

An aerial photograph showing a river restoration project in a forested landscape. The river is a narrow, winding stream with a rocky bed, surrounded by dense evergreen trees. The surrounding area is a mix of forest and open, grassy areas with scattered logs and debris. In the background, a range of mountains is visible under a blue sky with light clouds.

Stage Zero River Restoration

Basis and Theory

Colin Thorne
University of Nottingham

OVERVIEW

Basis:

The Stream Evolution Model

Anabranching Rivers in Nature

Theory:

Bankfull Flow in Transport and Response reaches

Valley Confinement: 'Strings of Beads' & Ribbons

Single-thread, stable channels: not the only choice?

Basis:

THE STREAM EVOLUTION MODEL

ANABRANCHING CHANNELS IN NATURE

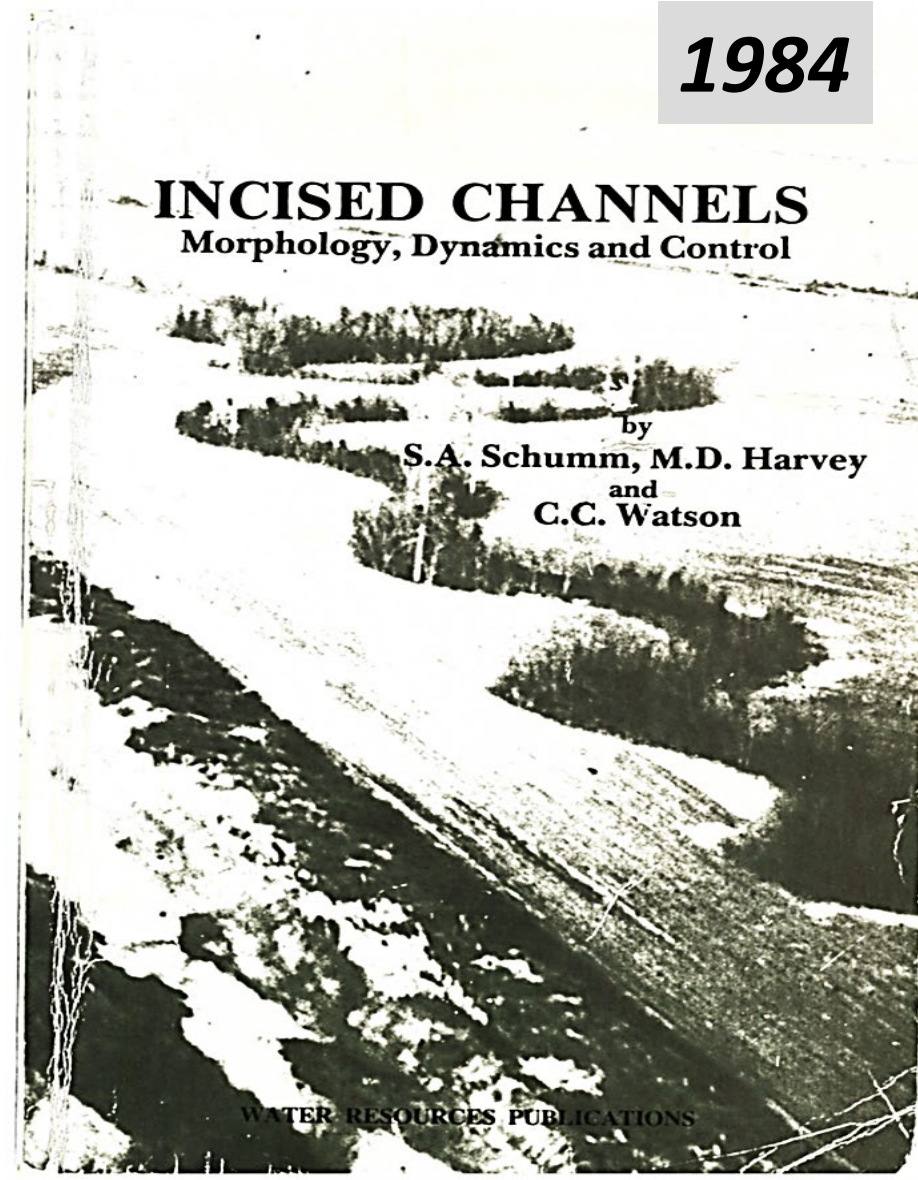
Channel Evolution Models...

INCISED CHANNELS Morphology, Dynamics, and Control

Schumm, Harvey & Watson

Water Resources Publications,
Littleton, Colorado

1984





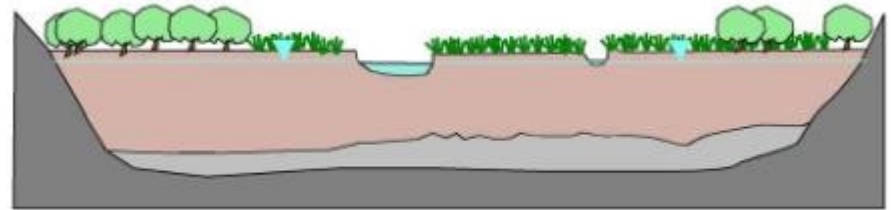
Floodplain Disconnection:
Crowder Creek, North Mississippi: late-1970s

Response to Channel – Floodplain Disconnection



Connected floodplain system:

- sedge meadows
- deep accumulation of sediments
- elevated water table

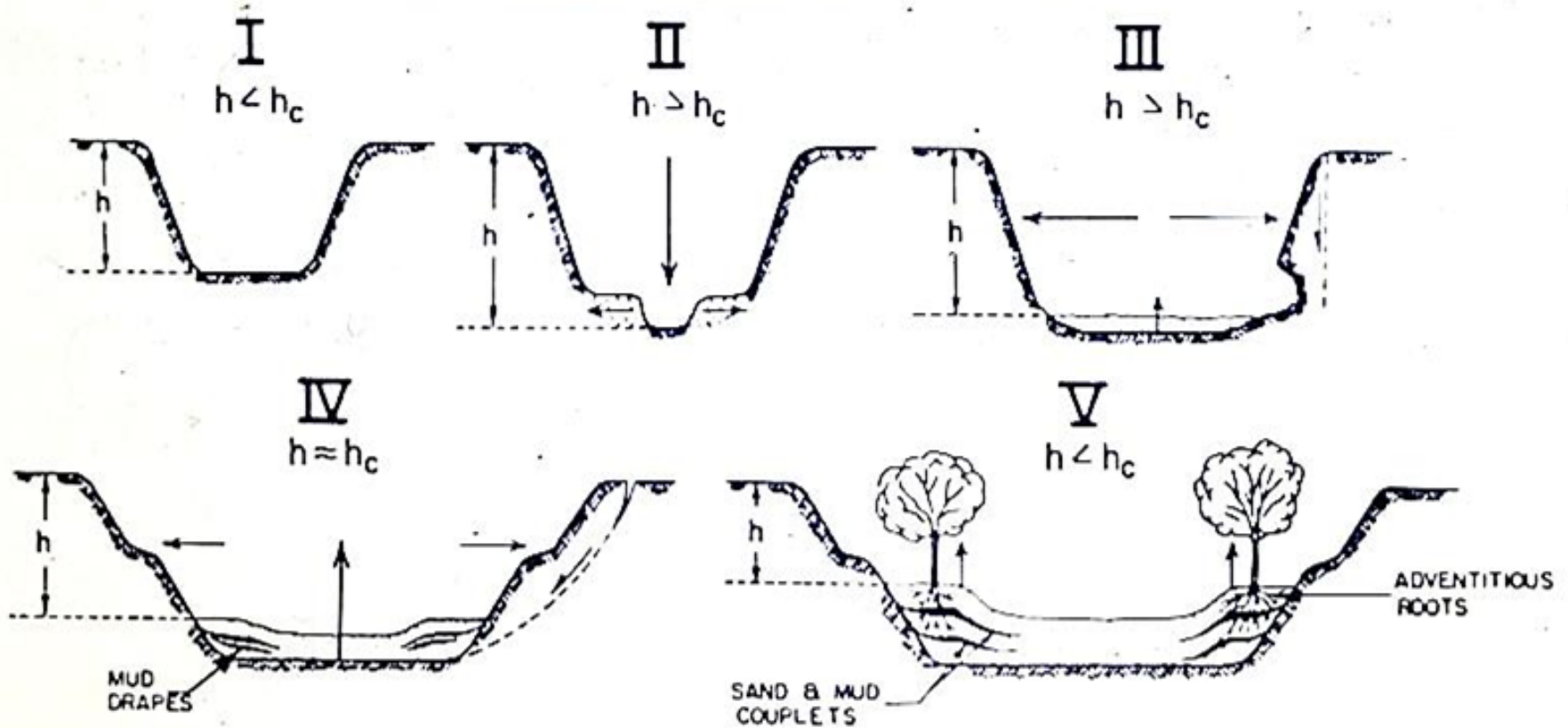


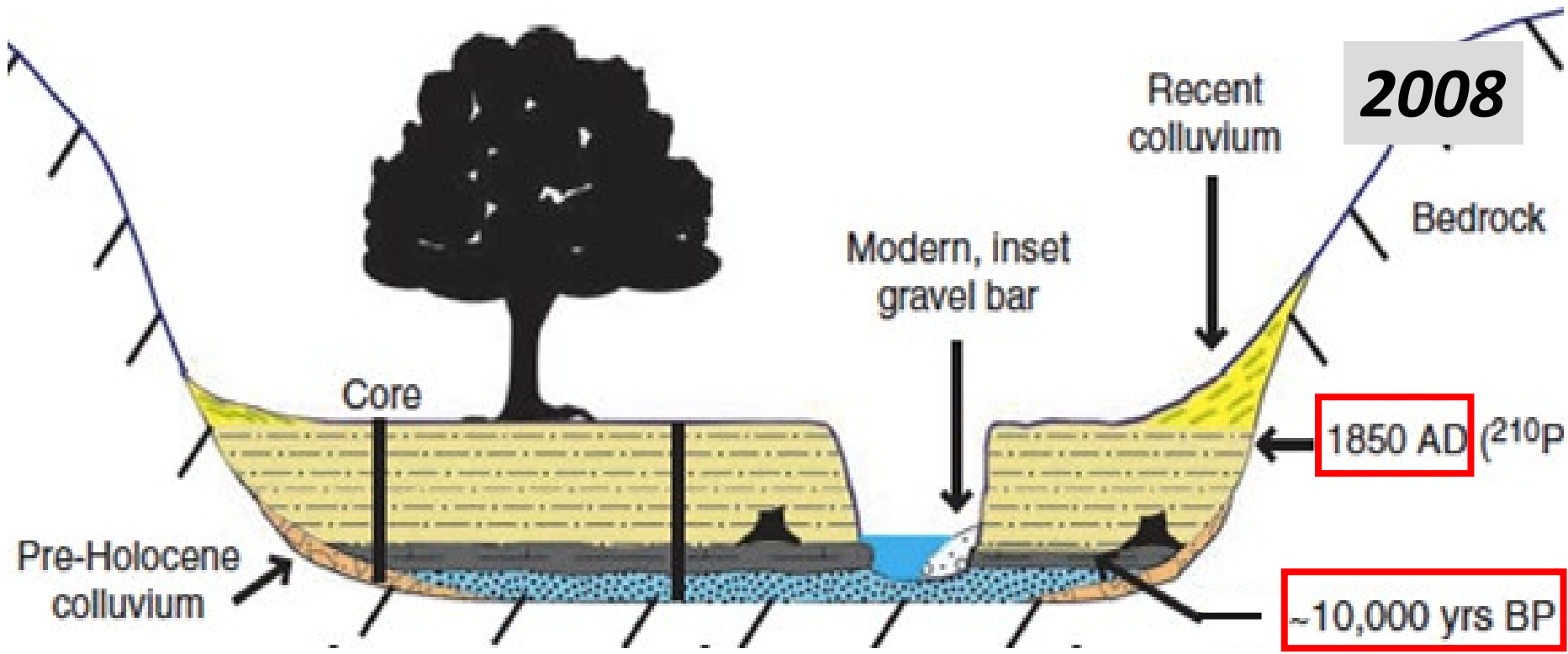
Disconnected floodplain system:

