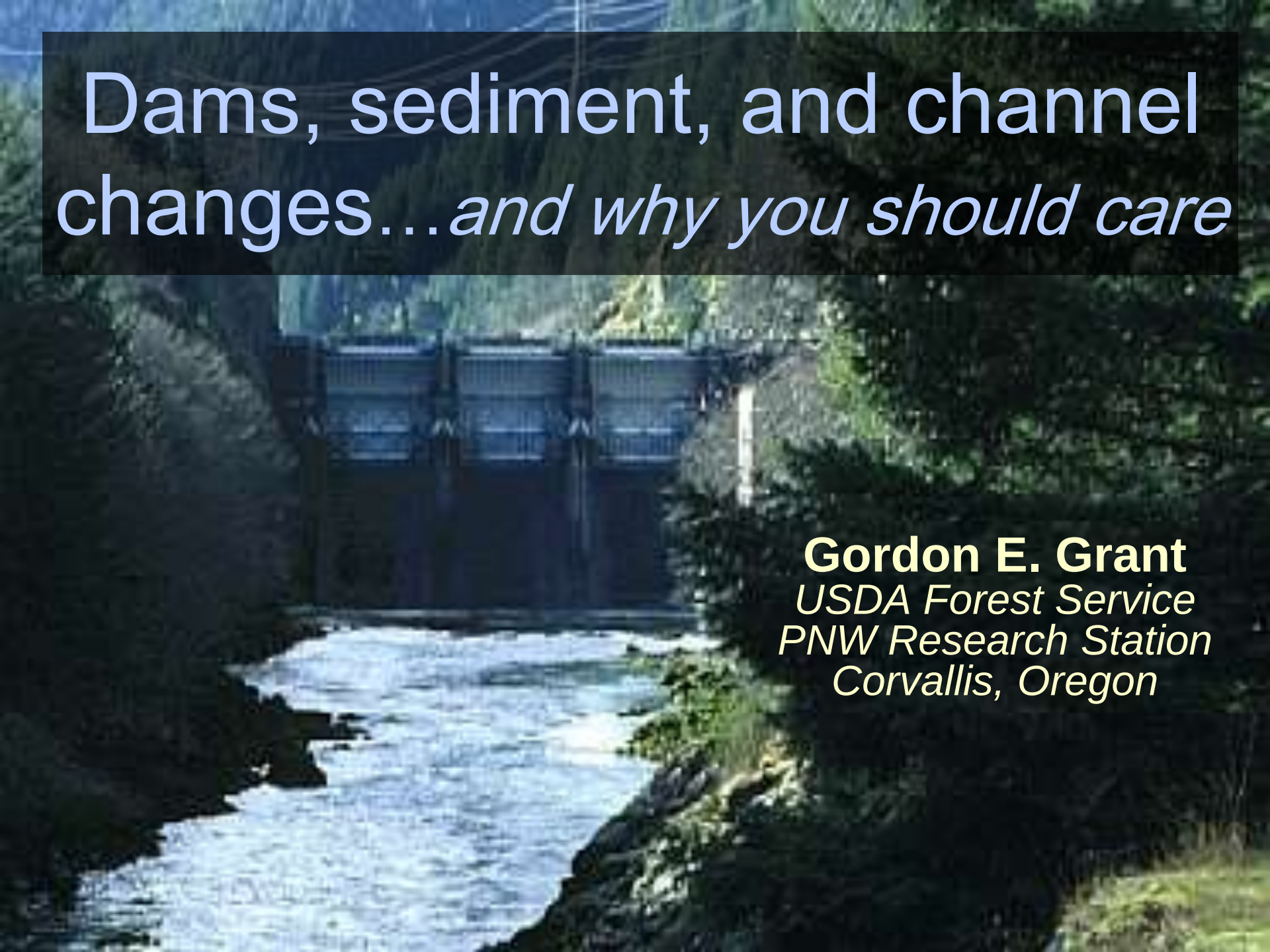
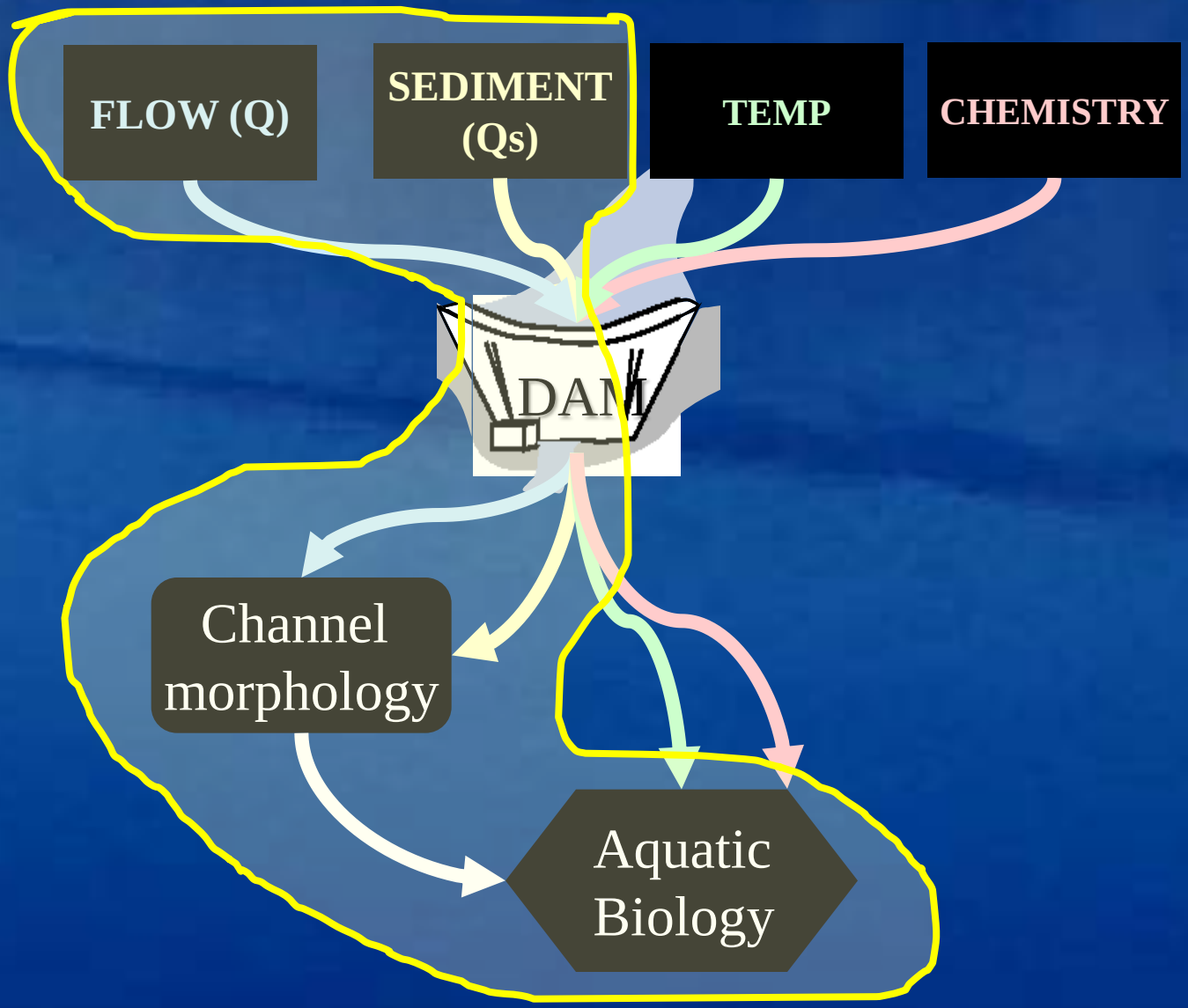
Dams, sediment, and channel changes…*and why you should care*

