Defining reference conditions for assessing biophysical status of rivers

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Environmental legislation

US
- Clean Water Act
- Endangered Species Act

EU
- Water Framework Directive
- Habitats Directive

Maintain & restore biophysical condition
- Establish reference conditions & intrinsic potential
    - Assess status
    - Target desired future conditions
    - Defensible management

How far back?

Primeval ——— Present

Pristine (old-growth forest)

Moderate disturbance (cleared forest)

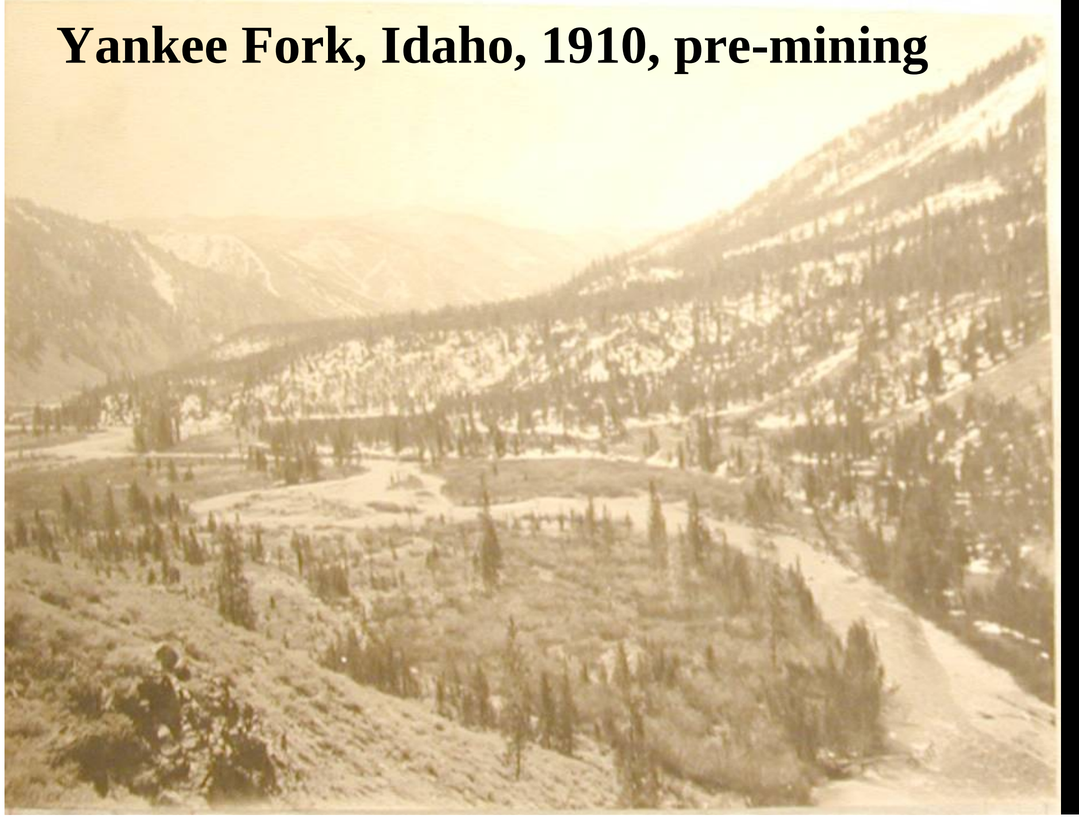
Severe disturbance (urbanizing channel; Montgomery et al. 2003)

Methods for determining reference conditions

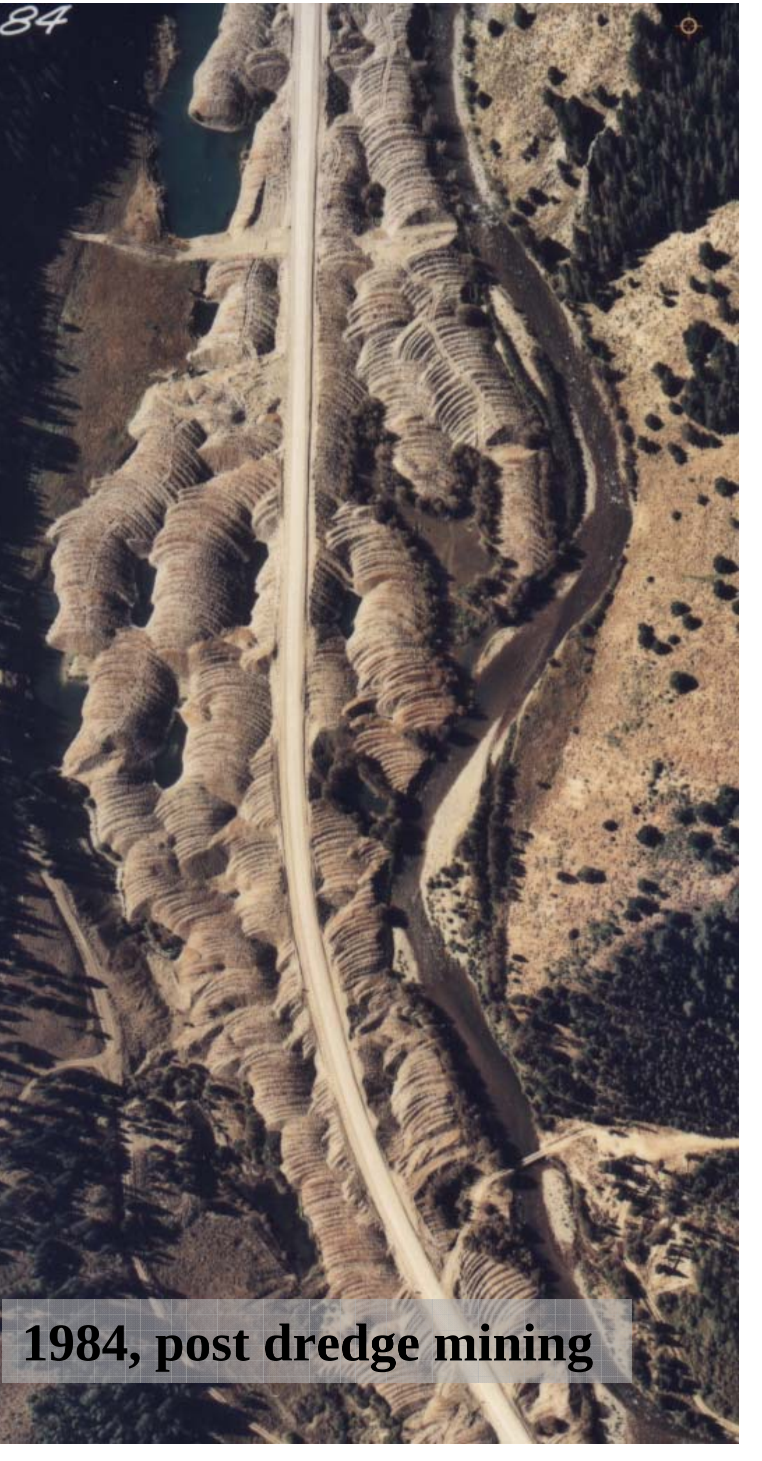
- Historical reconstruction (human and Holocene time scales)
- Analogues (paired basins; space-for-time substitution)
- Theoretical prediction (analytical reference state; *Dietrich et al. 1996*)