- conversion to sagebrush
- lowered water table
- intermittent streamflow



Channel Evolution Phases





“...before European settlement, the streams were small, anabranching channels within extensive, vegetated wetlands”

River Planforms over Geological Time

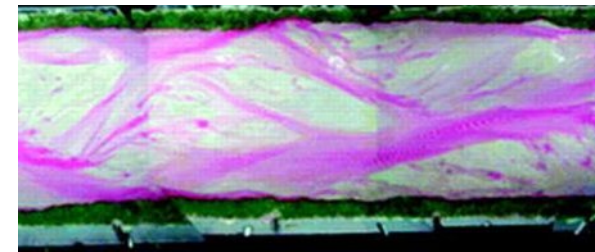
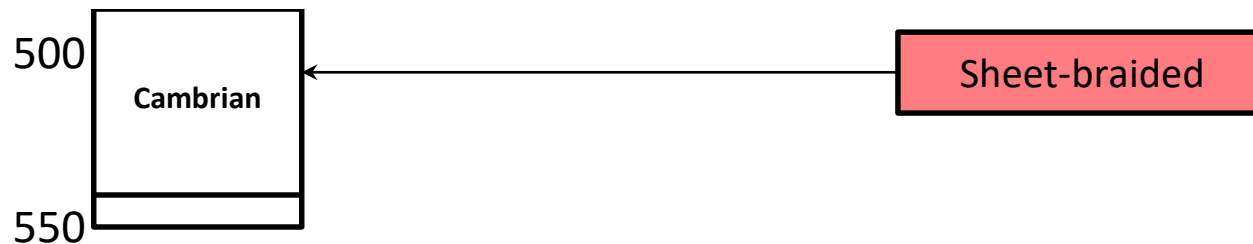
Plant Evolution

Fluvial Style

Mya

“...expansion of tree habitats led to the crossing of a threshold in vegetative control of floodplain and river morphology.”

Davies, N.S. and Gibling, M.R., 2011. *Nature Geoscience*, 4(9), pp.629-633



Until global vegetation, most rivers BRAIDED. After plants appeared rivers started MEANDERING and become ANASTOMOSED after modern trees evolved. Slide compiled by Dr Matt Johnson, Nottingham U.

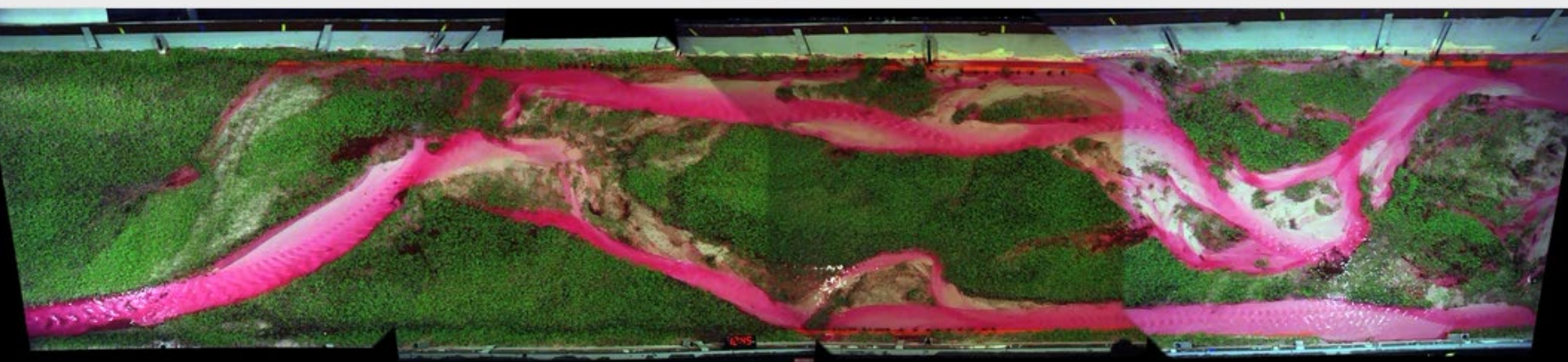
Mical Tal: Interactions between vegetation and braiding leading to a single-thread channel





“Fight the enemy where he isn’t”

General Sun Tzu - ‘The Art of War’ (512 BC)



Mical Tal: Interactions between vegetation and braiding leading to a single-thread channel

A STREAM EVOLUTION MODEL INTEGRATING HABITAT AND ECOSYSTEM BENEFITS

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^a *Fluvial Geomorphologist, Southwest Region, NOAA's National Marine Fisheries Service, Santa Rosa, California, USA*

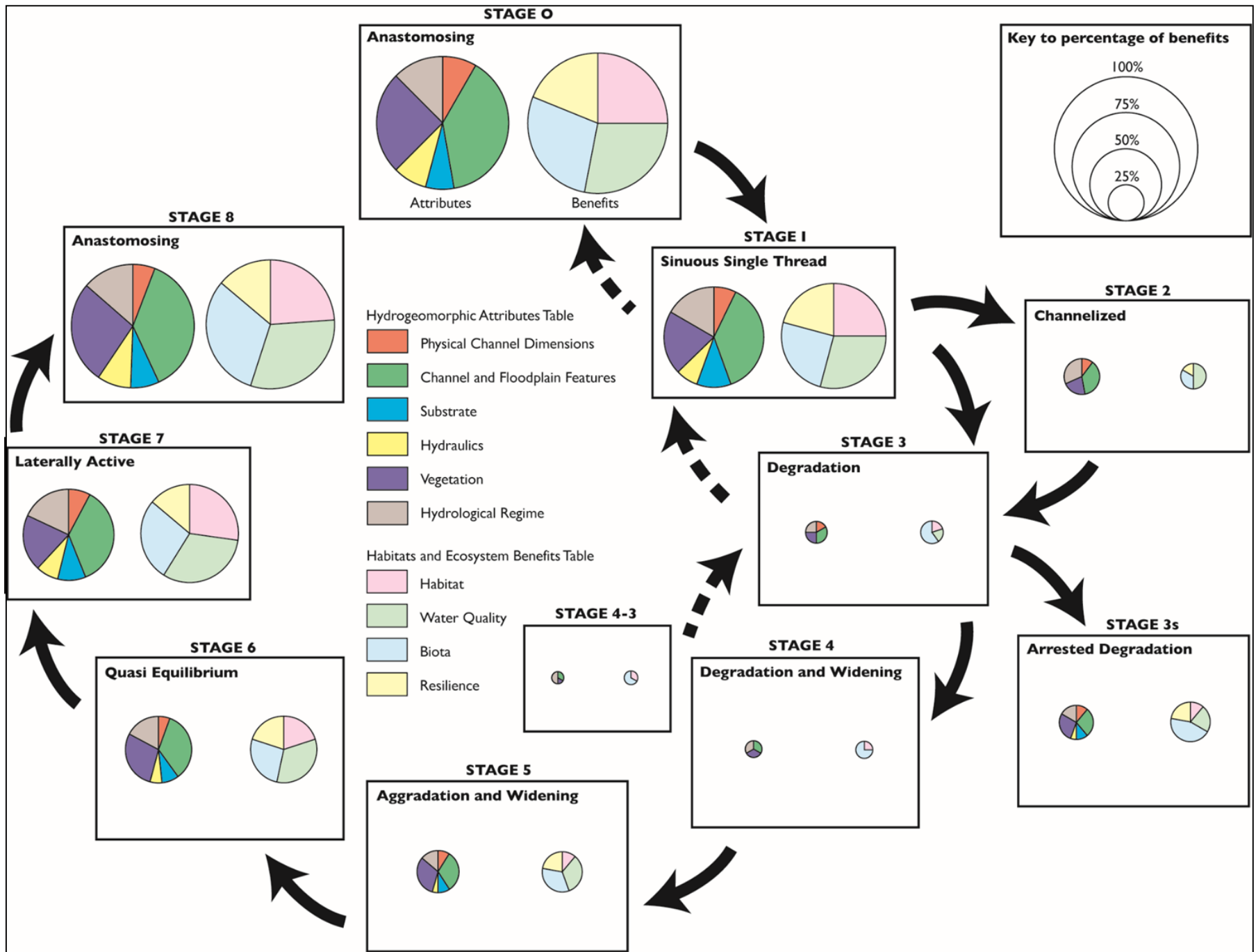
^b *Chair of Physical Geography, University of Nottingham, Nottingham, UK*

ABSTRACT

For decades, Channel Evolution Models have provided useful templates for understanding morphological responses to disturbance associated with lowering base level, channelization or alterations to the flow and/or sediment regimes. In this paper, two well-established Channel Evolution Models are revisited and updated in light of recent research and practical experience. The proposed Stream Evolution Model includes a precursor stage, which recognizes that streams may naturally be multi-threaded prior to disturbance, and represents stream evolution as a cyclical, rather than linear, phenomenon, recognizing an *evolutionary cycle* within which streams advance through the common sequence, skip some stages entirely, recover to a previous stage or even repeat parts of the evolutionary cycle.

The hydrologic, hydraulic, morphological and vegetative attributes of the stream during each evolutionary stage provide varying ranges and qualities of habitat and ecosystem benefits. The authors' personal experience was combined with information gleaned from recent literature to construct a fluvial habitat scoring scheme that distinguishes the relative, and substantial differences in, ecological values of different evolutionary stages. Consideration of the links between stream evolution and ecosystem services leads to improved understanding of the ecological status of contemporary, managed rivers compared with their historical, unmanaged counterparts. The potential utility of the Stream Evolution Model, with its interpretation of habitat and ecosystem benefits includes improved river management decision making with respect to future capital investment not only in aquatic, riparian and floodplain conservation and restoration but also in interventions intended to promote species recovery. Copyright © 2013 John Wiley & Sons, Ltd.

