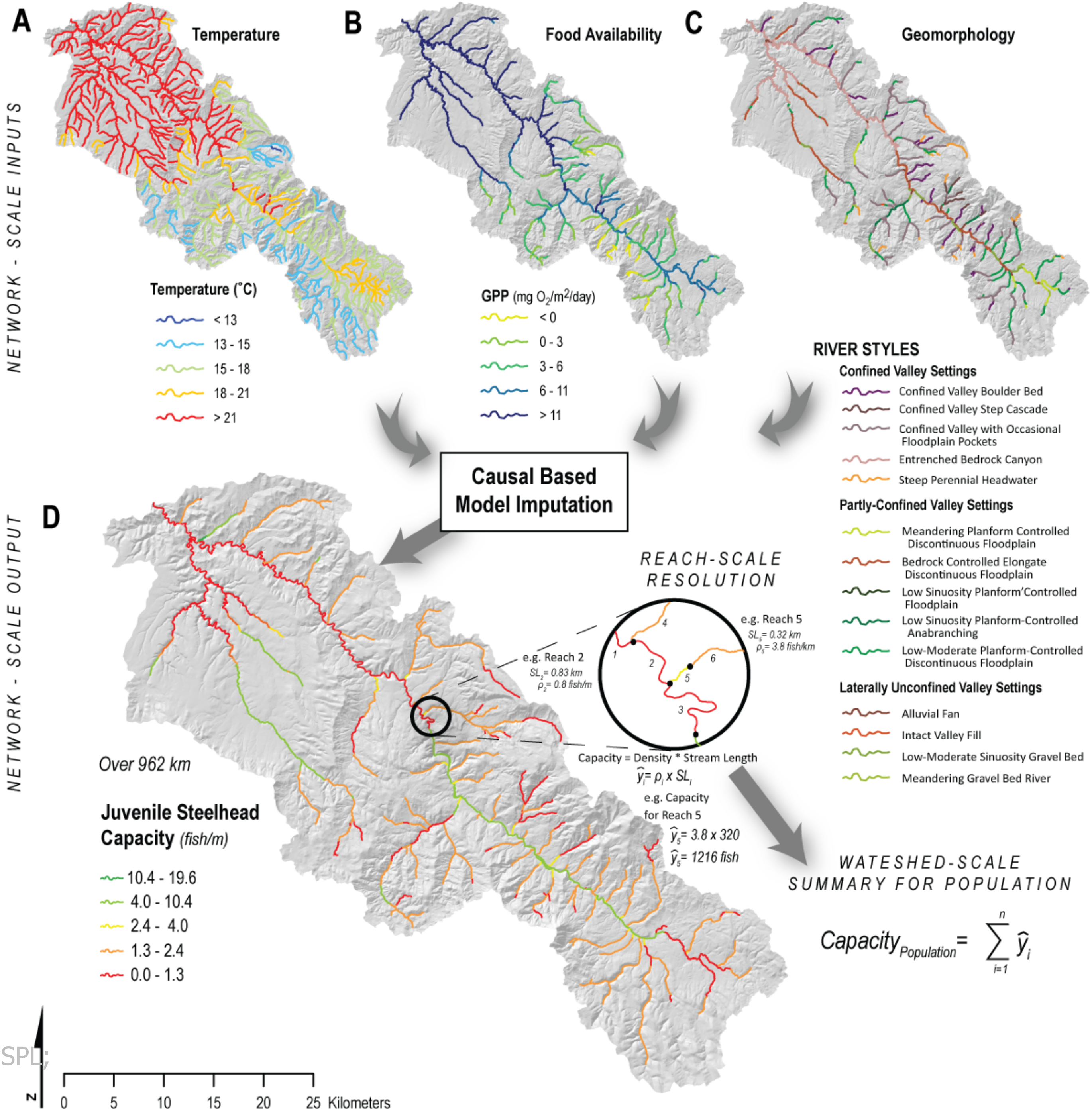
Reach-scale mechanistic model
- Water depth
- Water velocity
- Water temperature
- Invertebrate prey

Network Extrapolation

Structural equation modeling:
- GPP
- Riparian vegetation
- Geomorphic character
- water temperature