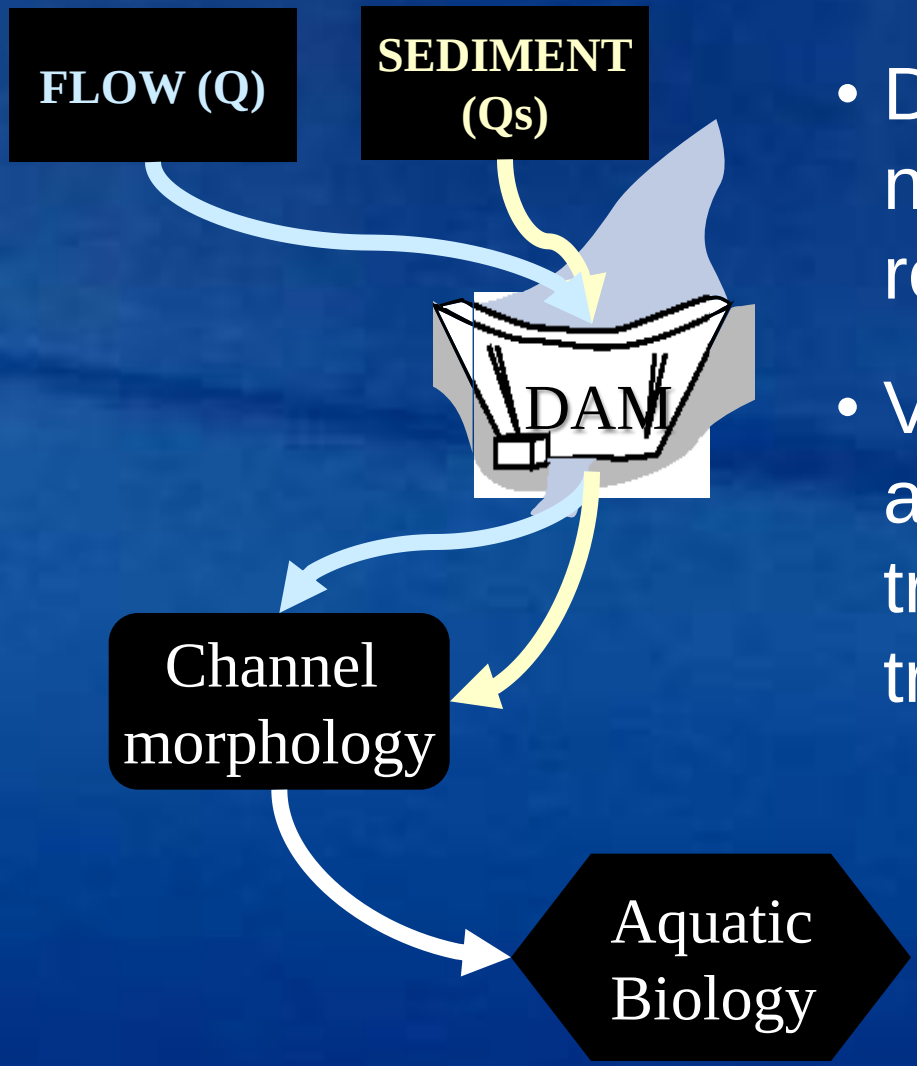


Gordon E. Grant
USDA Forest Service
PNW Research Station
Corvallis, Oregon

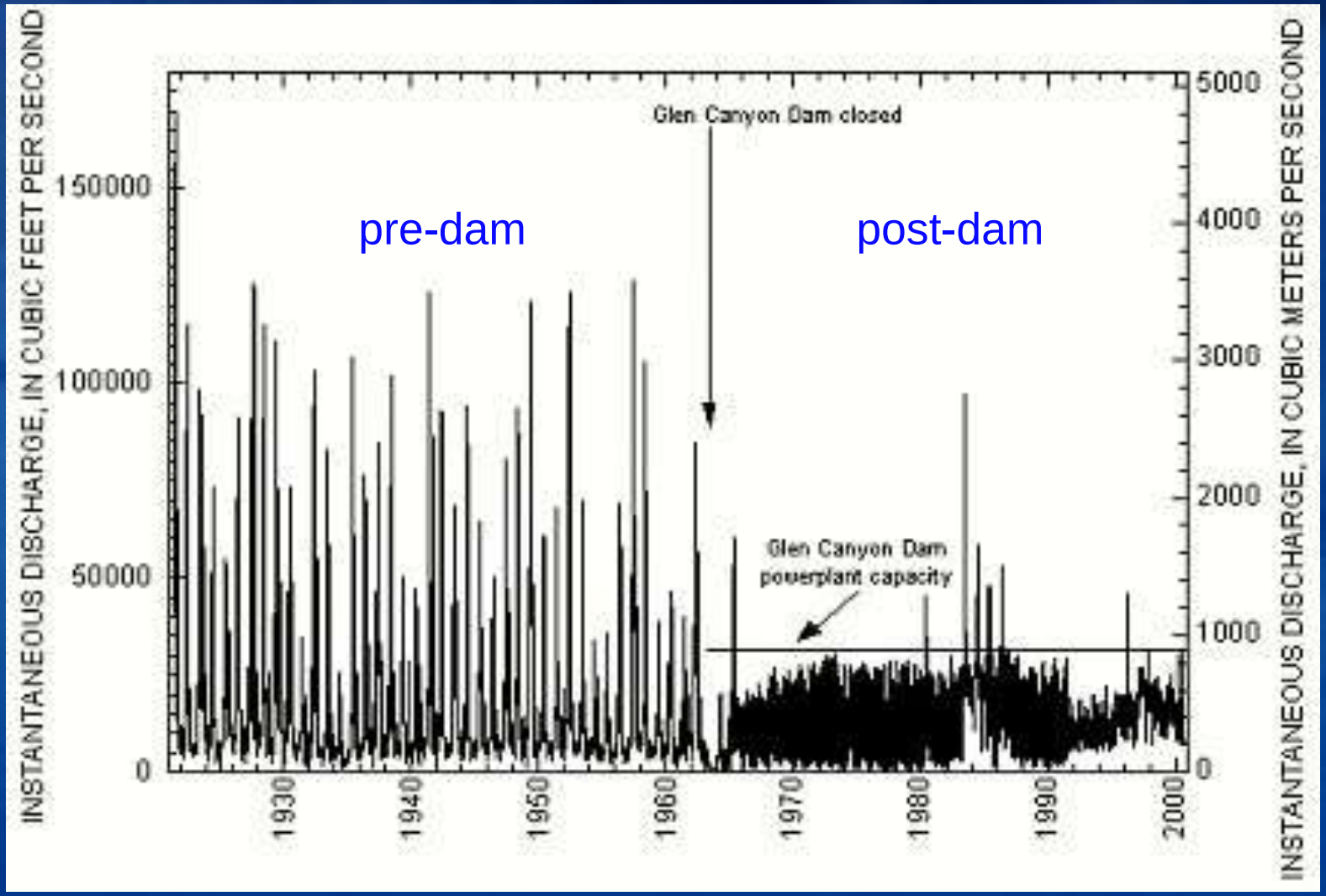
Dam effects on river regimes



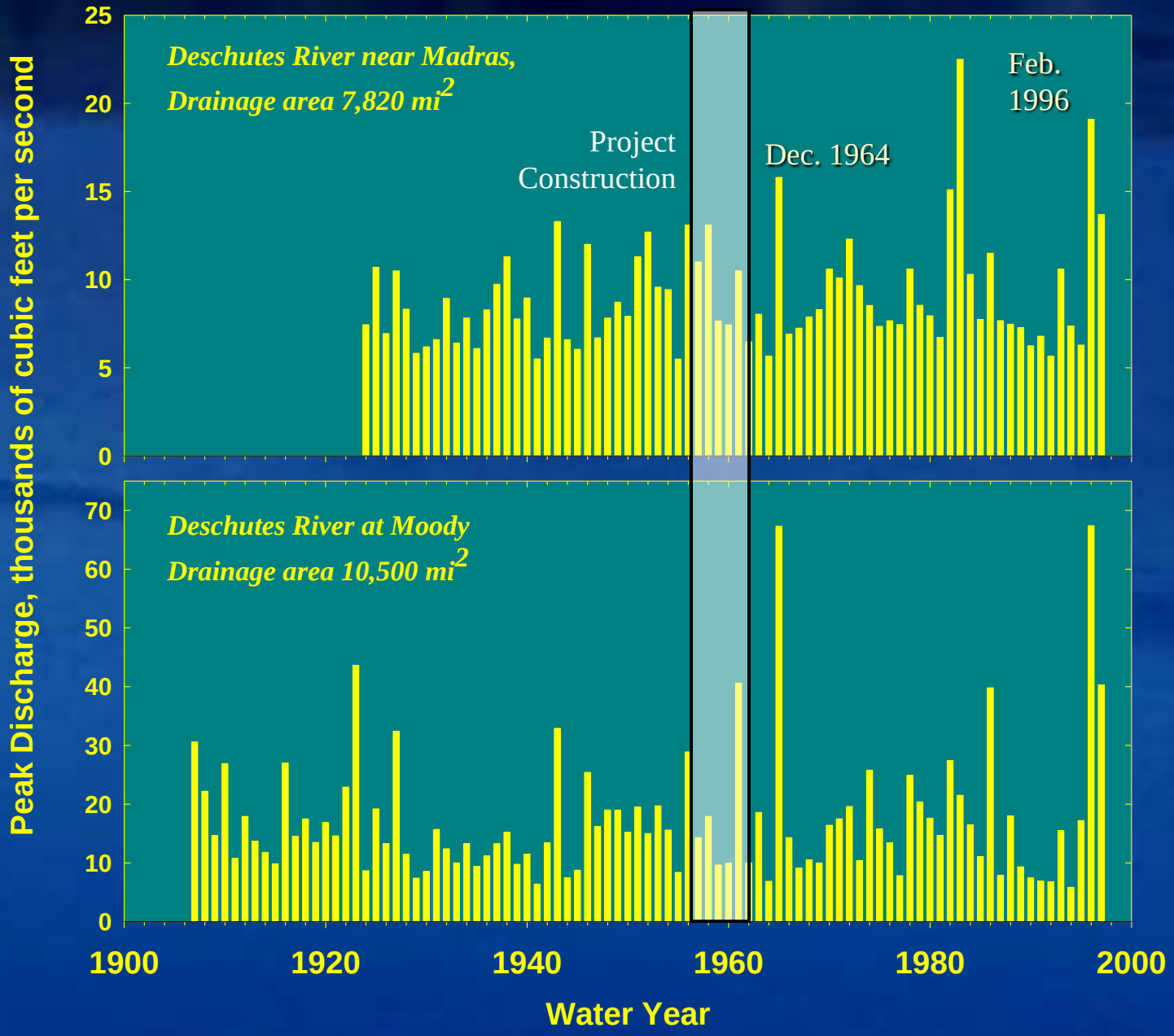
Dam effects on river regimes



- Dams may or may not affect the flow regime
- Virtually all dams affect the sediment transport regime by trapping sediment



Discharge record 1920-2000, Colorado River below Glen Canyon Dam



Pre- and post- dam discharge record for Deschutes River, Oregon

Dams trap sediment