KEY WORDS: Stream Evolution Model (SEM); channel evolution; freshwater ecology; habitat; conservation; river management; restoration; climate resilience



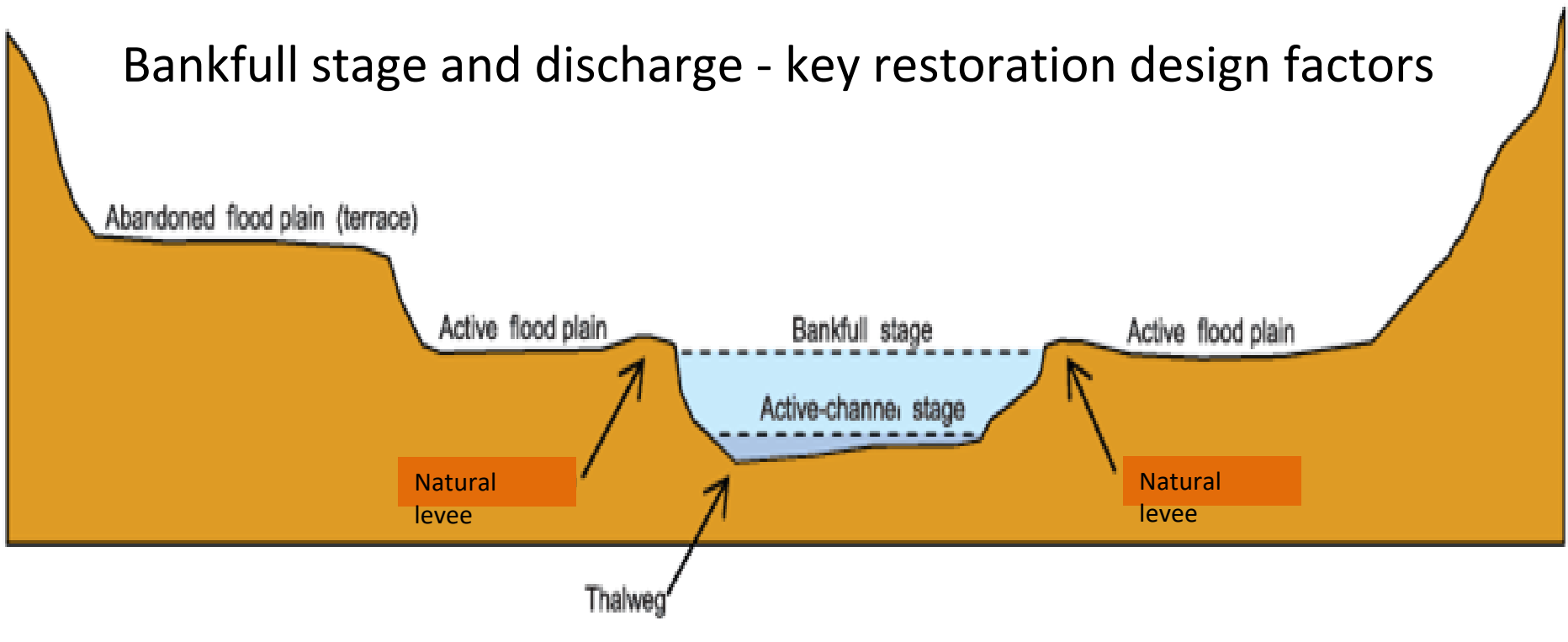
Theory:

BANKFULL FLOW IN TRANSPORT AND RESPONSE REACHES

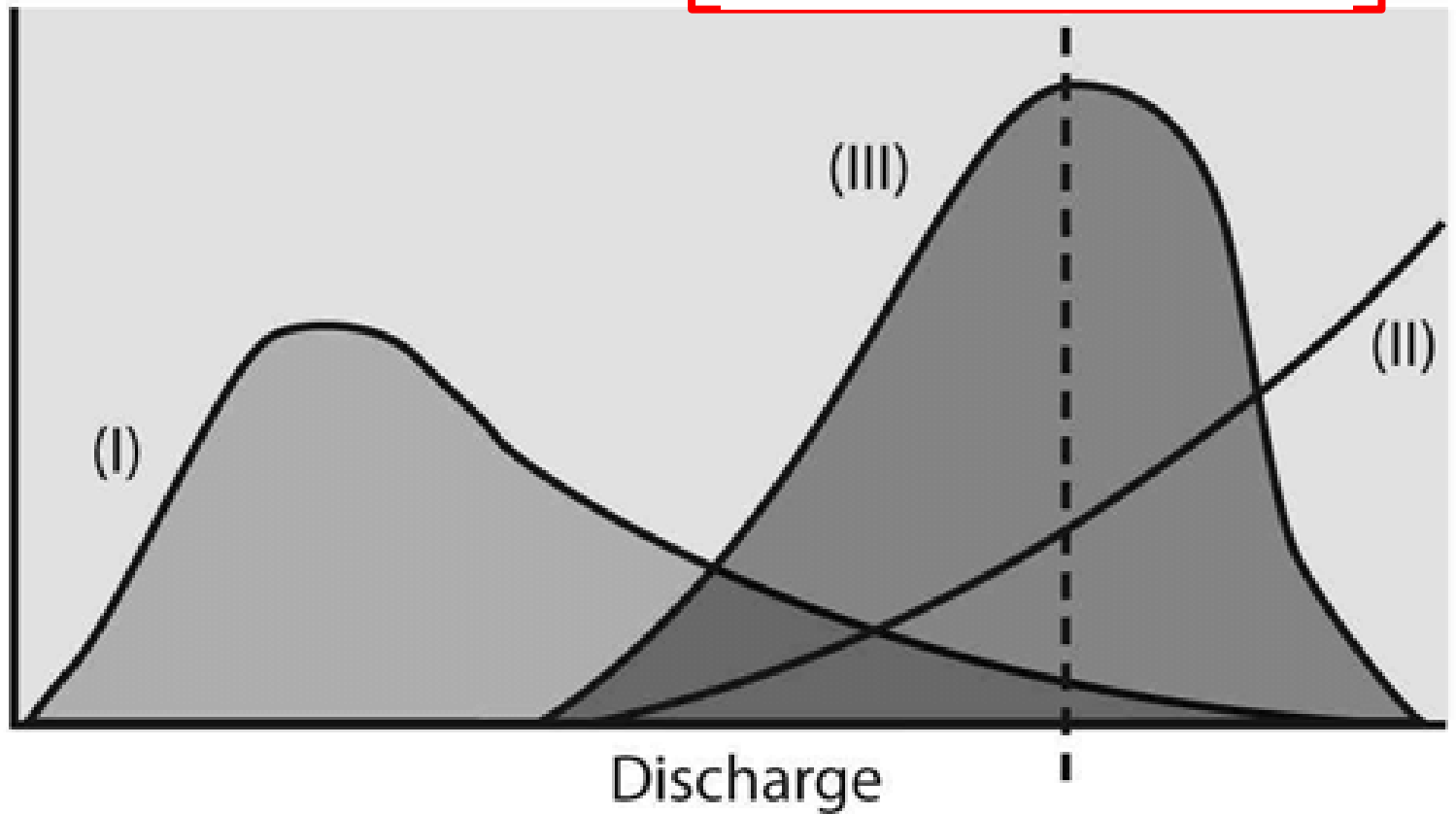
VALLEY CONFINEMENT

STABLE CHANNEL DESIGN

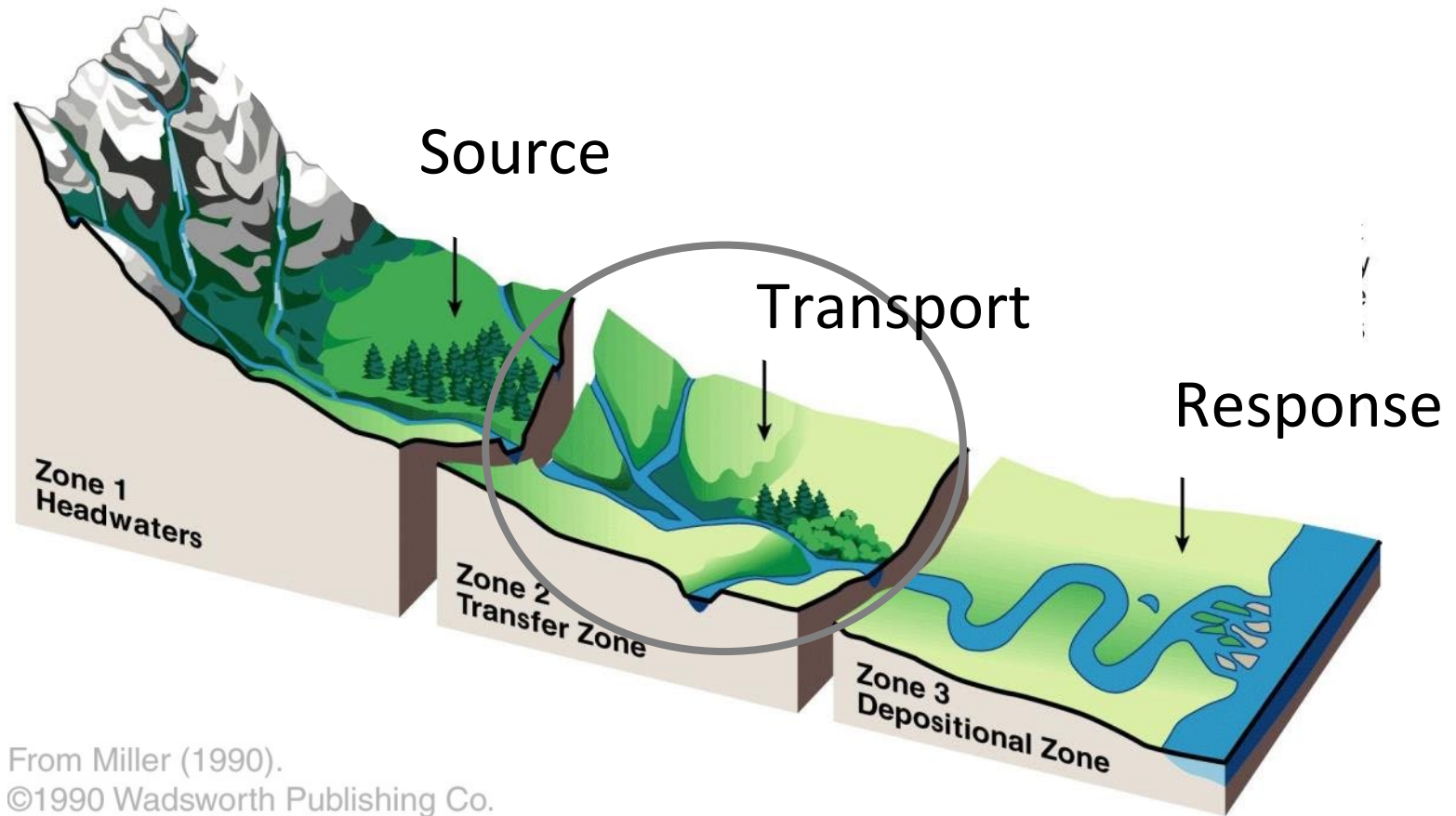
Bankfull stage and discharge - key restoration design factors



- (I) Frequency
- (II) Sediment discharge rating curve
- (III) Collective sediment discharge



Bankfull Discharge =
Return period ~1.5
years



From Miller (1990).
©1990 Wadsworth Publishing Co.