Historical reconstruction

- Aerial photographs
- Historical documents (photographs, maps, written accounts)
- Quaternary geology (relict landforms & sedimentary deposits)
- Paleoecology (pollen, isotopes)



Yankee Fork, Idaho, 1910, pre-mining



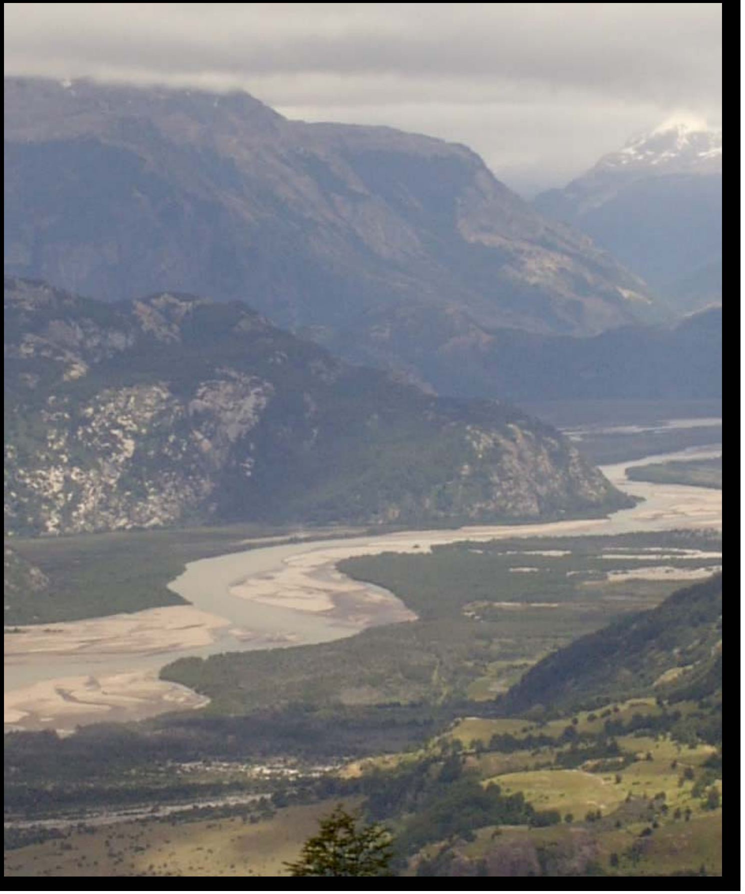
1984, post dredge mining

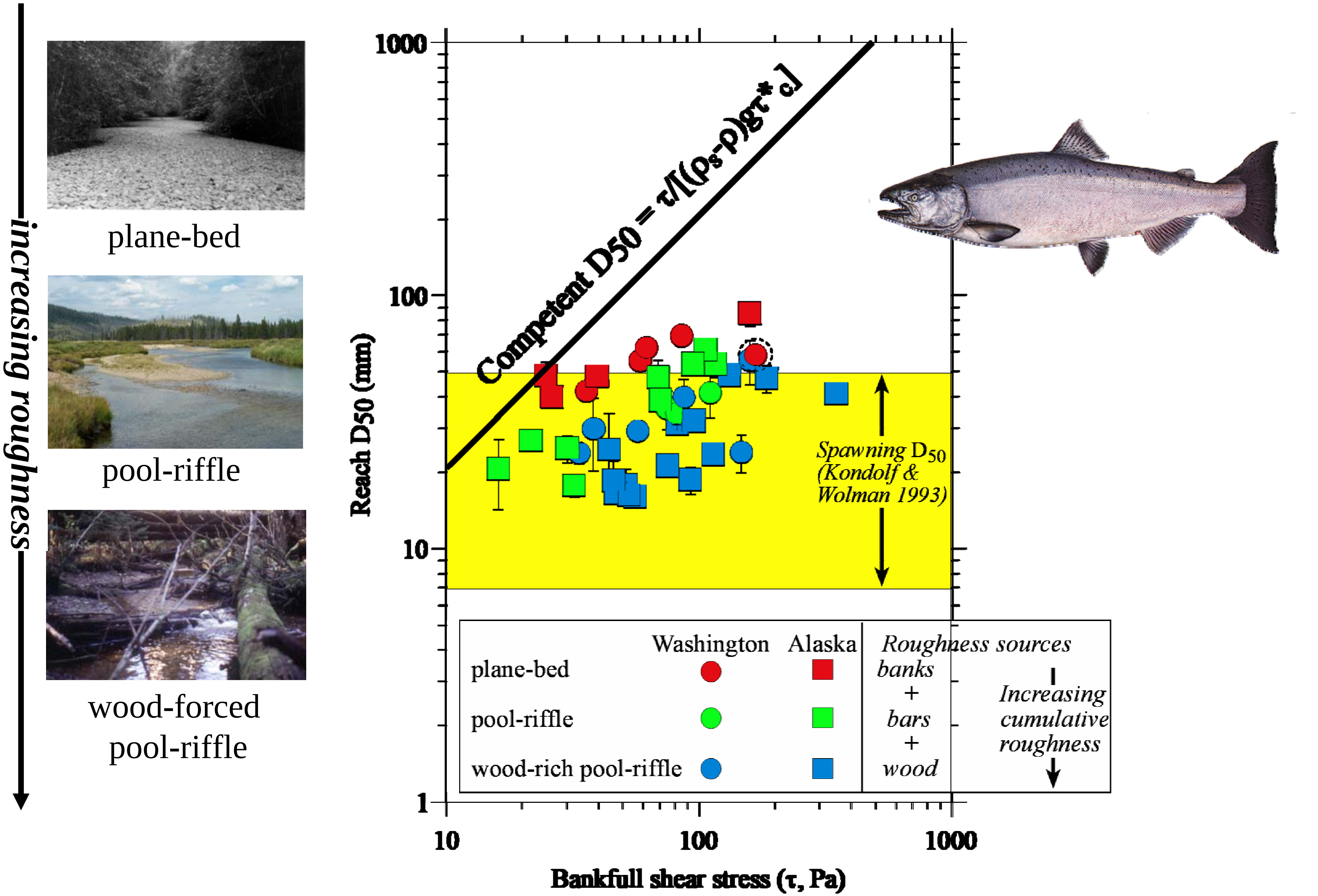
Analogue (paired basin)

- Space-for-time substitution