Cougar Reservoir drawdown 2002, SF McKenzie River, Oregon

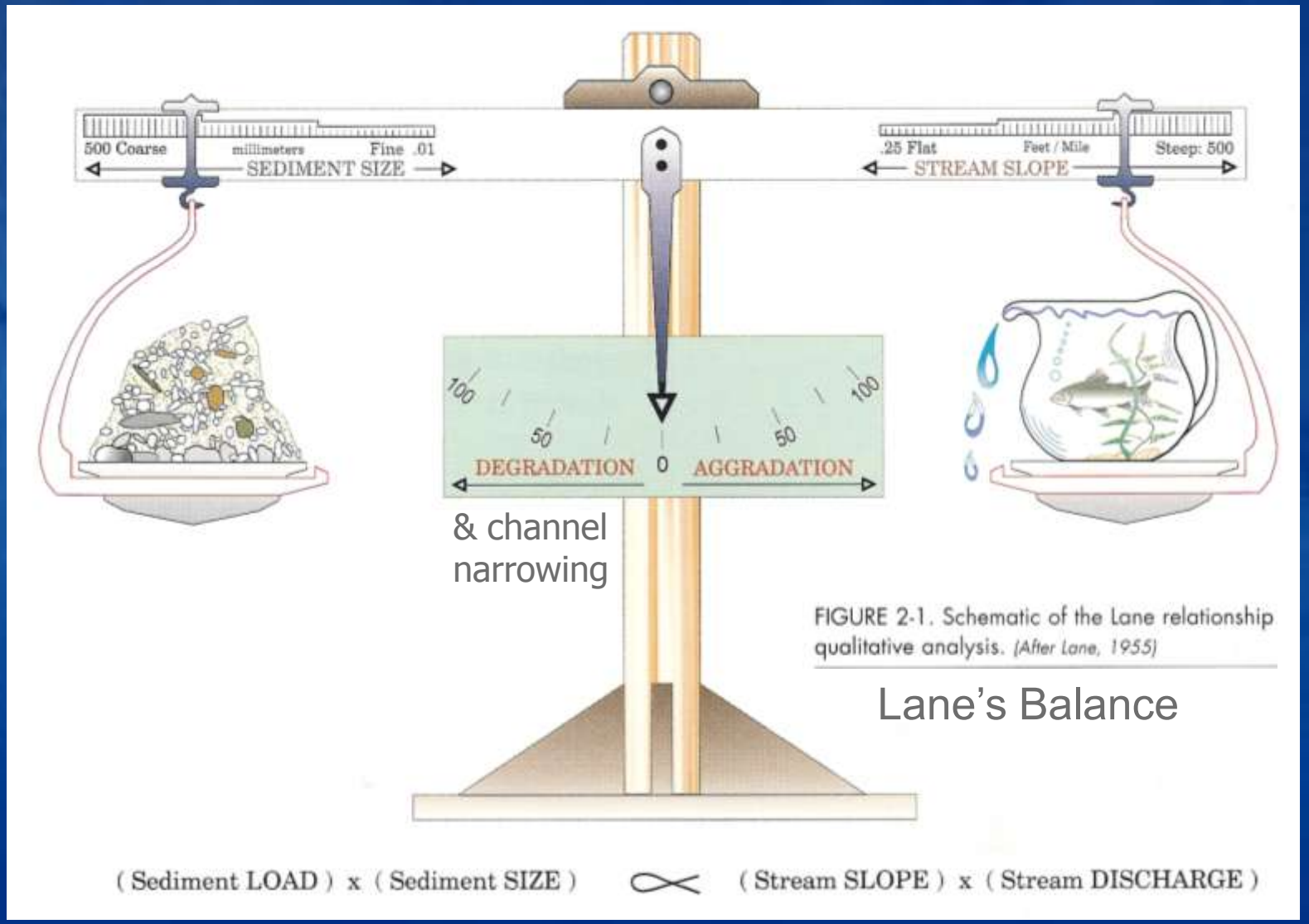
If we understand how dams change flow and sediment regimes, can we predict downstream channel response?

Principle of River Equilibrium

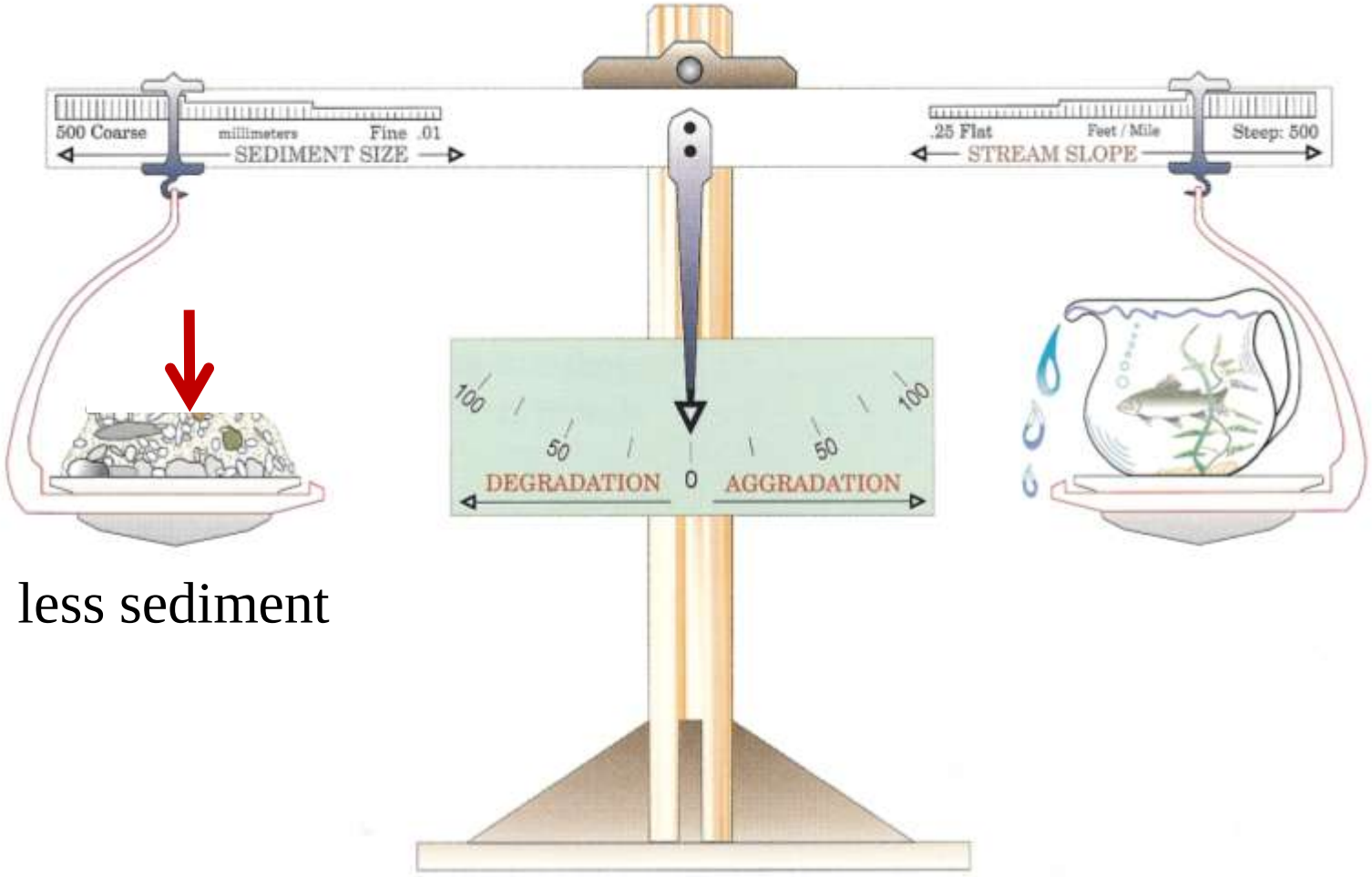
A graded stream responds to a change in conditions in accordance with Le Chatelier's general law:—"if a stress is brought to bear on a system in equilibrium, a reaction occurs, displacing the equilibrium in a direction that tends to absorb the effect of the stress."