DYNAMIC PROCESS-RESPONSE MODEL OF RIVER CHANNEL DEVELOPMENT

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School of Environmental Sciences, University of East Anglia, Norwich NR4 7TJ, England

Received 24 March 1977

Revised 6 March 1978

SUMMARY

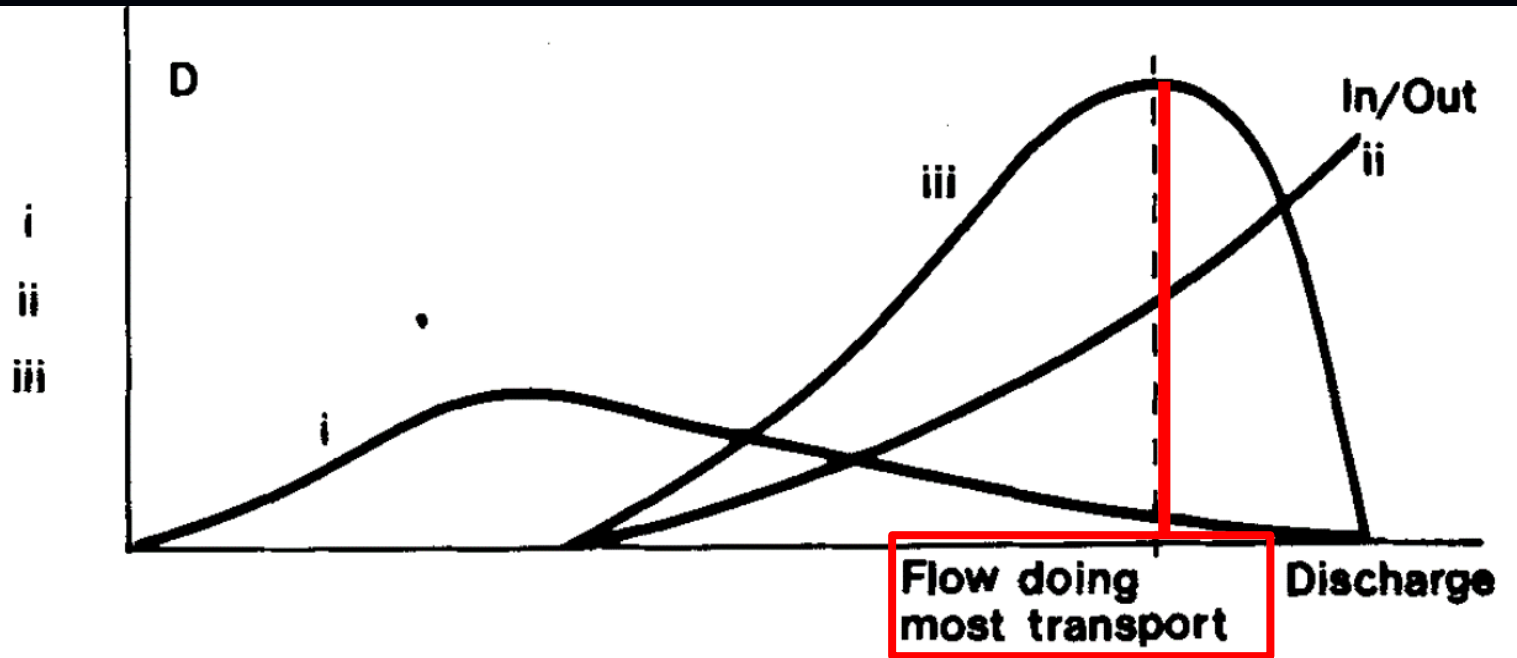
Feedback mechanisms, which operate upstream through drawdown and backwater effects and downstream through sediment discharge are responsible for channel evolution. By combining these mechanisms with channel processes it enables a dynamic process-response model to be developed to simulate the initial evolution of straight gravel-bed channels.

When erosion commences on a land surface, sediment entrained in the headwater reach by hydraulic action is selectively transported, deposited and reworked. This produces a damped oscillation between degradation and aggradation as the channel and valley respond to spatial and temporal variations in sediment calibre and hydraulic conditions. The initial cut and fill phases are responsible for valley incision and floodplain development while secondary and subsequent activity can produce river terraces.

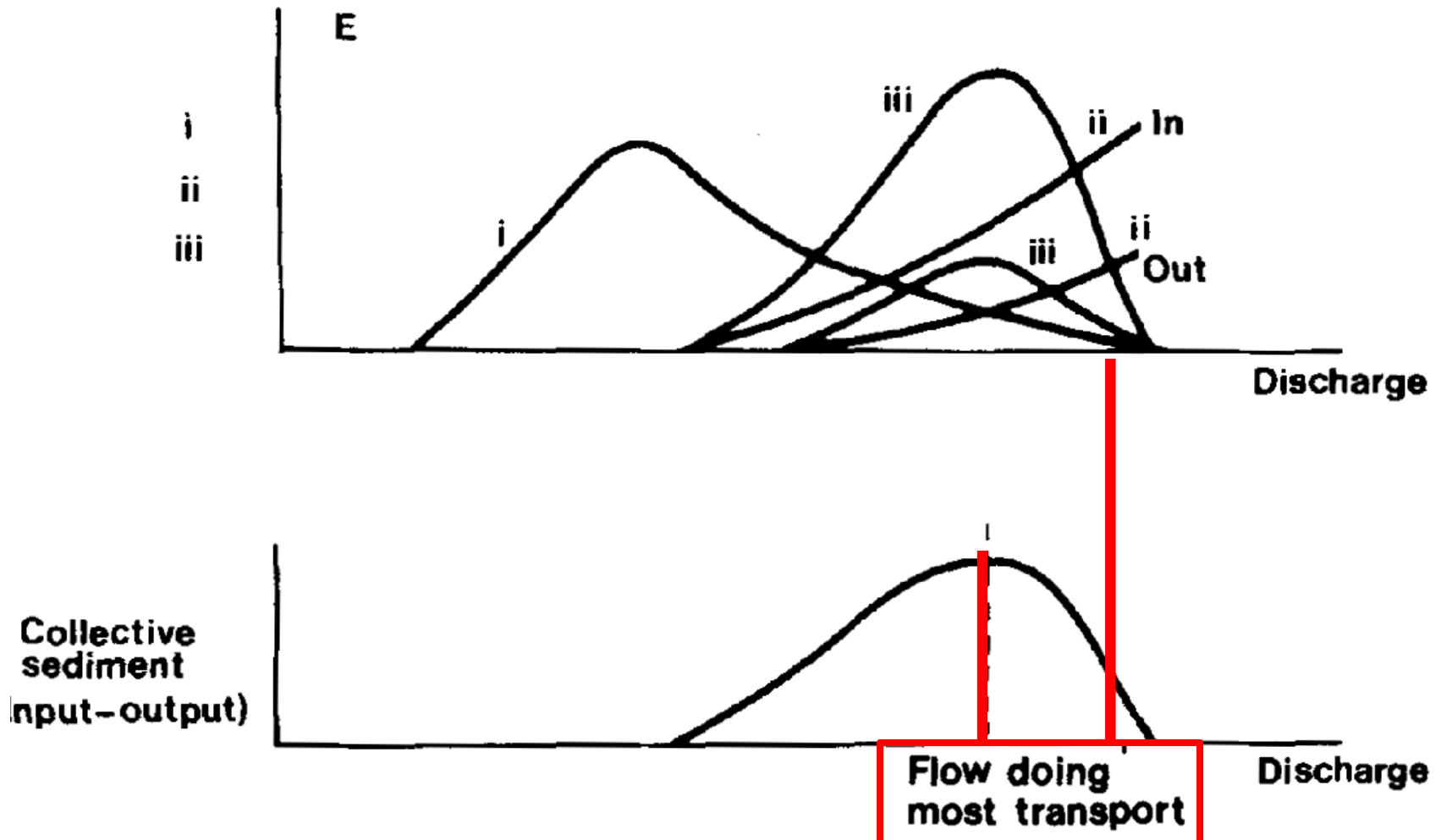
Eventually sediment entrainment in the headwaters declines as slopes are reduced. Subsequent channel evolution is relatively insignificant because it is dependent on local weathering activity producing material that can be transported on declining slopes. Therefore landforms produced during the initial phase of development, when local weathering was non-limiting, dominate the landscape.

KEY WORDS Channels Evolution Processes Responses Dynamic Model Erosion Deposition Weathering Sediment Valley Floodplain Terraces

Transport Reach – $Qs_{in} = Qs_{out}$



Depositional Reach – $Qs_{in} > Qs_{out}$



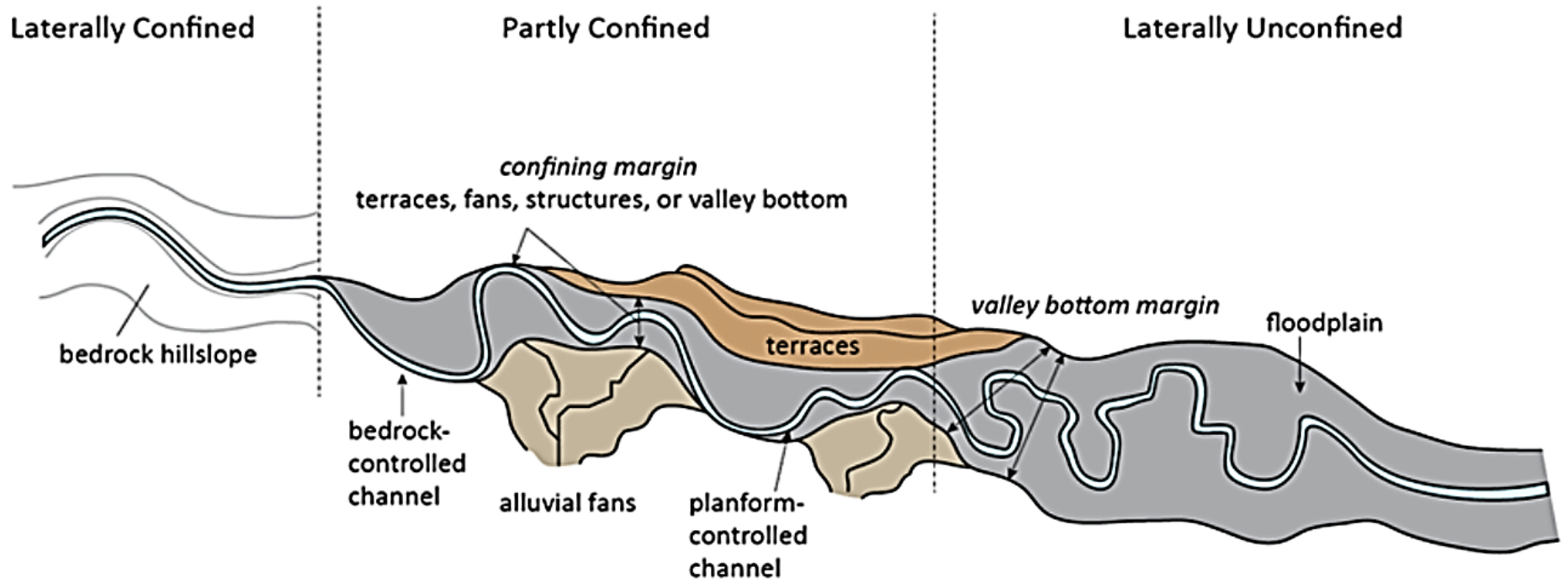
Theory:

**BANKFULL FLOW IN TRANSPORT AND RESPONSE REACHES
VALLEY CONFINEMENT
STABLE CHANNEL DESIGN**

“ ***valley confinement*** - a primary control on many fluvial geomorphic processes that occur on (and along) valley bottoms.....