- Similarity in basin size, physiography and geologic history, but difference in anthropogenic impact.

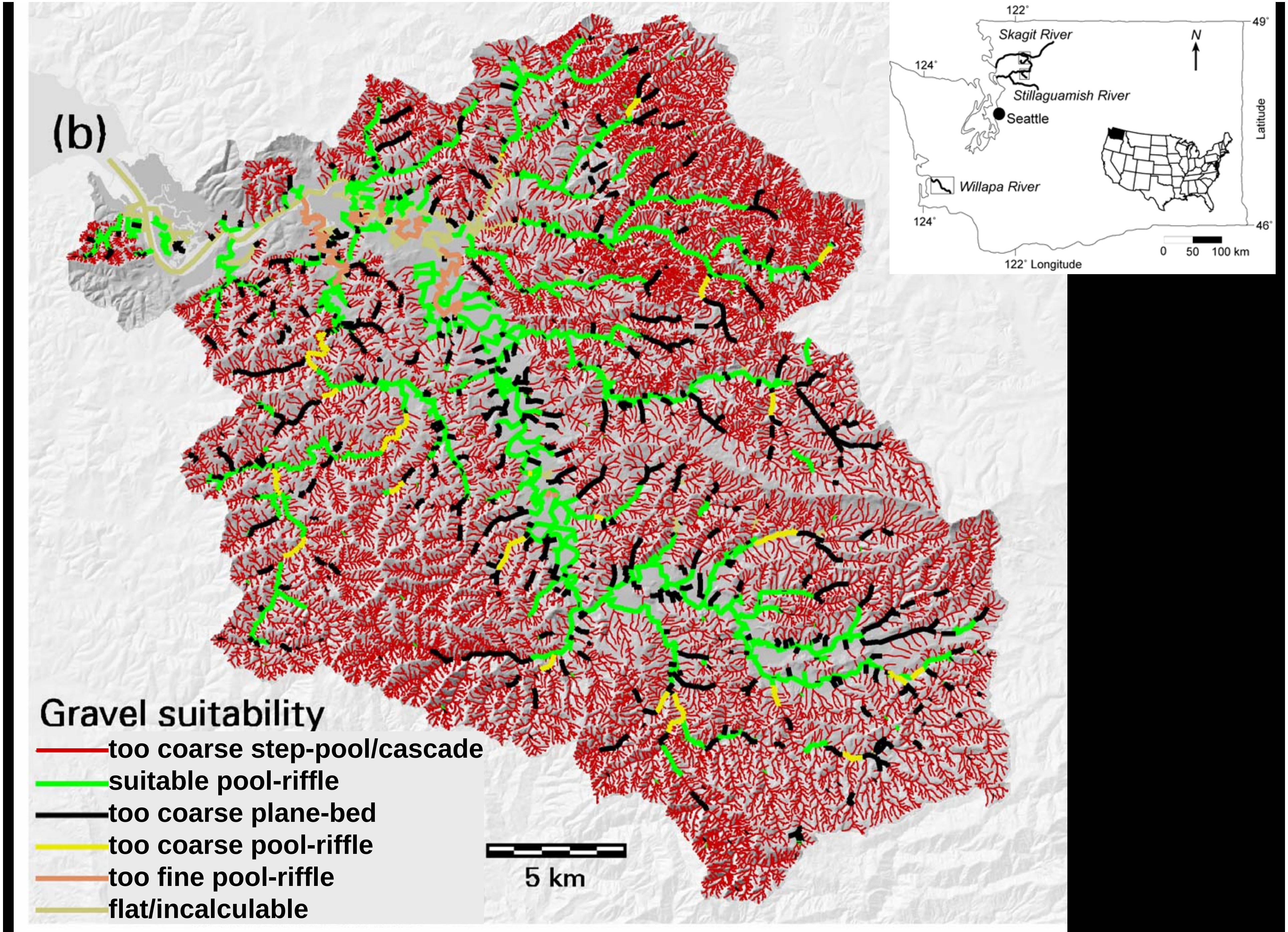
Theoretical prediction (analytical reference; Dietrich et al. 1996)

- Mechanistic model for predicting expected conditions.
- Provides a reference (end-member condition) from which to interpret causes for deviation from predicted values.