J. Hoover Mackin, 1948. The concept of the graded river. GSA Bulletin; v. 59; no. 5; p. 463-512; DOI: 10.1130/0016-7606(1948)59[463:COTGR]2.0.CO;2

Using Lane's Balance to predict downstream changes

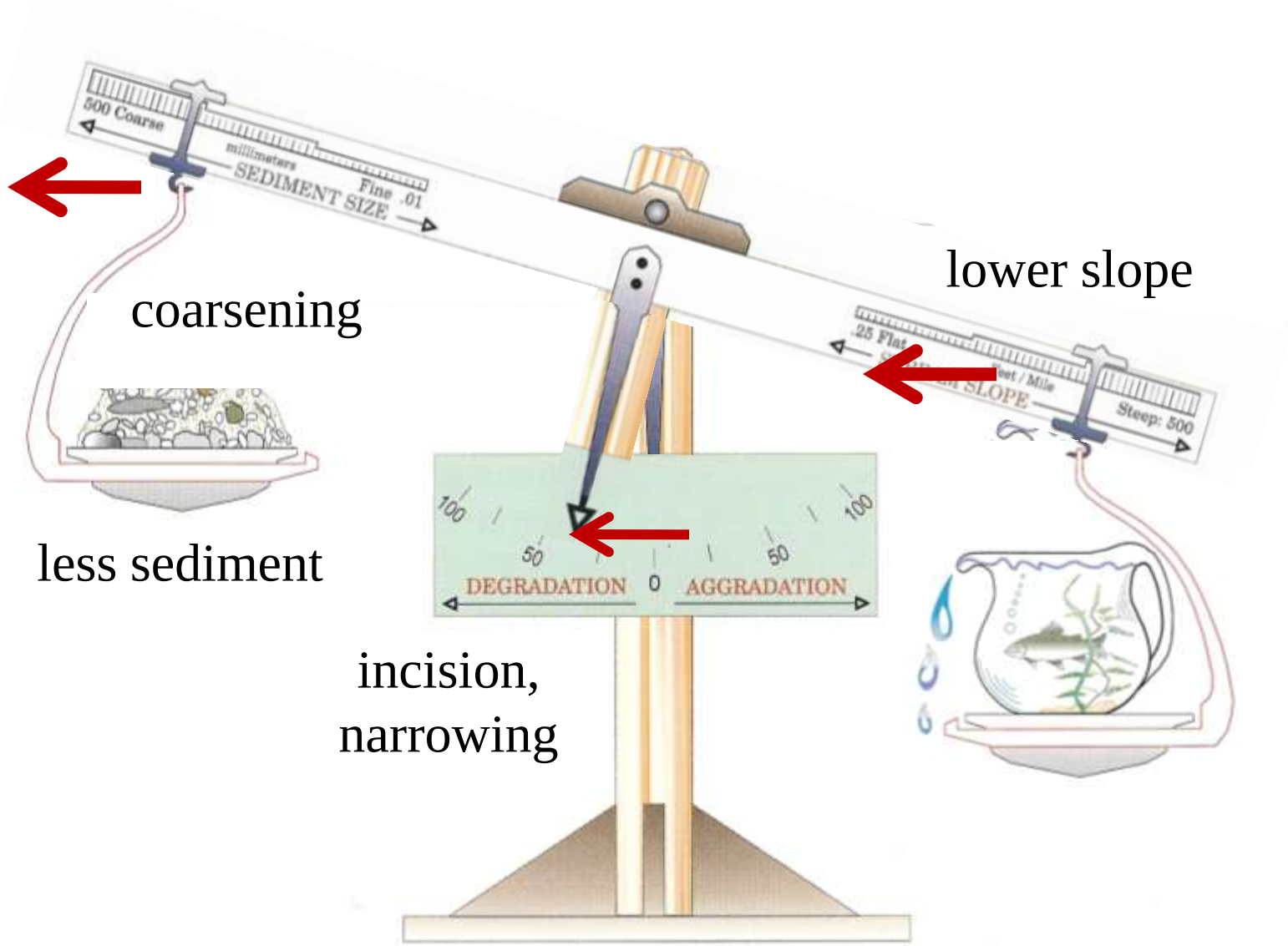