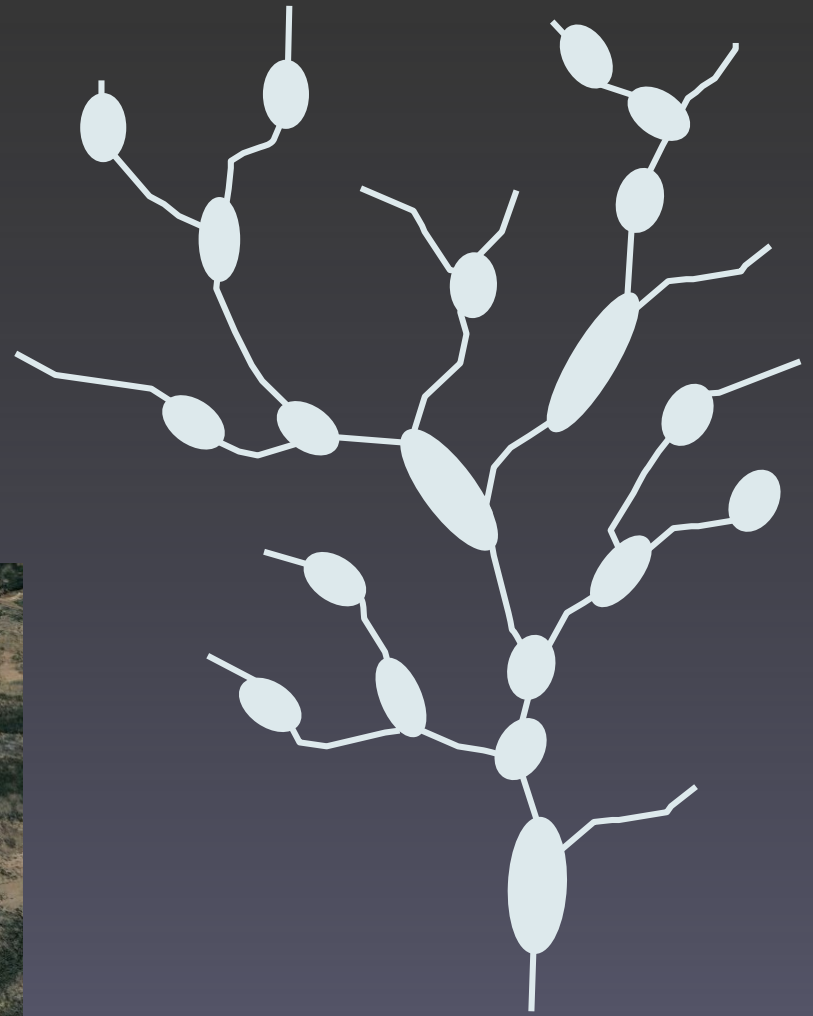
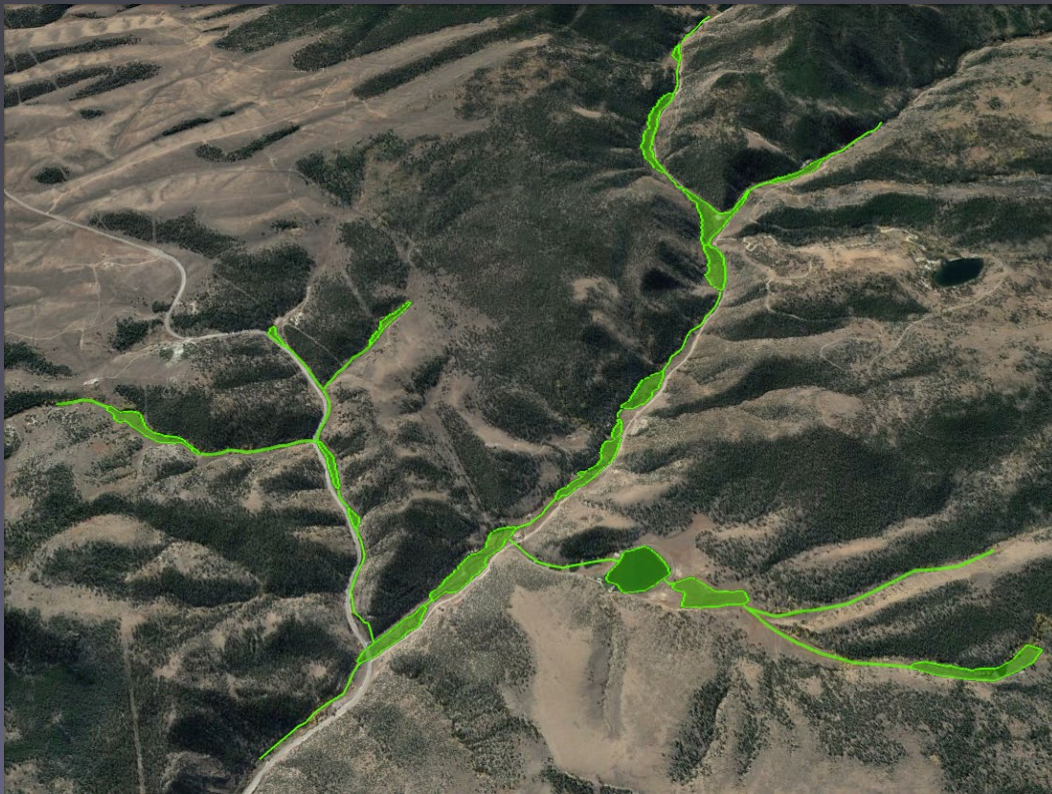
downstream sequence of valley settings - a key control on longitudinal patterns of hydrology and sediment flux, as well as dictating the pattern of river types”