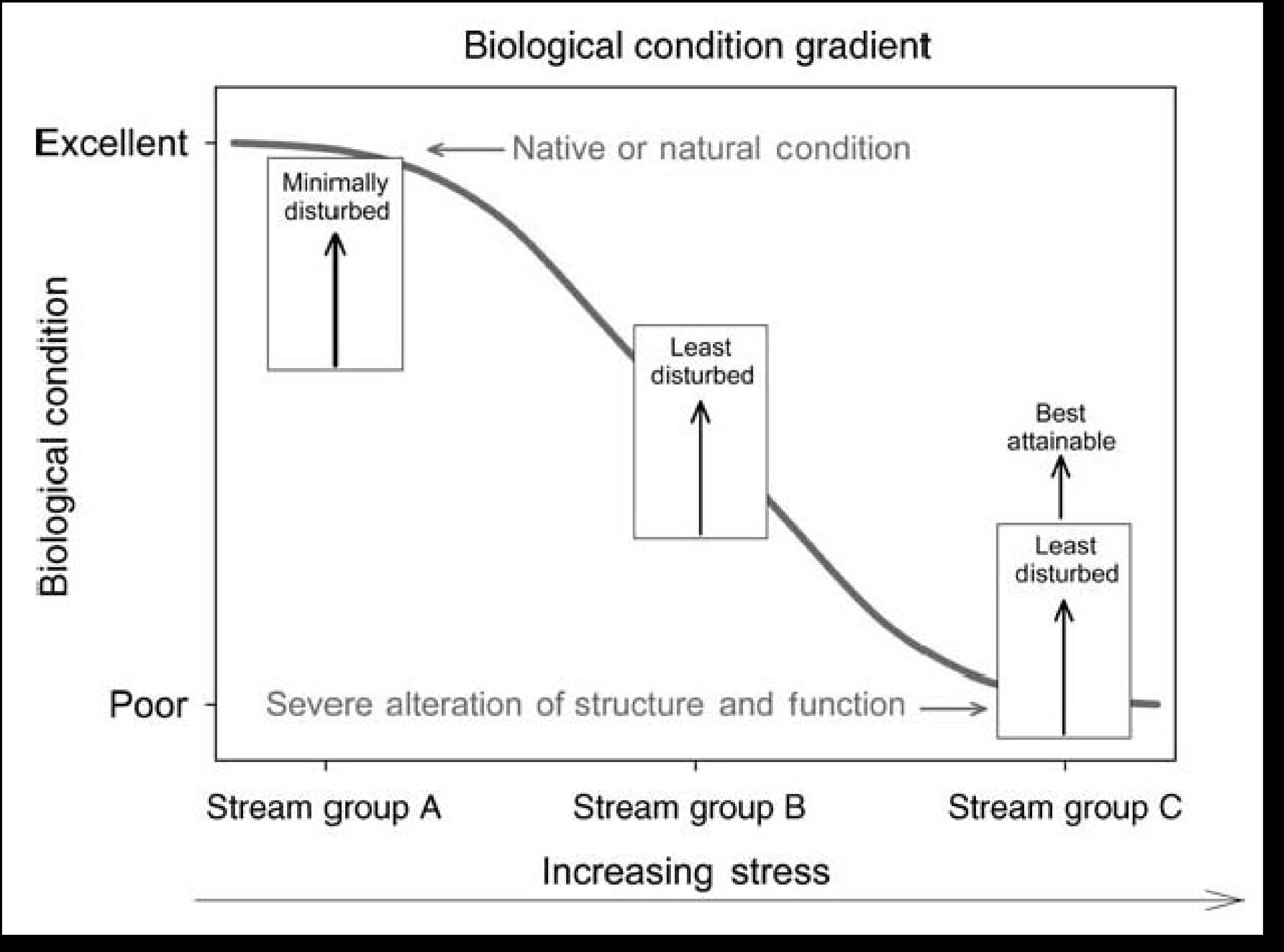
(*Dietrich et al. 1996; Buffington and Montgomery 1999*)



(*Buffington et al. 2004*)

Method	*Pro*	*Con*
Historical	• Longer-term view of the river (human & geologic time scales).	• Data incomplete or limited in space & time.
Analogue	• Allows direct comparison and contemporaneous measurements between sites over multiple spatial & temporal scales. • Can incorporate natural variability by selecting population of sites.	• Similitude not exact (no perfect control). • Few undisturbed sites remain world wide, particularly for larger rivers. • Long-term data rare & typically for small-scale basins.
Theoretical	• Process based (allows quantitative interpretation & hypothesis testing). • Can be coupled with DEMs & extrapolated across the landscape. • May avoid bias (professional judgment of what reference conditions “should be”).	• Parameter and model uncertainty & simplifications lead to prediction uncertainty. • Tradeoff between simple vs. complex models & static vs. dynamic predictions.