Applied River Morphology, Dave Rosgen, 1996

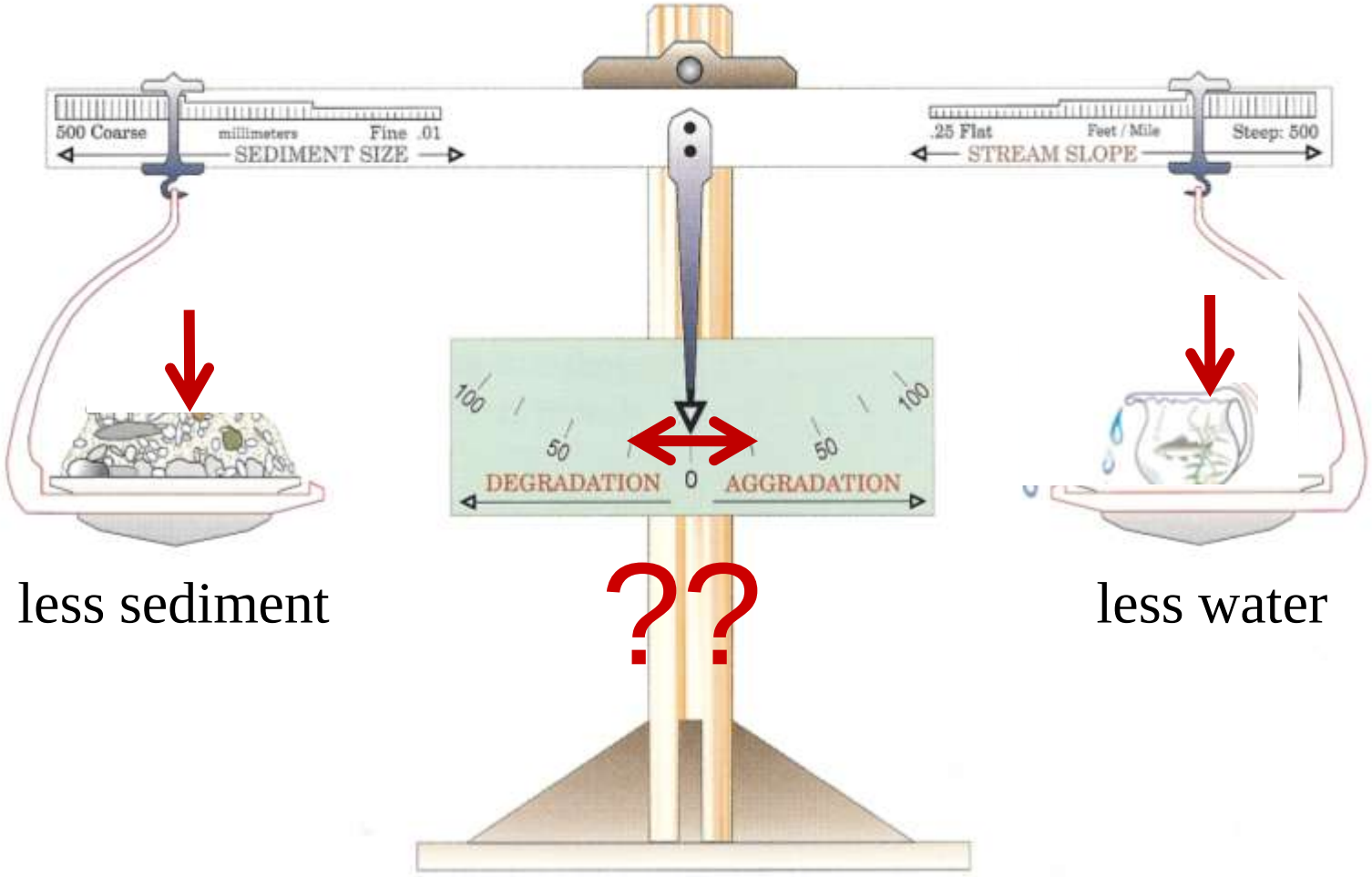


less sediment

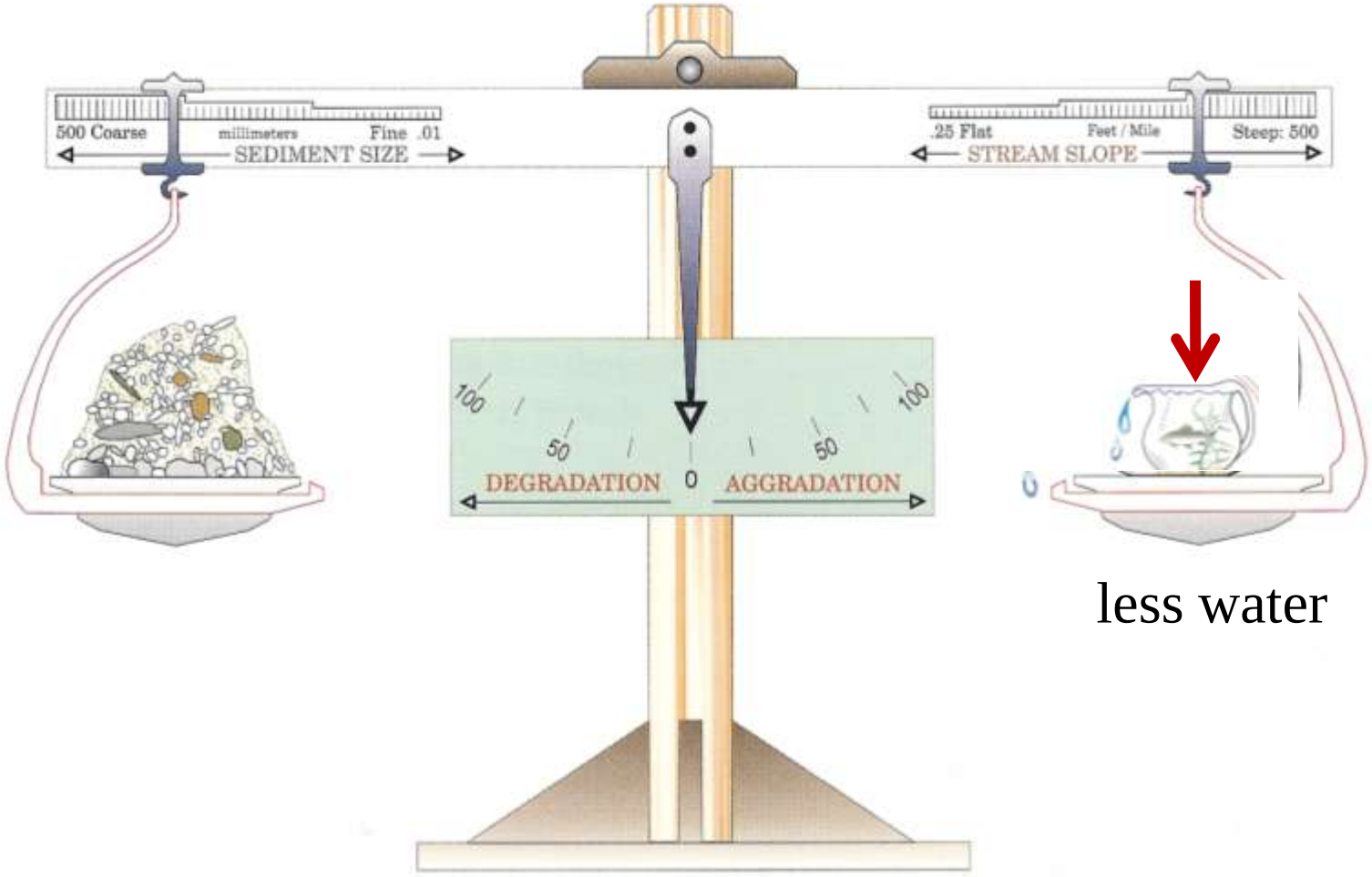
A. Dam traps sediment, no change to flow



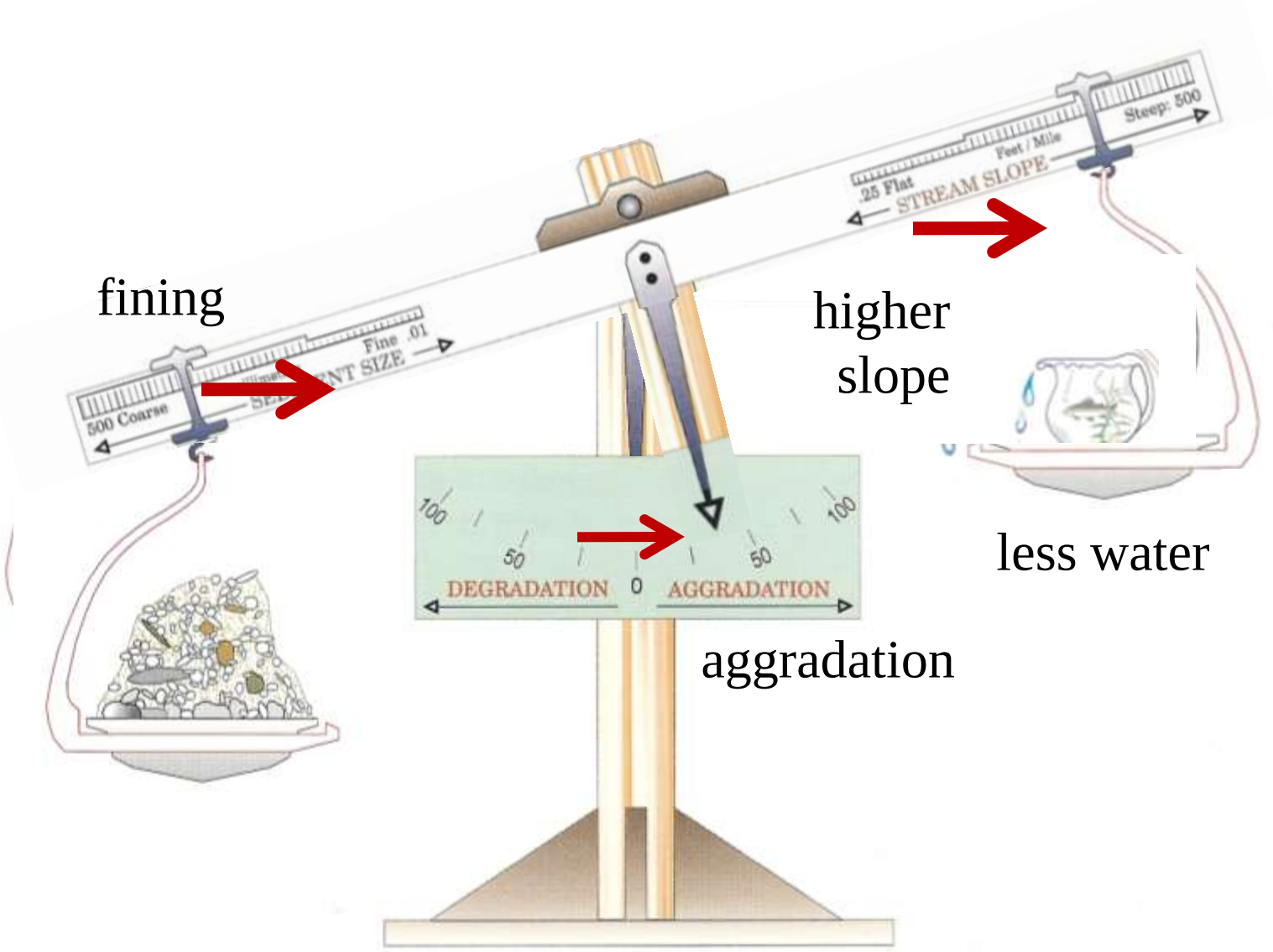
A. Dam traps sediment, no change to flow