Valley Confinement and Confining Features





Beads on a string



Mark Beardsley

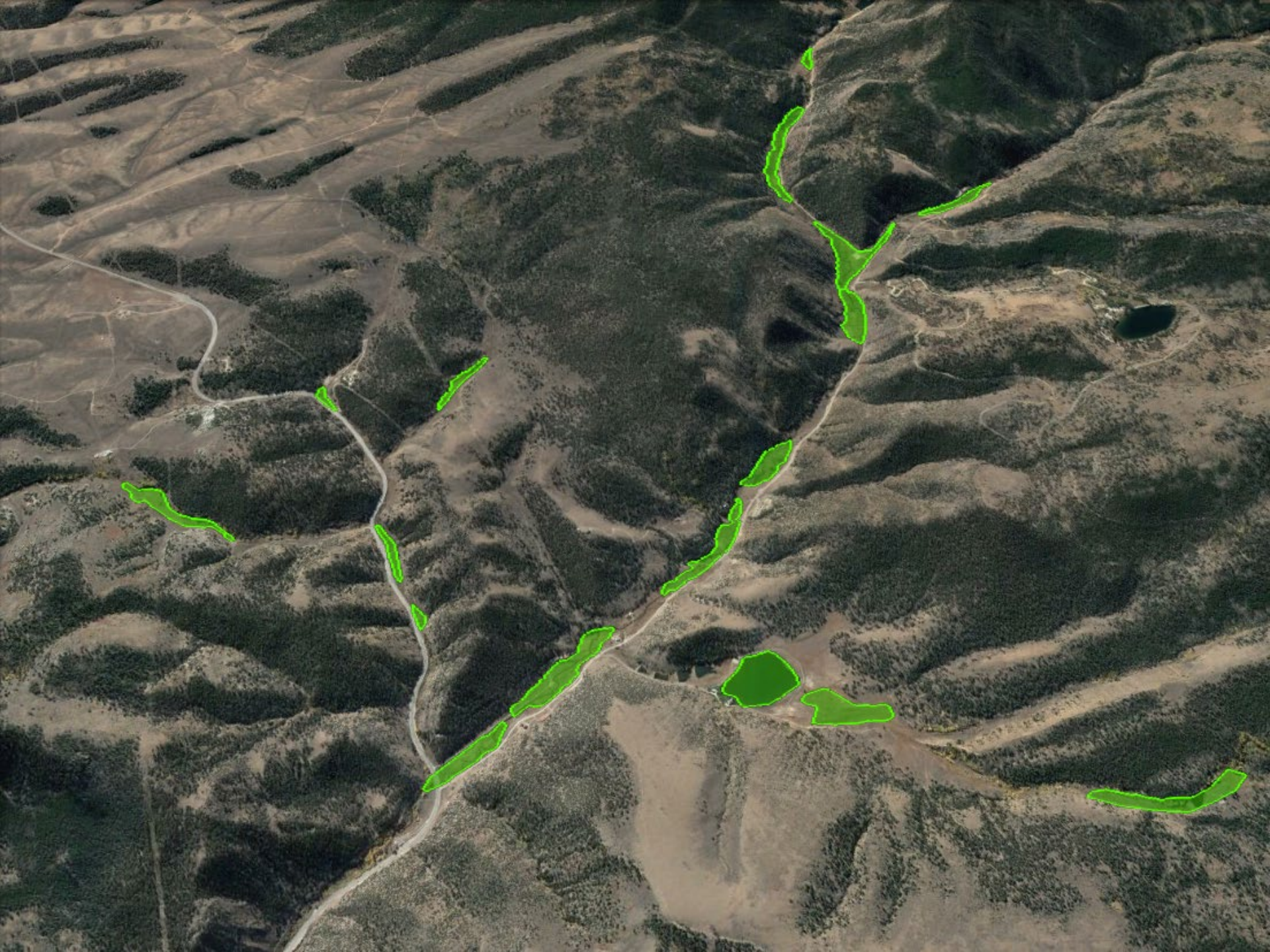


EcoMetrics

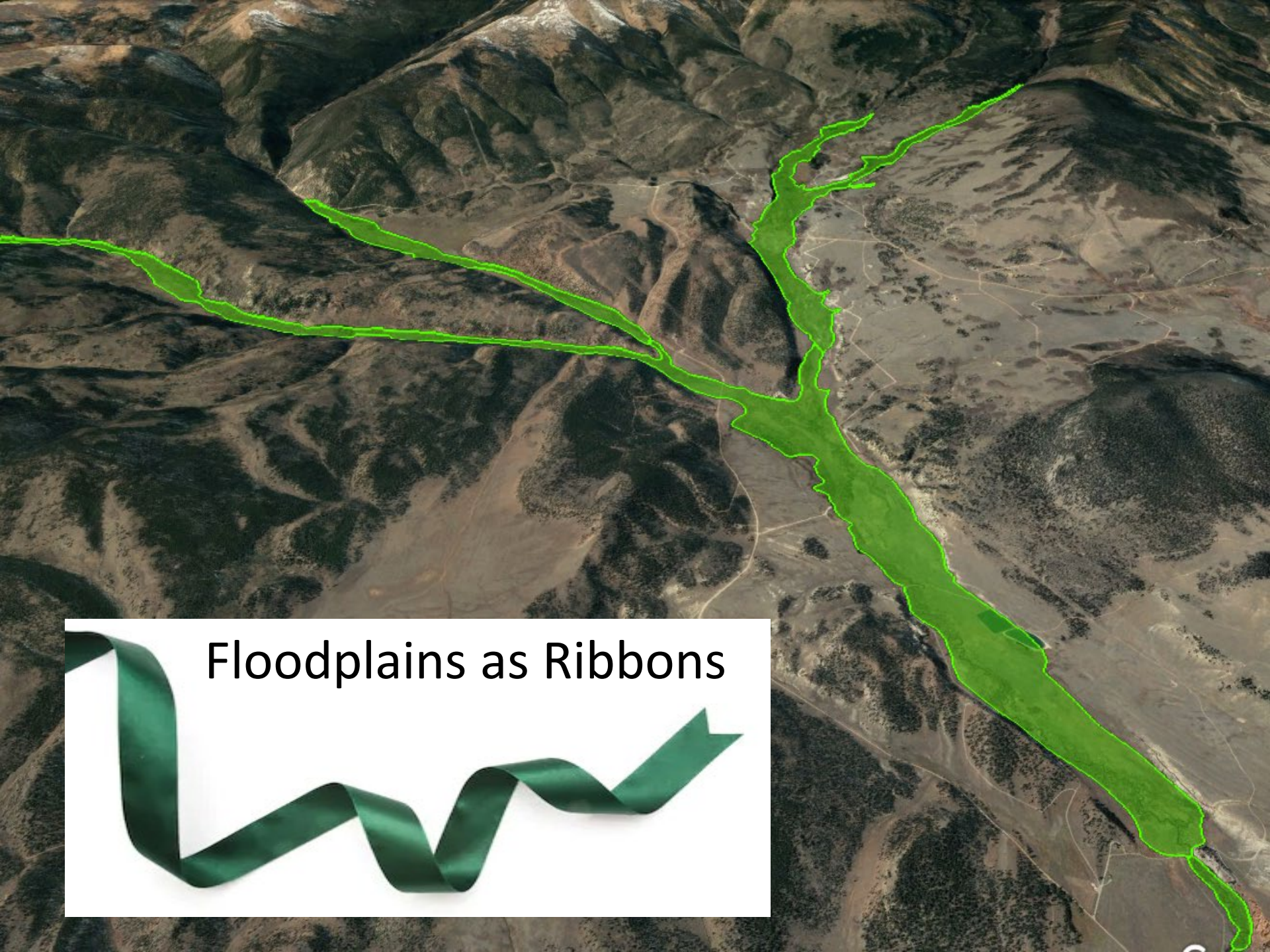
Stream & Riparian Monitoring, Assessment & Restoration

Riparian







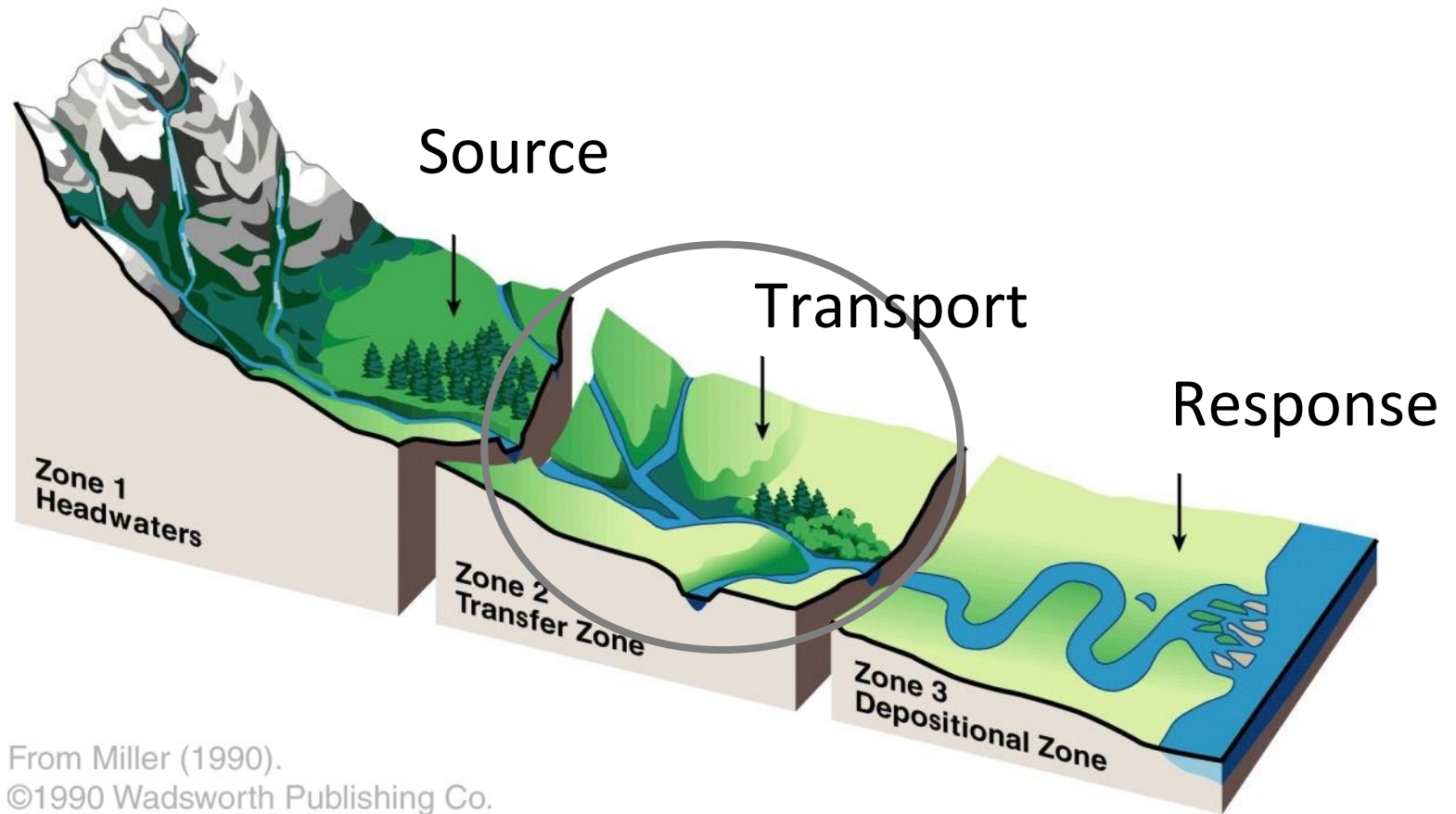


Floodplains as Ribbons



Theory:

**BANKFULL FLOW IN TRANSPORT AND RESPONSE REACHES
VALLEY CONFINEMENT
STABLE CHANNELS**

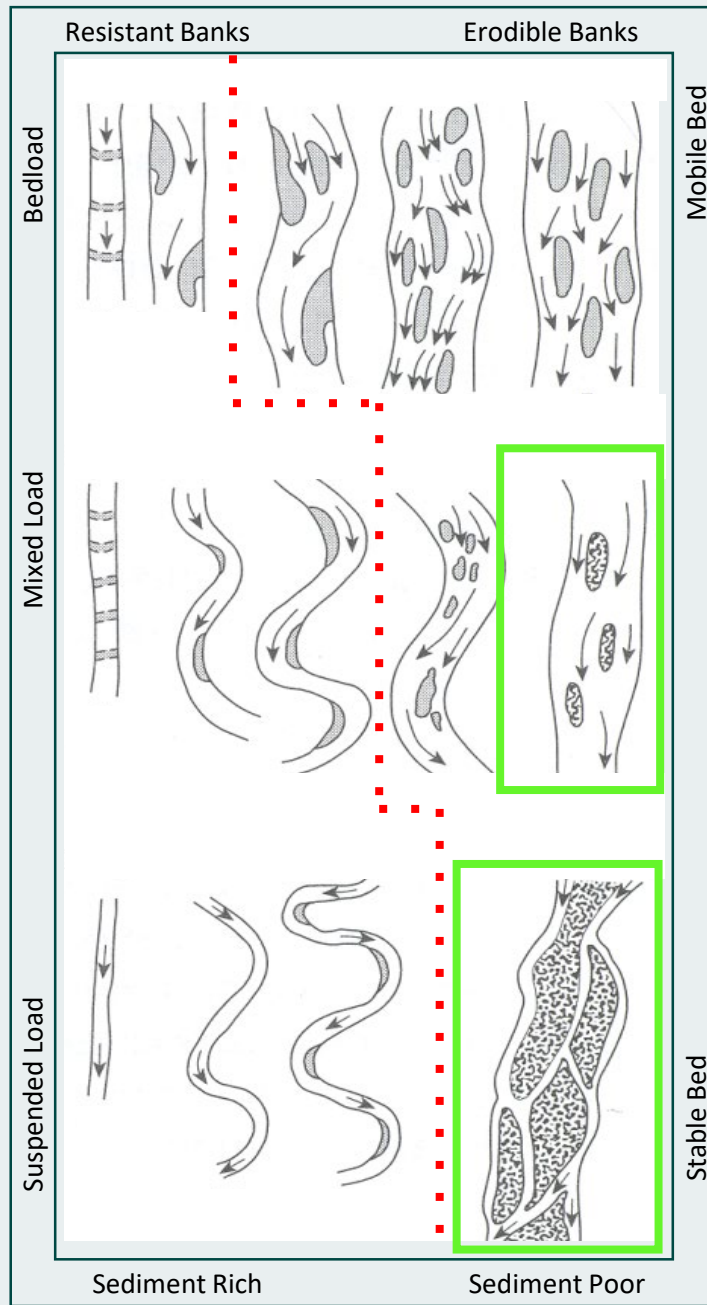


From Miller (1990).
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**Dynamically Stable,
Stable,
Single-thread
planforms**