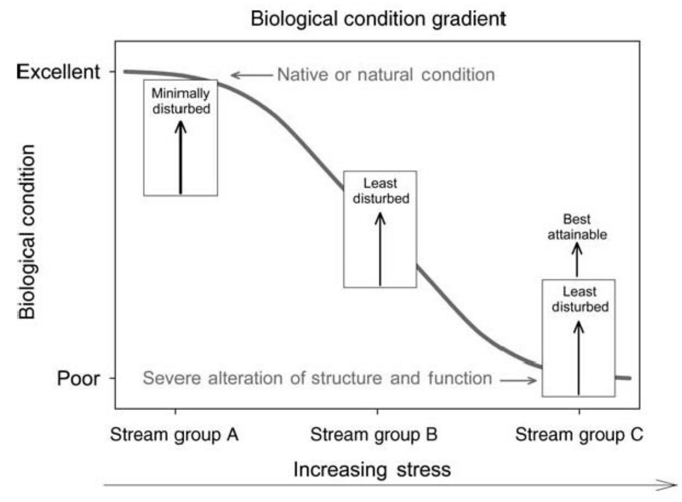
Distribution of conditions

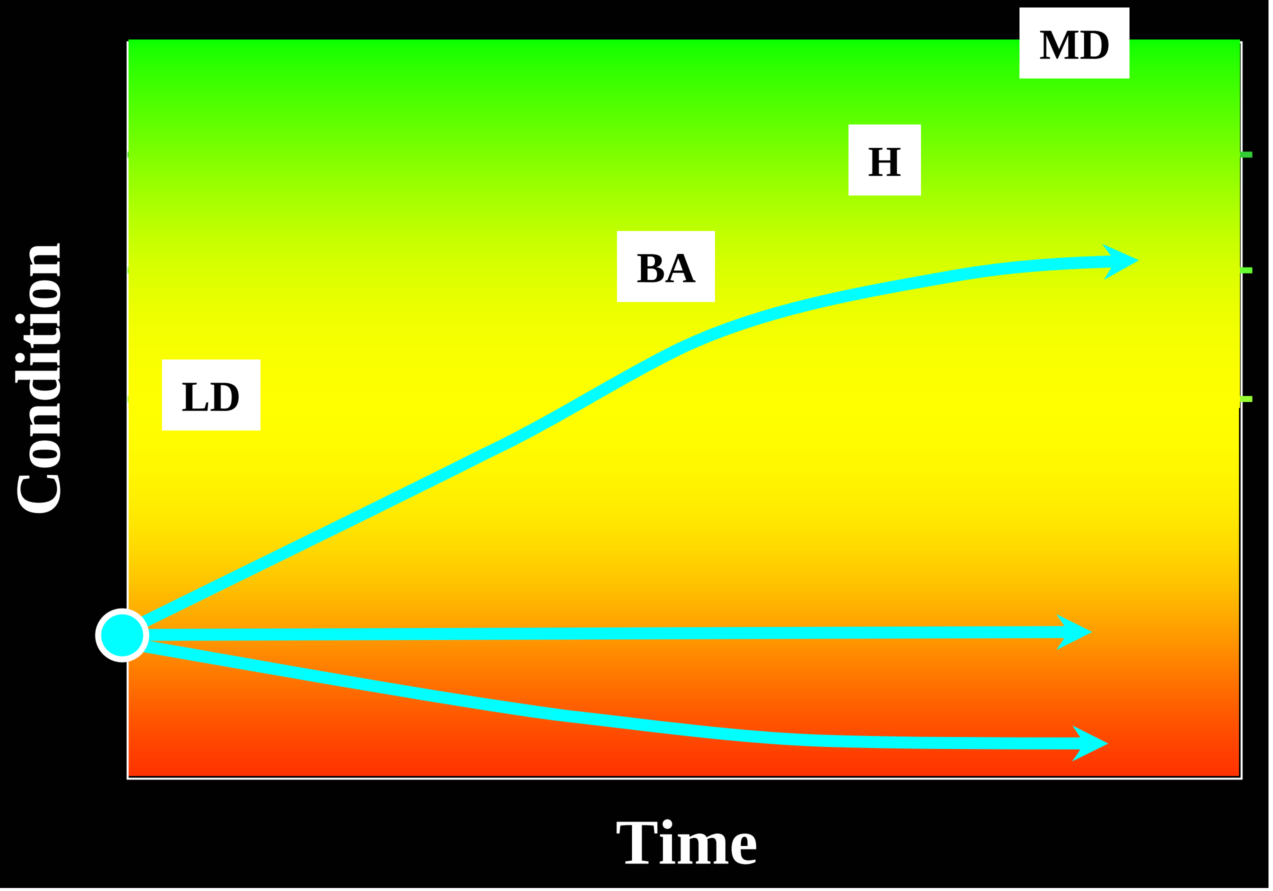


(Stoddard et al. 2006)

Multiple reference conditions

- Minimally disturbed – MD
- Historical – H
- Best attainable – BA
- Least disturbed – LD





(Jacobson 2008, modified from Stoddard et al. 2006)