B. Dam traps sediment and reduces flows



C. Dam reduces flows, sediment influx below dam



C. Dam reduces flows, sediment influx below dam

Textural coarsening

Clackamas River, Oregon

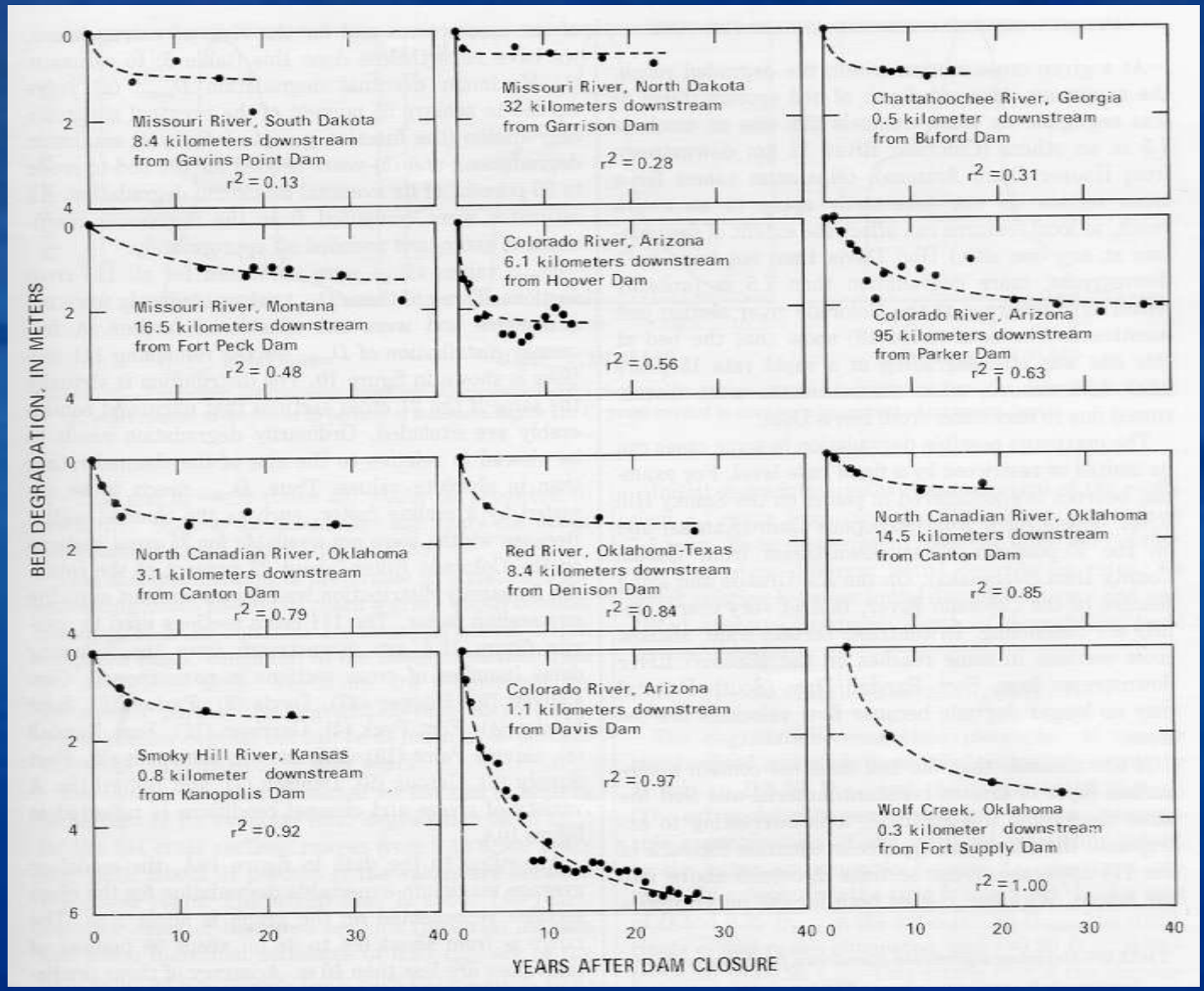
Incision / bed degradation

Arno River at Empoli

Large decrease in eddy sand bars

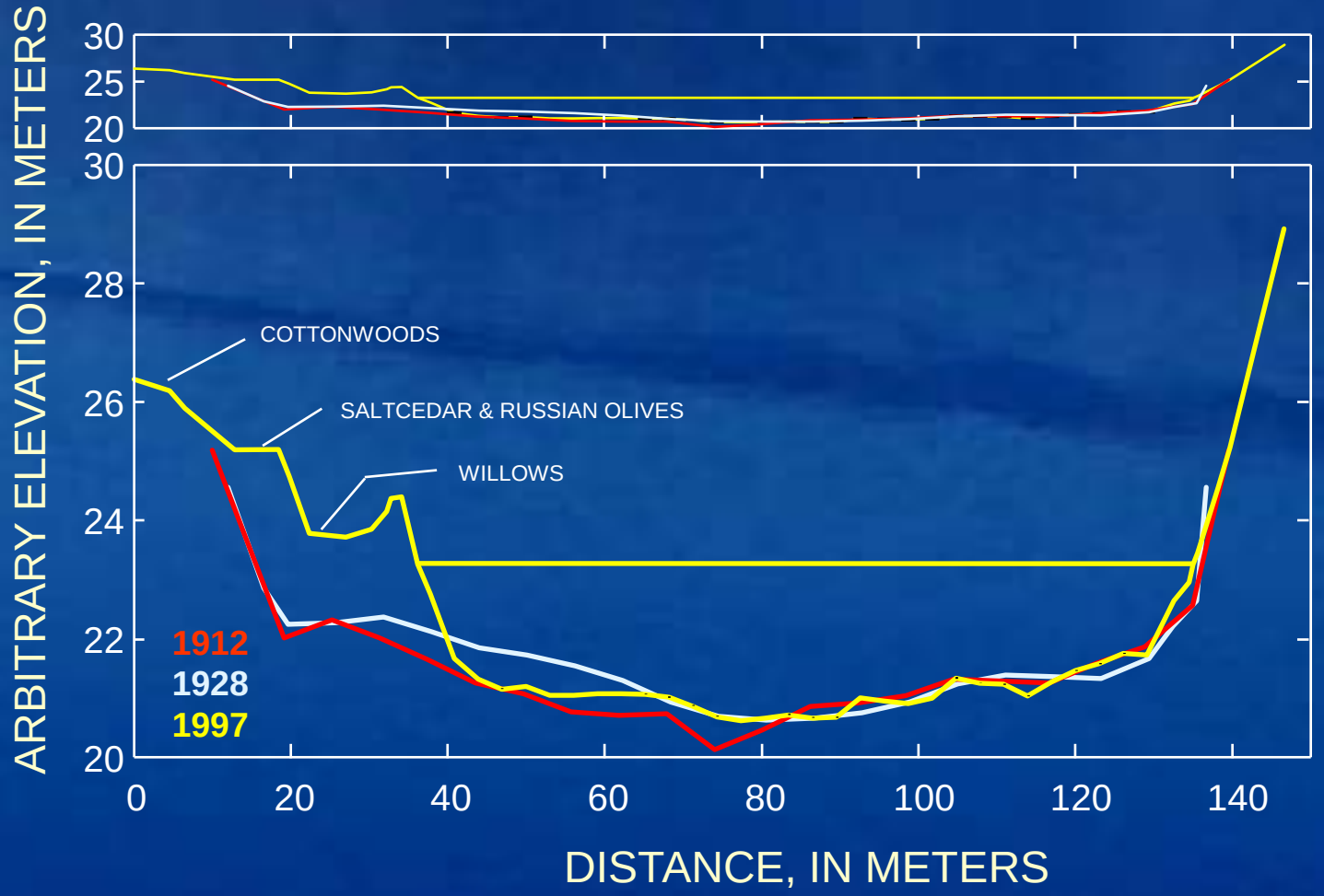
Grand Canyon

Post-dam bed degradation



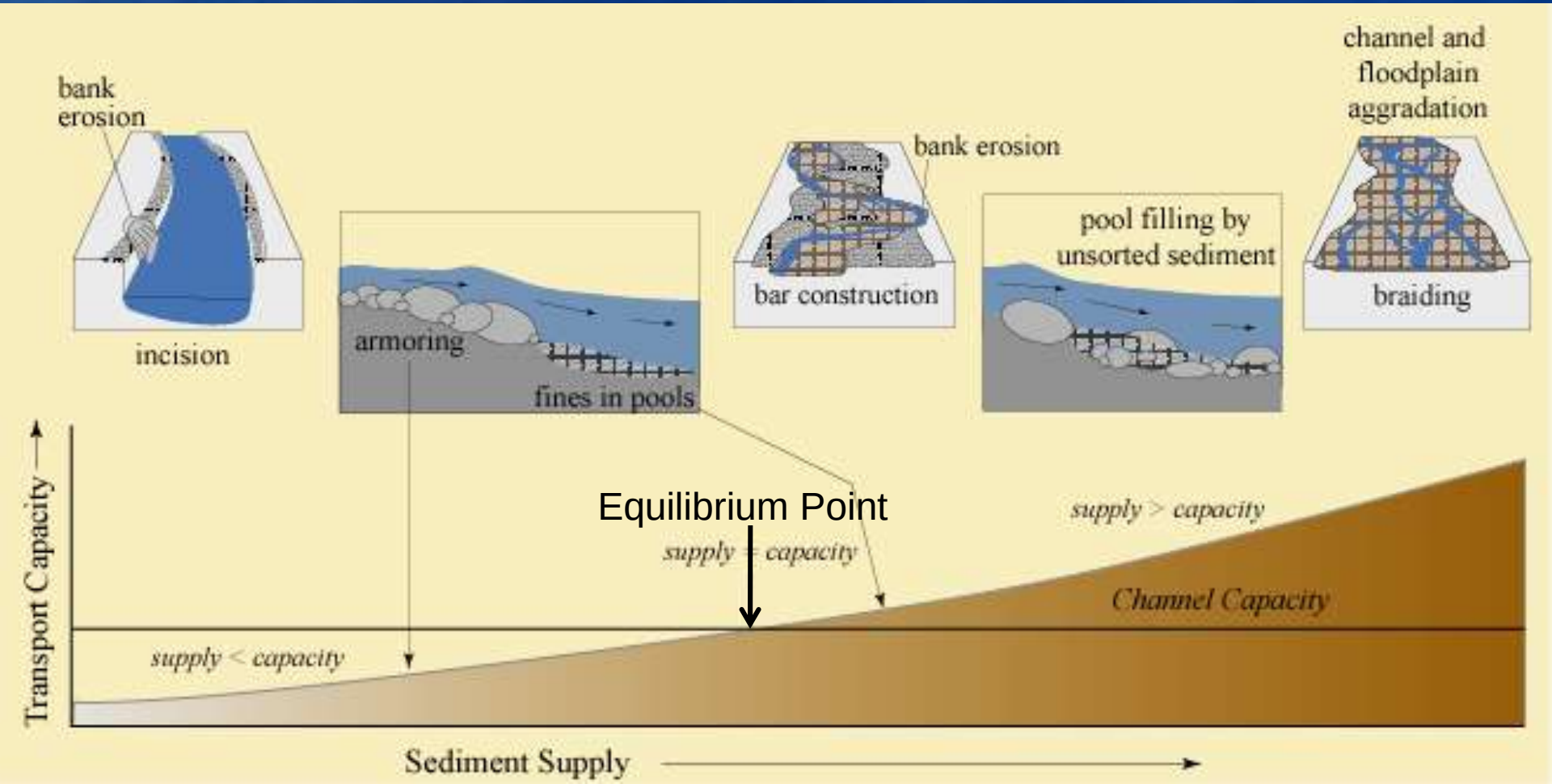
Williams & Wolman, 1984