Straight

Meandering



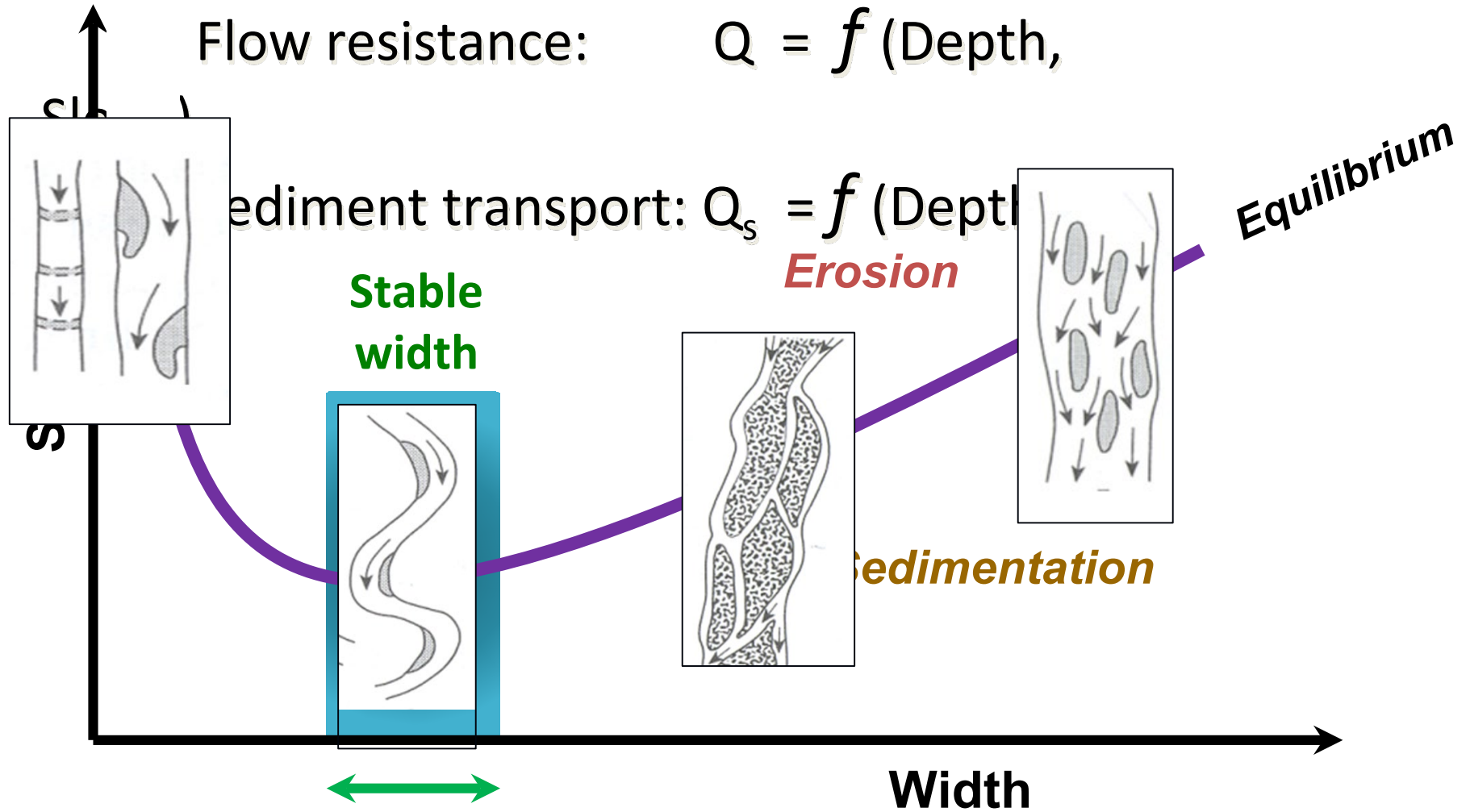
**Dynamically Stable,
Multi-thread
planforms**

Braided

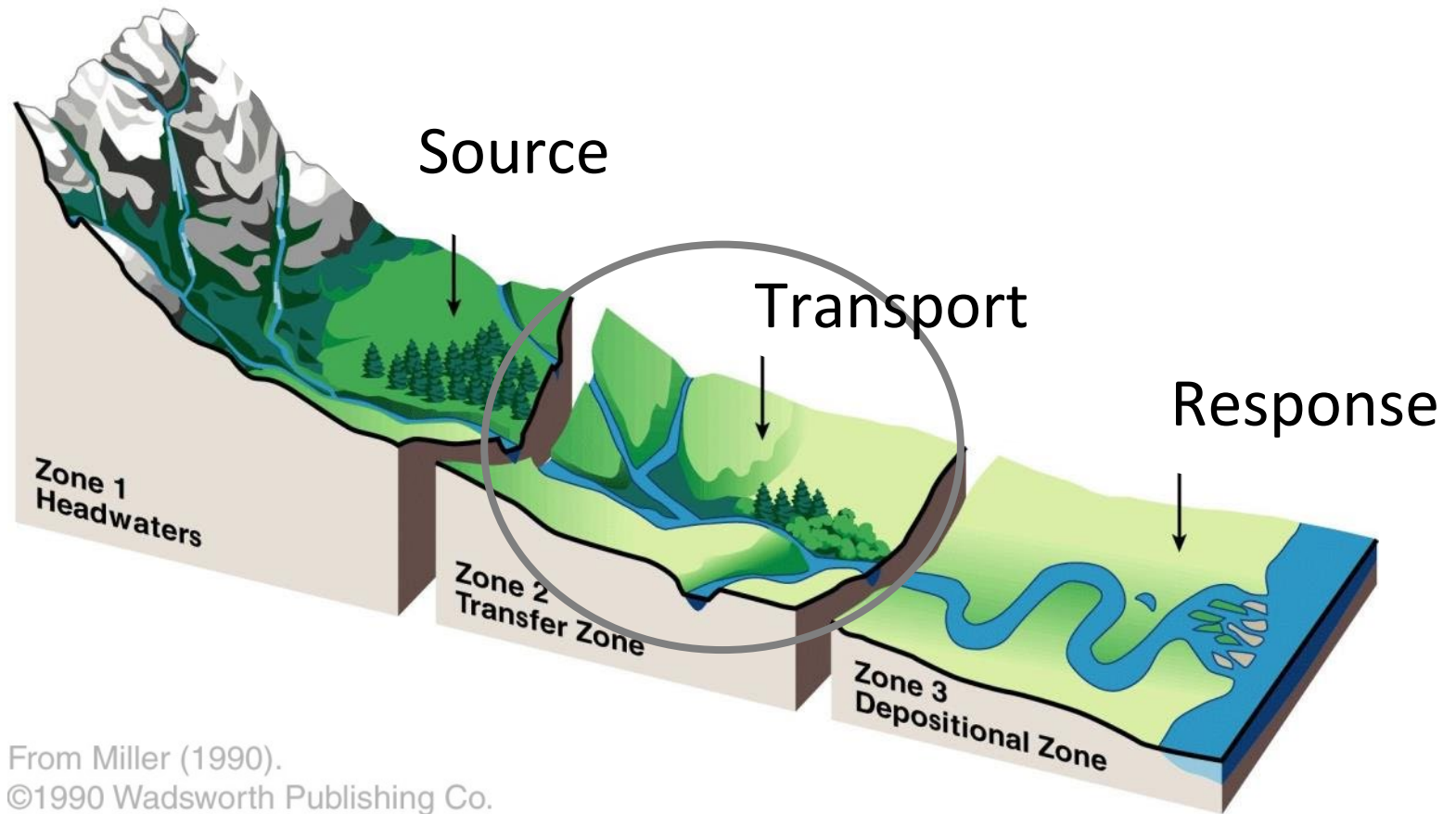
Island Braided

Anastomosed

Copeland Stable Channel Design Method: for a given Width:



US Army Corps of Engineers: SAM = Stable Analytical Method

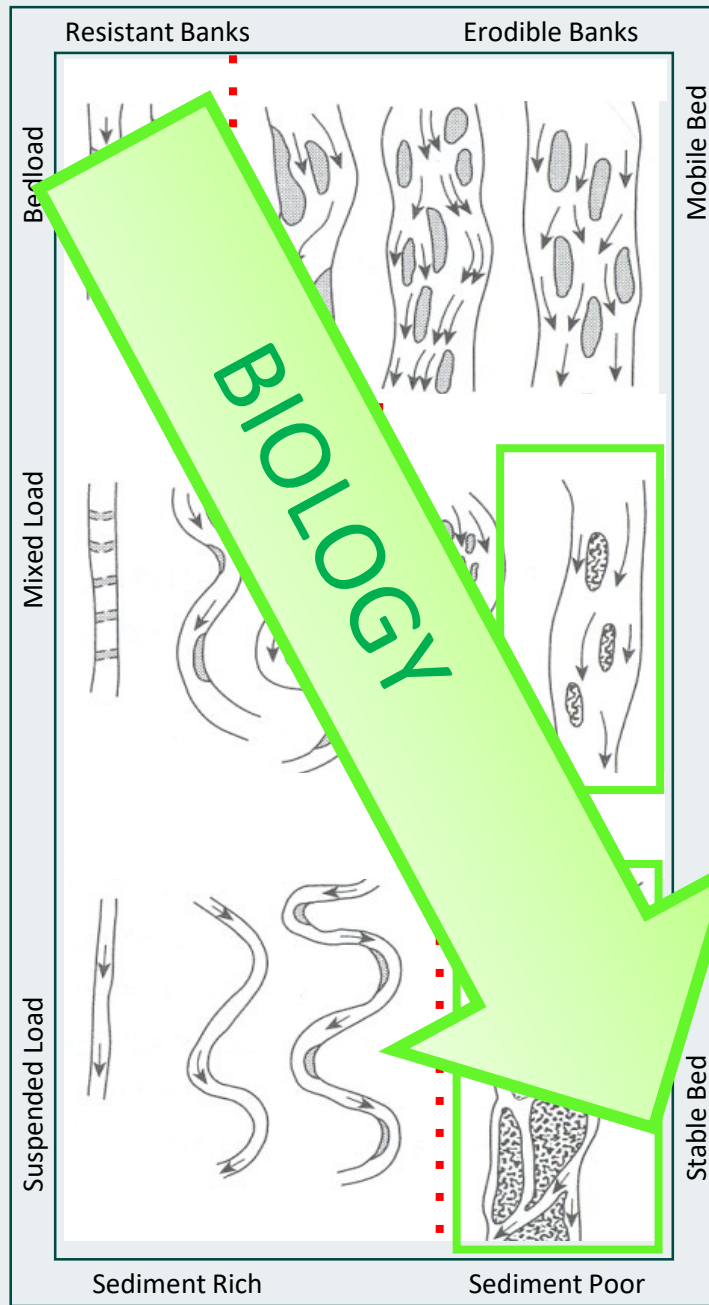


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**Dynamically Stable,
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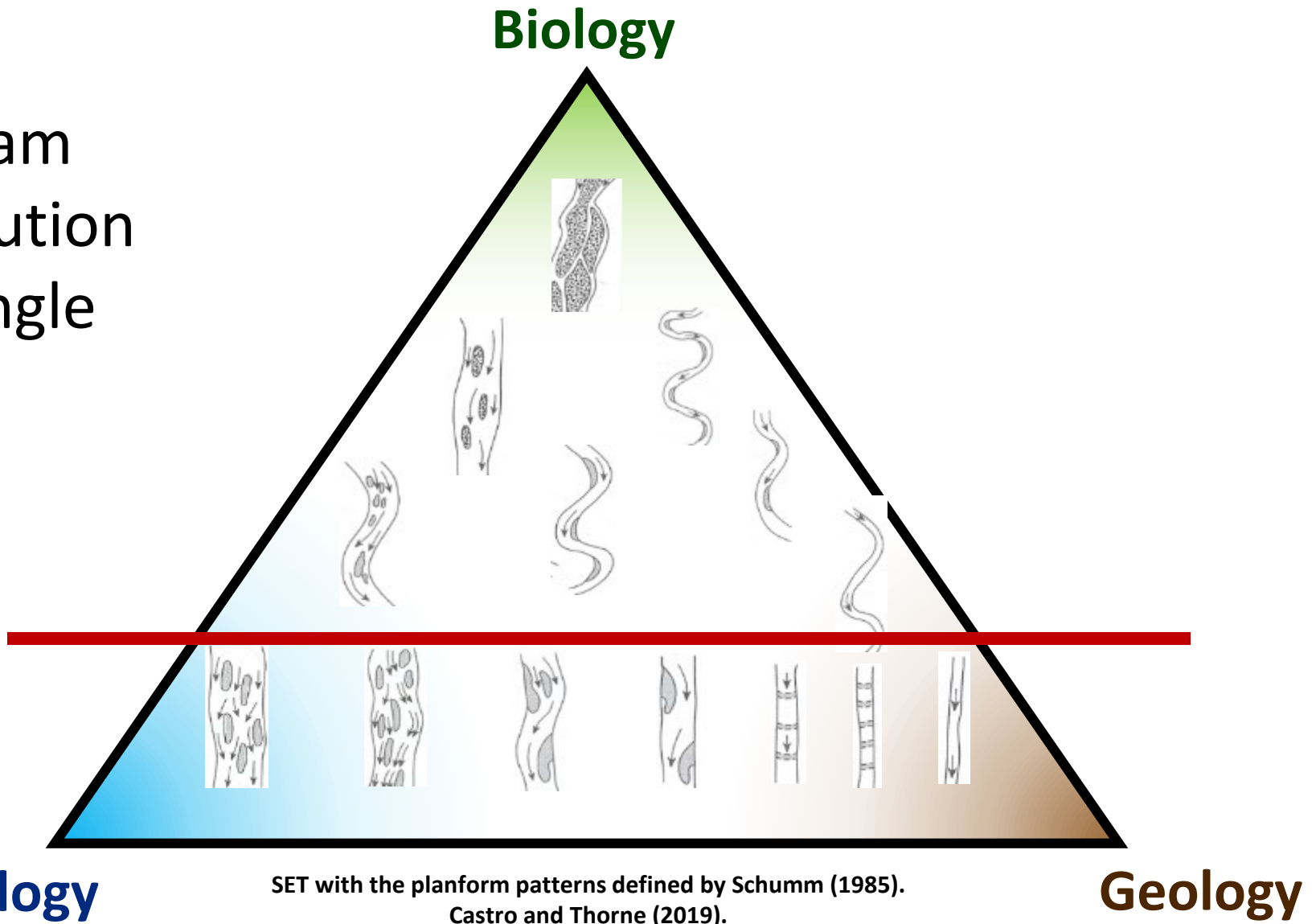
**Dynamically Stable,
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Braided

Island Braided

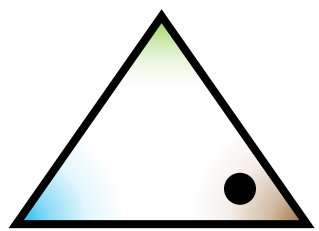
Anastomosed

The Stream Evolution Triangle



SET with the planform patterns defined by Schumm (1985).
Castro and Thorne (2019).

Castro, J.M. and Thorne, C.R. 2019. The Stream Evolution Triangle: linking Geology, Hydrology and Biology, *River Research and Applications*. <https://doi.org/10.1002/rra.3421>

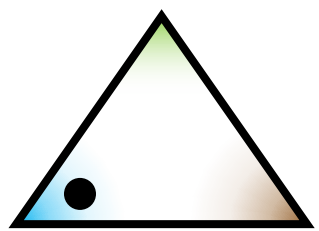


Colorado River,
USA

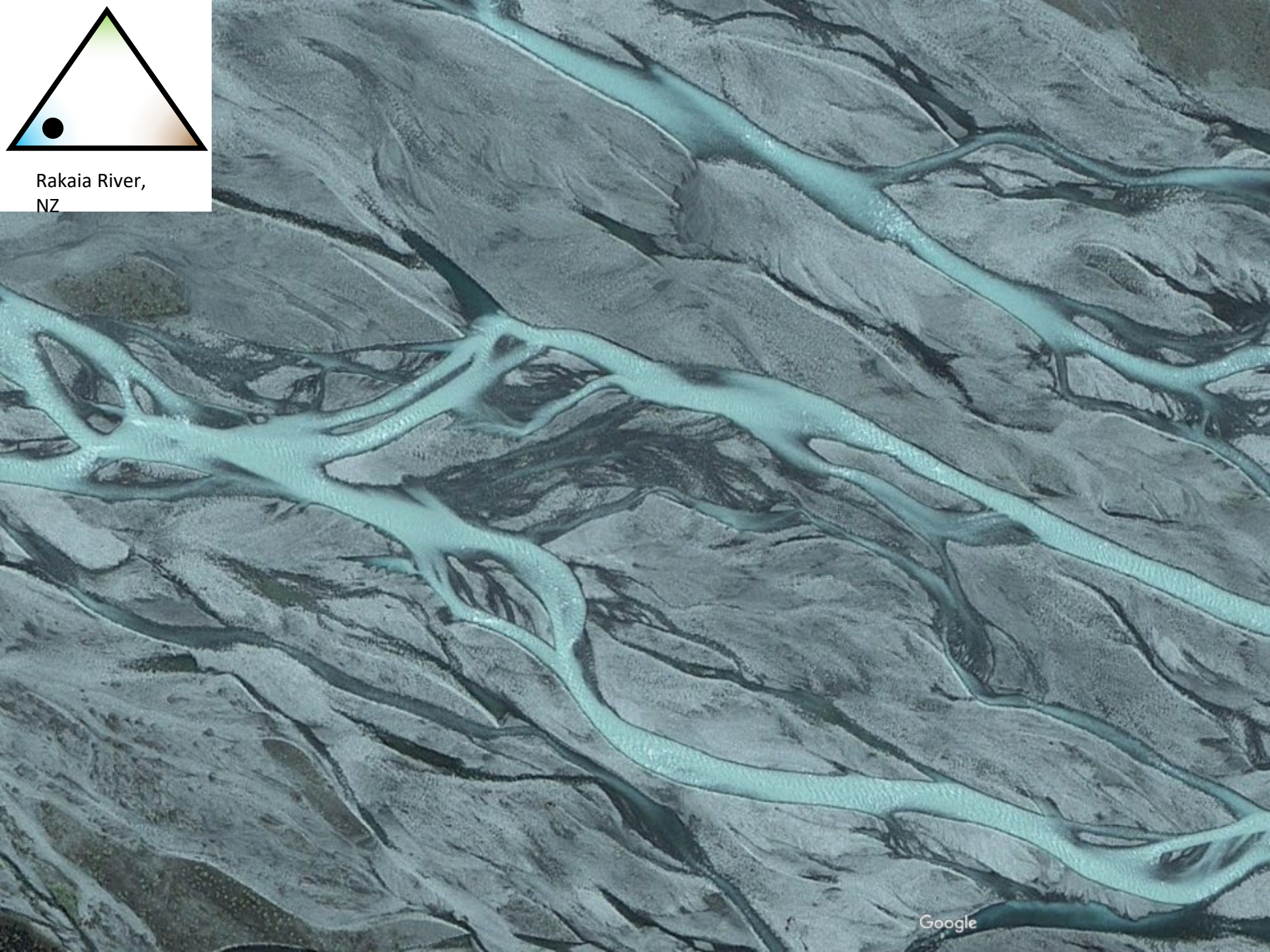


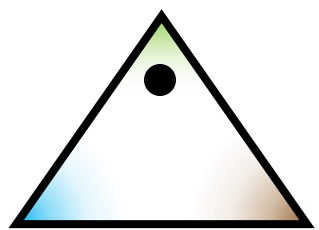
Google

Google Earth



Rakaia River,
NZ

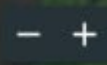




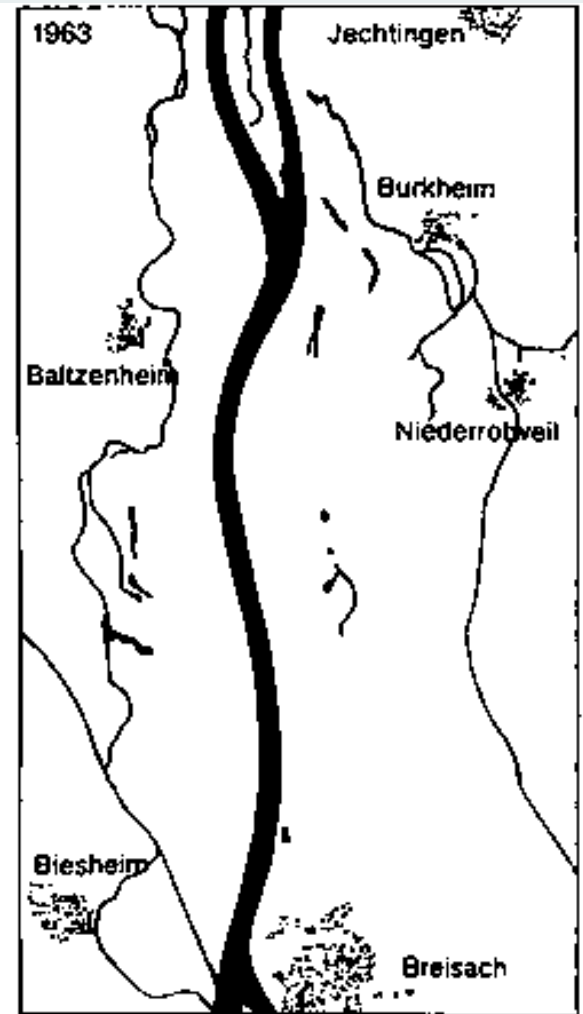
Rio Negro, BR



Google



Why don't we see many anastomosed rivers?



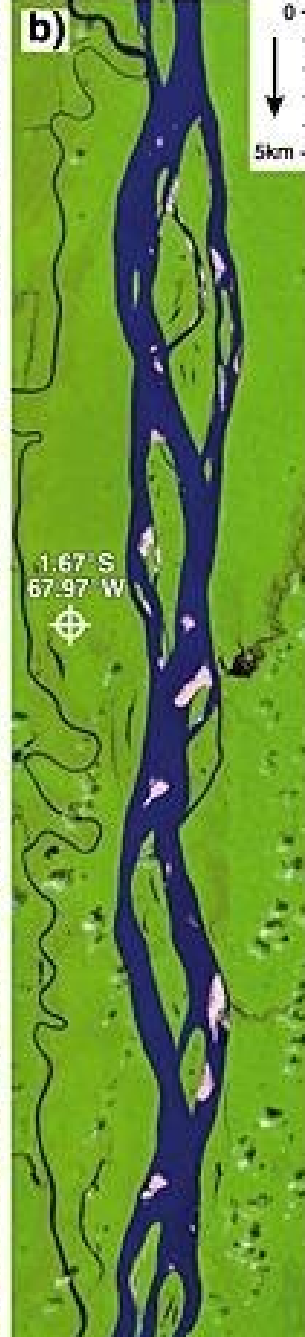
Meandering
1963 – fully canalised
single-thread

by Johann Gottfried Tulla

River Rhine, Germany



Parana



Japura



Brahmaputra



Orinoco

Post-2000 research challenges single-thread, meandering as a natural, ubiquitous pre-disturbance condition:

Europe - Tony Brown, John Lewin, Nicola Surian

Eastern US - Robert Walter and Dorothy Merritts

California – Robin Grossinger and others

Pacific Northwest - Dave Montgomery and Brian Collins



Photograph by Brian Cluer

Further Reading

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