Spatial & temporal scales

catchment

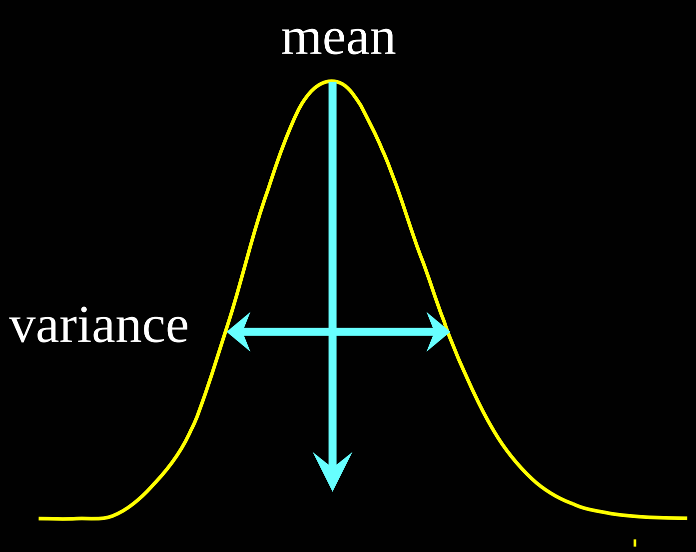
valley segment

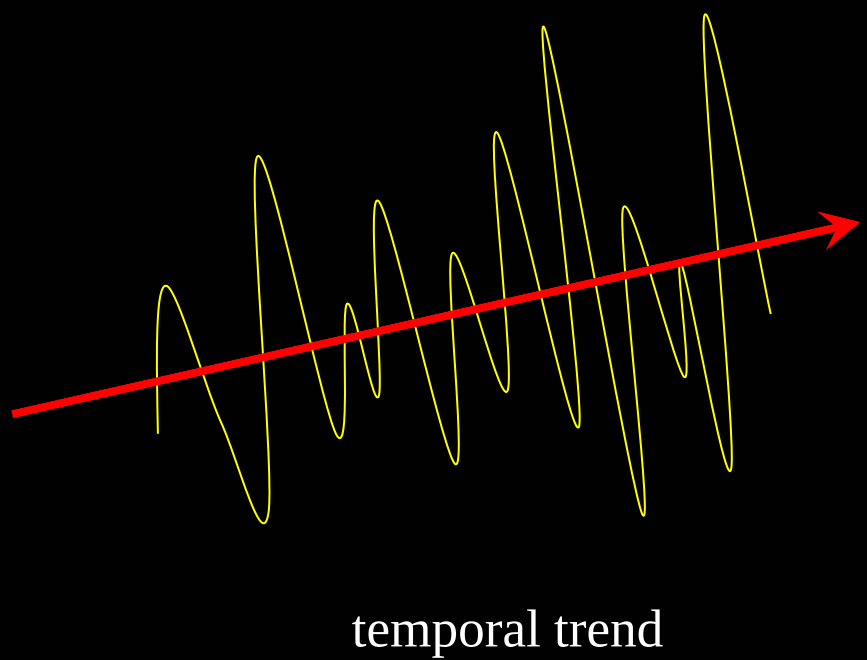
reach

patch

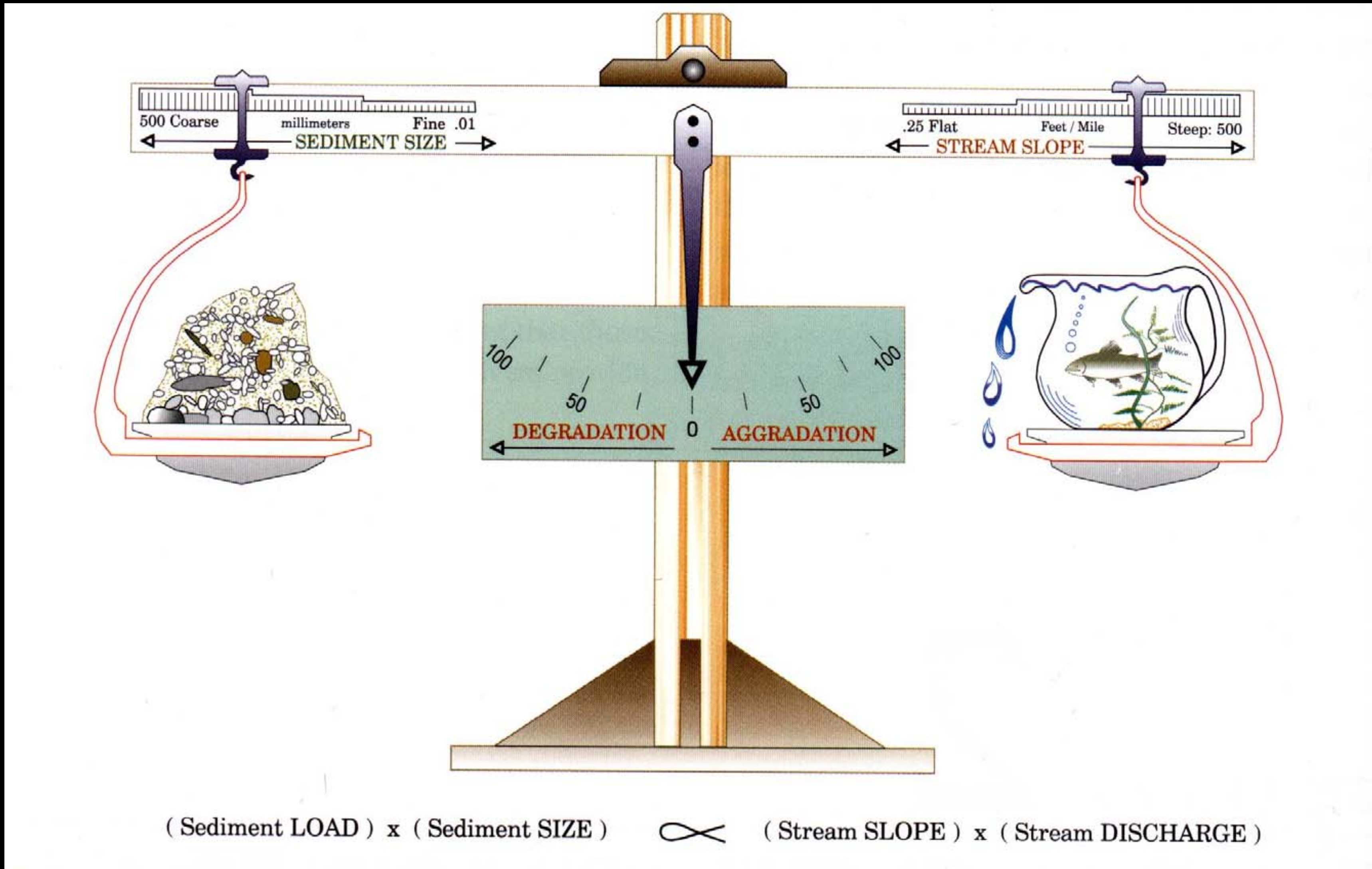
No single reference condition will satisfy all scales & species, so compromise is inevitable