Channel narrowing

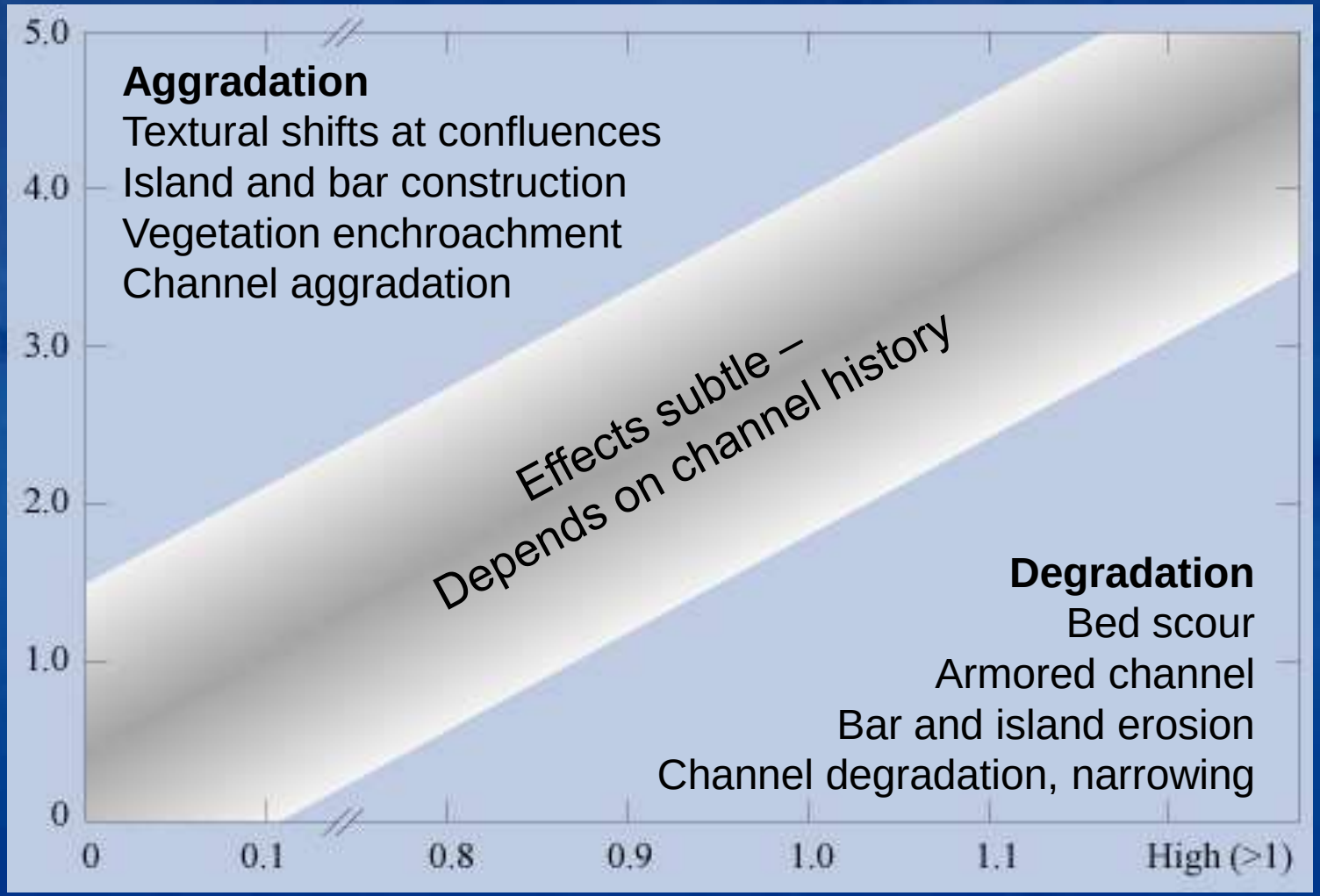


Green River, Utah; Grams and Schmidt, unpublished data

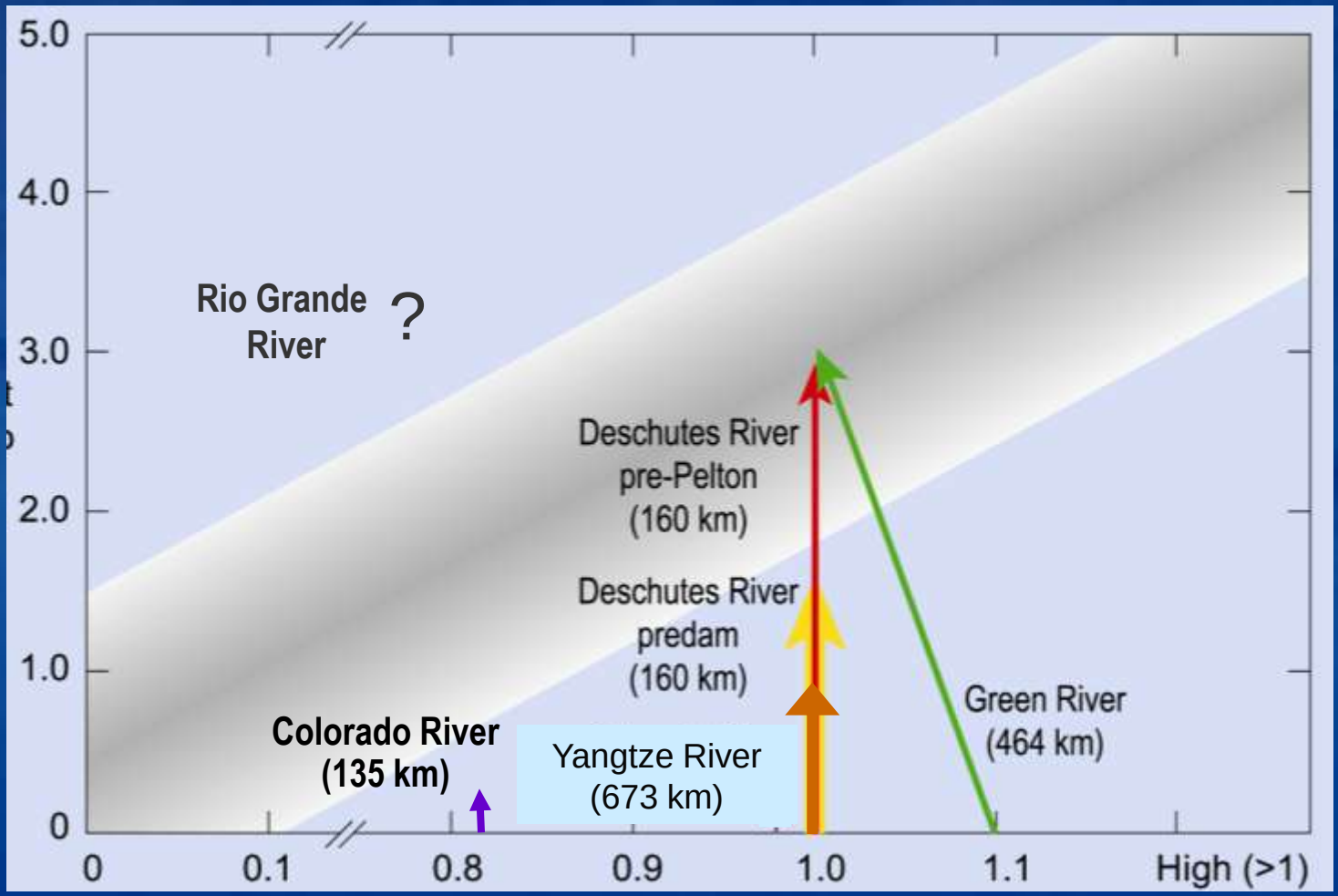
Framework for downstream channel response



How do we bring hydrologic and sediment transport effects together?



Δ Sediment Supply

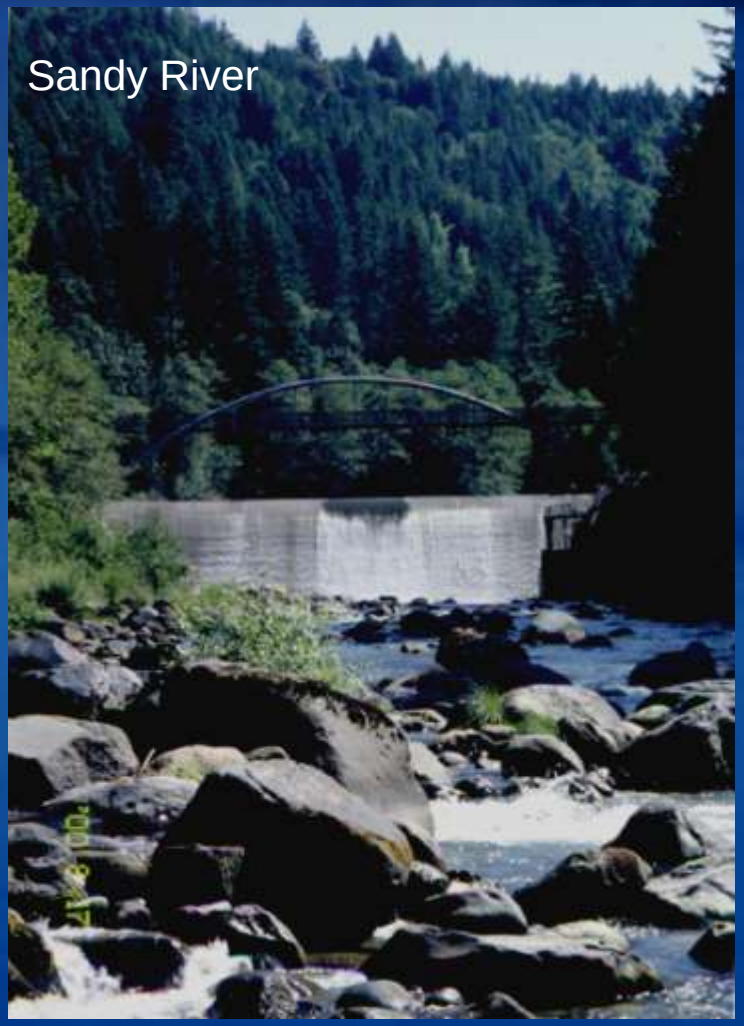


Δ Transport Capacity

A summary of sorts…

- Although dams change water and sediment regimes, the nature and direction