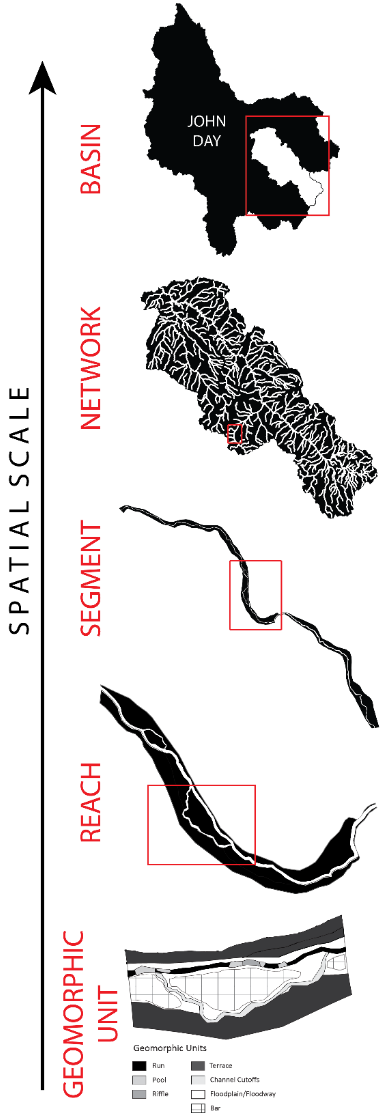
MAGIC STEP

- Imputation
- This step is one of our biggest development hurdles…
- Can we predict site level summary from network level output?



From: Wheaton et al. (2017) – ESPL; DOI: 10.1002/esp.4137

GEOMORPHIC UNIT IS NEXUS
& HRT GOT IS THERE

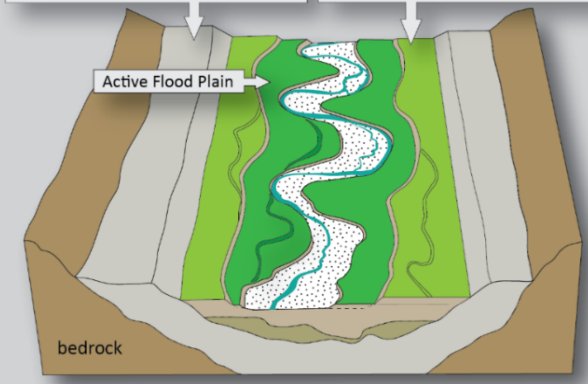


ABANDONED FLOOD PLAIN (TERRACE)

Tier 1 - (< or > bankful)
Tier 2- Active Flood plain
Tier 3 - Bank Attached
Tier 4 - Floodplain

Abandoned Floodplain (Terrace)
-coarse grained, older, valley fill

Abandoned Floodplain (Terrace)
Fine-grained, younger inset deposit



GEOMORPHIC FORM

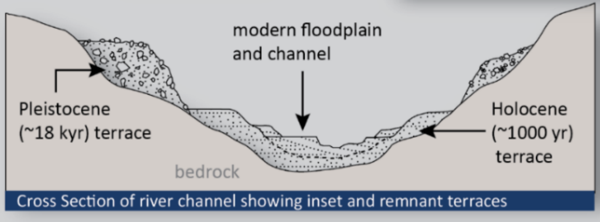
An abandoned Flood Plain (Terrace) is a valley bottom, planar accumulation of stream-deposited alluvium that is no longer directly associated with the active channel. Terraces comprise a ***tread***, the planar upper surface representing the relict floodplain surface; and a ***riser***, the erosional slope or flank of the terrace landform. Terrace sequences can be inset within other terrace deposits forming "flights" of step-like features surrounding the active channel (see above and right).

TIERED GEOMORPHIC UNIT BUILDING BLOCK REFERENCE CARDS

PROCESS INTERPRETATION

Terraces form as valley-fill floodplain sediments are later eroded (incised) and remnant surfaces are left abandoned along the channel margins. Terraces can form as ***cut*** features, by subsequent incision of valley fill alluvium; as ***fill*** features that are subsequently eroded into terrace forms; or as purely erosional ***strath*** surfaces, etched into resistant deposits, or even bedrock of the confining canyon walls.

Snake River, WY



Cross Section of river channel showing inset and remnant terraces

ASSOCIATED GEOMORPHIC UNITS AND STRUCTURAL ELEMENTS

Abandoned floodplains-terraces-are closely associated with both floodplain and hillslope geomorphic units. Older, coarse terrace remnants directly overlie bedrock (above); younger, fine-grained and inset terraces underlie the contemporary floodplain and include paleochannels, channel cutoffs and banks (at left). Terraces are generally not in contact with instream geomorphic units, except where the abandoned floodplain acts as the confining boundary--in this case, the terrace riser would exhibit cutbank forms, and would supply sediment to the active channel.

CAREFUL WHAT YOU ASK FOR…

- We live in a time where we have rapidly moved from an era of being data poor to data rich…
- Even if you had that coveted data… what would you do with it?
- Does it *really* make your life easier?
- Don’t let the HRT be a substitute for thinking… instead use HRT to help shed light on your curiosities and big questions