Spatial & temporal variability



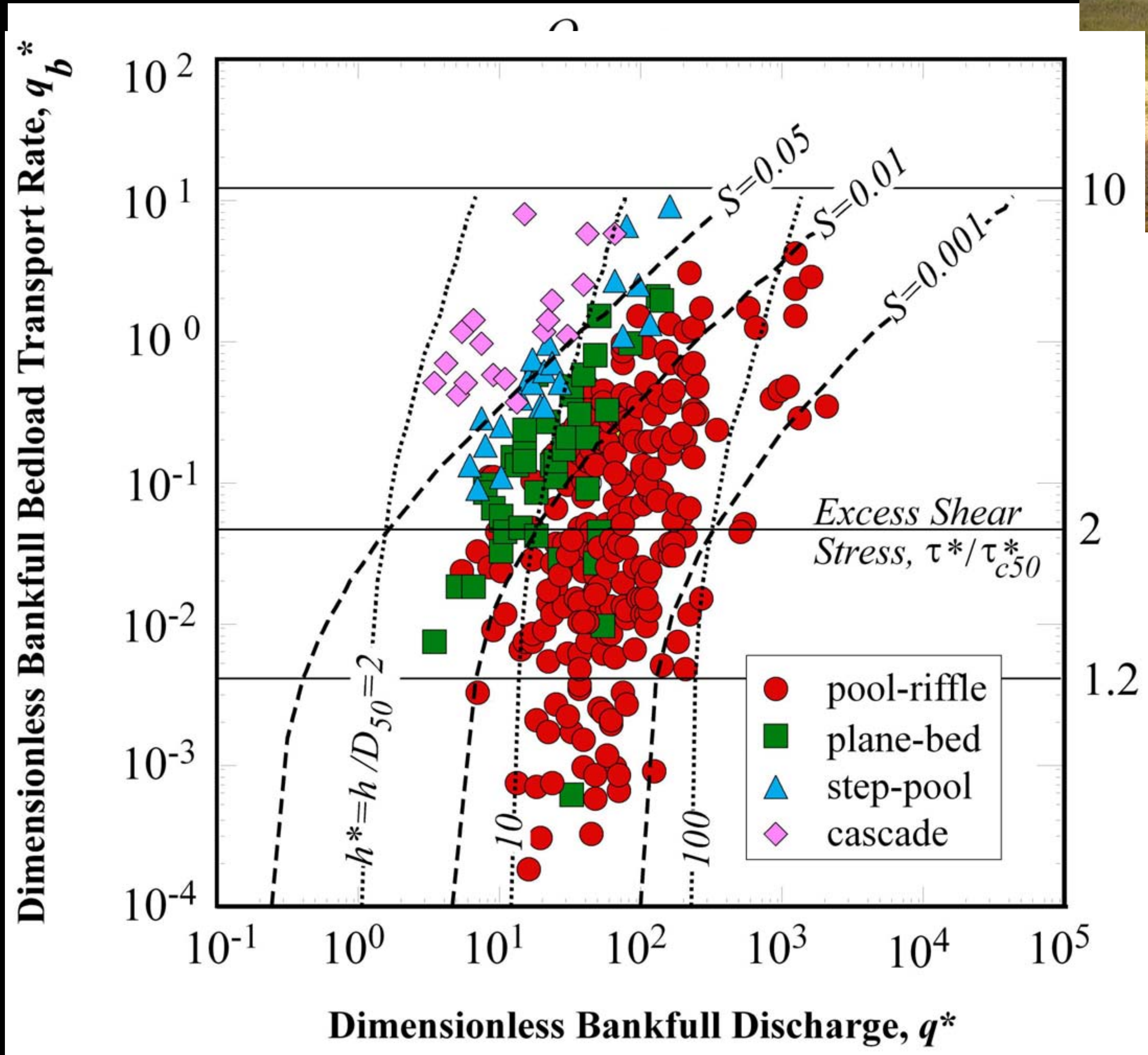


Channel morphology = balance between supply of water and sediment



(Rosgen 1996, after Gilbert 1917, Lane 1955, Schumm 1971)

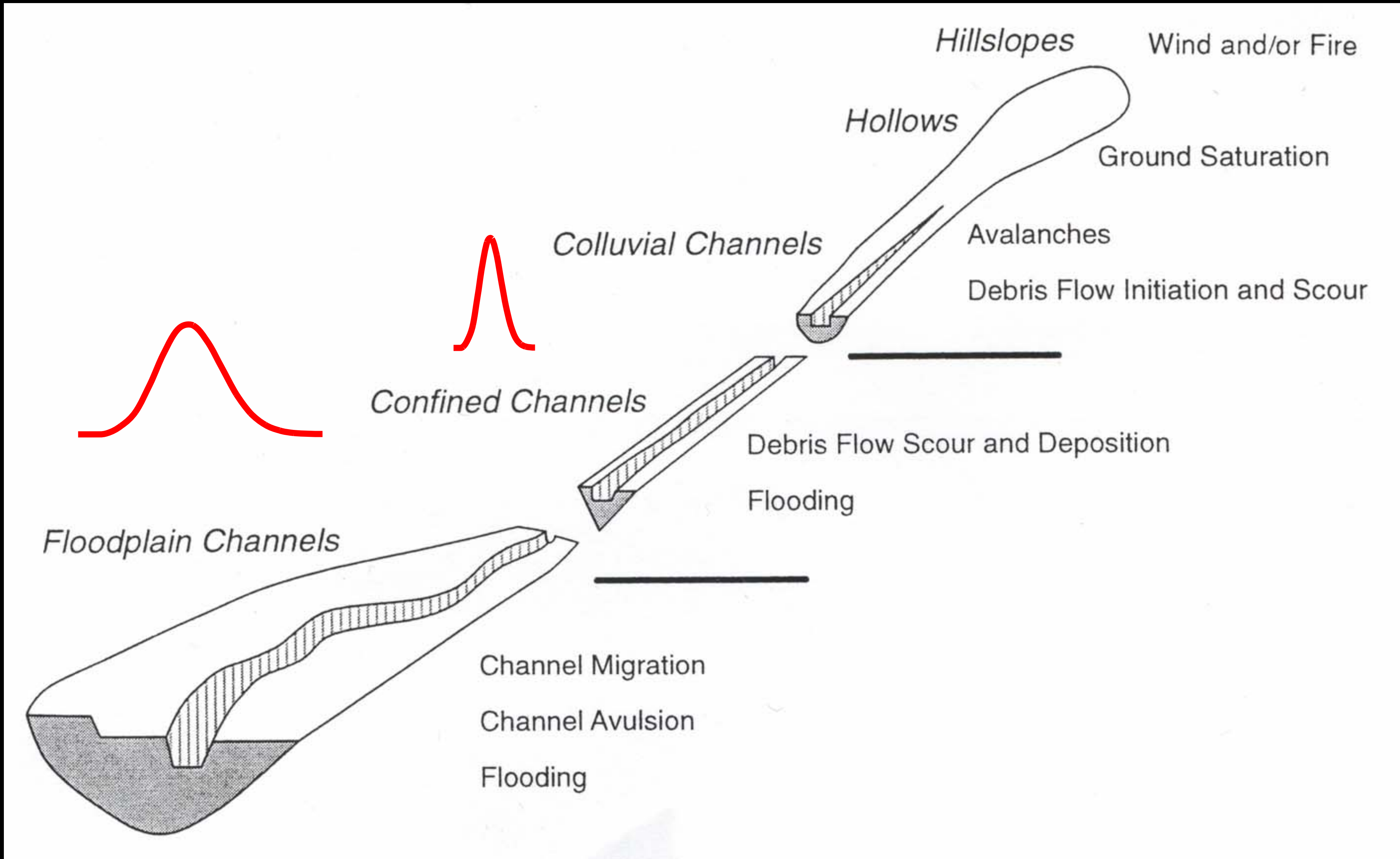
Channel response potential



Channel condition is dynamic and varies with physiography

(Buffington et al. 2003; Buffington & Parker 2005)

Channel morphology & location



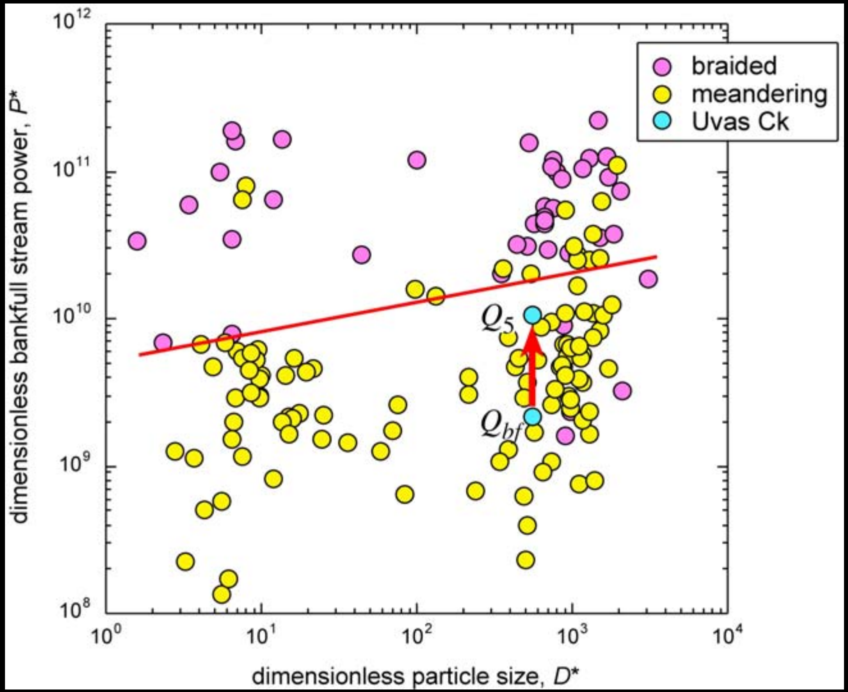
(*Montgomery*, 1999)

Dynamic variability and channel restoration

Uvas Creek (*Kondolf et al.* 2001)

Bankfull design (Q_{bf})

Response to 5-yr flood (Q_5)



(Buffington & Parker 2005)

Summary & conclusions

- Three methods exist for determining reference conditions (historical, analogue, theoretical).
- Where possible, each of these methods should be used since they may provide different types of information, or may provide complimentary lines of evidence that could strengthen management decisions.
- Reference conditions are not single-value static states, but are dynamic conditions with a range of variability.
- Successful management strategies must consider the spatial and temporal variability of biophysical processes to understand both the current status and the potential response to future disturbances.

Additional questions

- To what degree is ecology itself part of the definition of reference conditions (forests, beaver, wolves, etc.)?
- Reference conditions may not always be ‘good’ ecologically (e.g., naturally high sediment loads of fine material, high water temperatures, etc.)
    - Do current management policies/goals allow for this?
- Channel condition depends on basin history (timing, magnitude, and sequence of past disturbances)
    - Is it necessary to reconstruct this history to successfully treat/restore channel condition, and if so, is this feasible?
- Assessing dynamic variability and channel response potential to future disturbances requires a holistic view of the catchment (i.e., a given river reach does not operate in isolation from the rest of the river network & upstream landscape).
    - Does this require complex spatiotemporal models and a larger degree of investment than is currently being made?