of those changes depends on the dam itself and how it's operated
- Trajectories of downstream change are semi-predictable using simple analytical models
- Changing flow and sediment regimes translate to changes in channel form and aquatic habitat


For additional information
please visit us at:
www.fsl.orst.edu/wpg

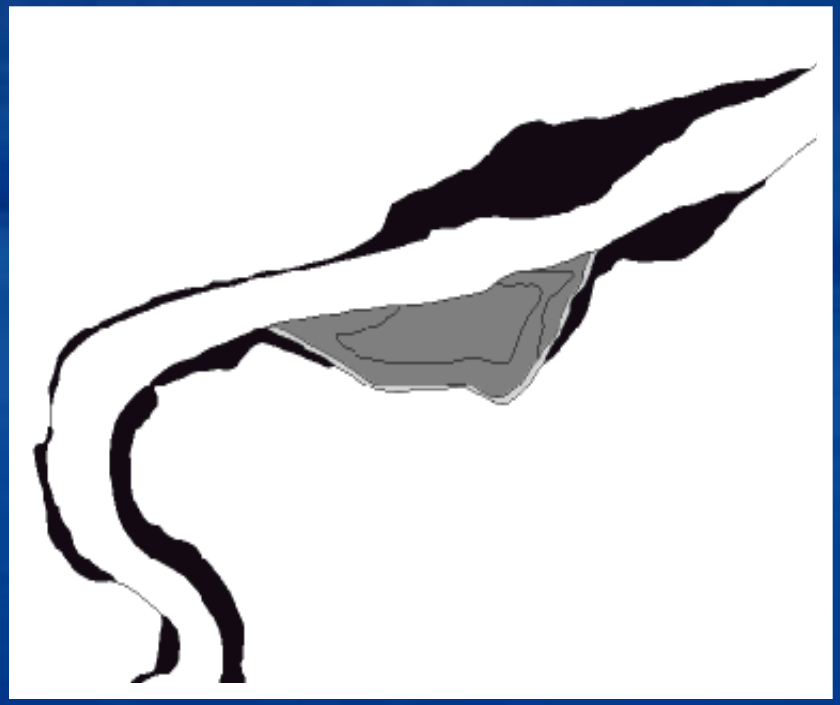


Other examples of channel response

Loss of secondary channels (simplification)

1938

1993

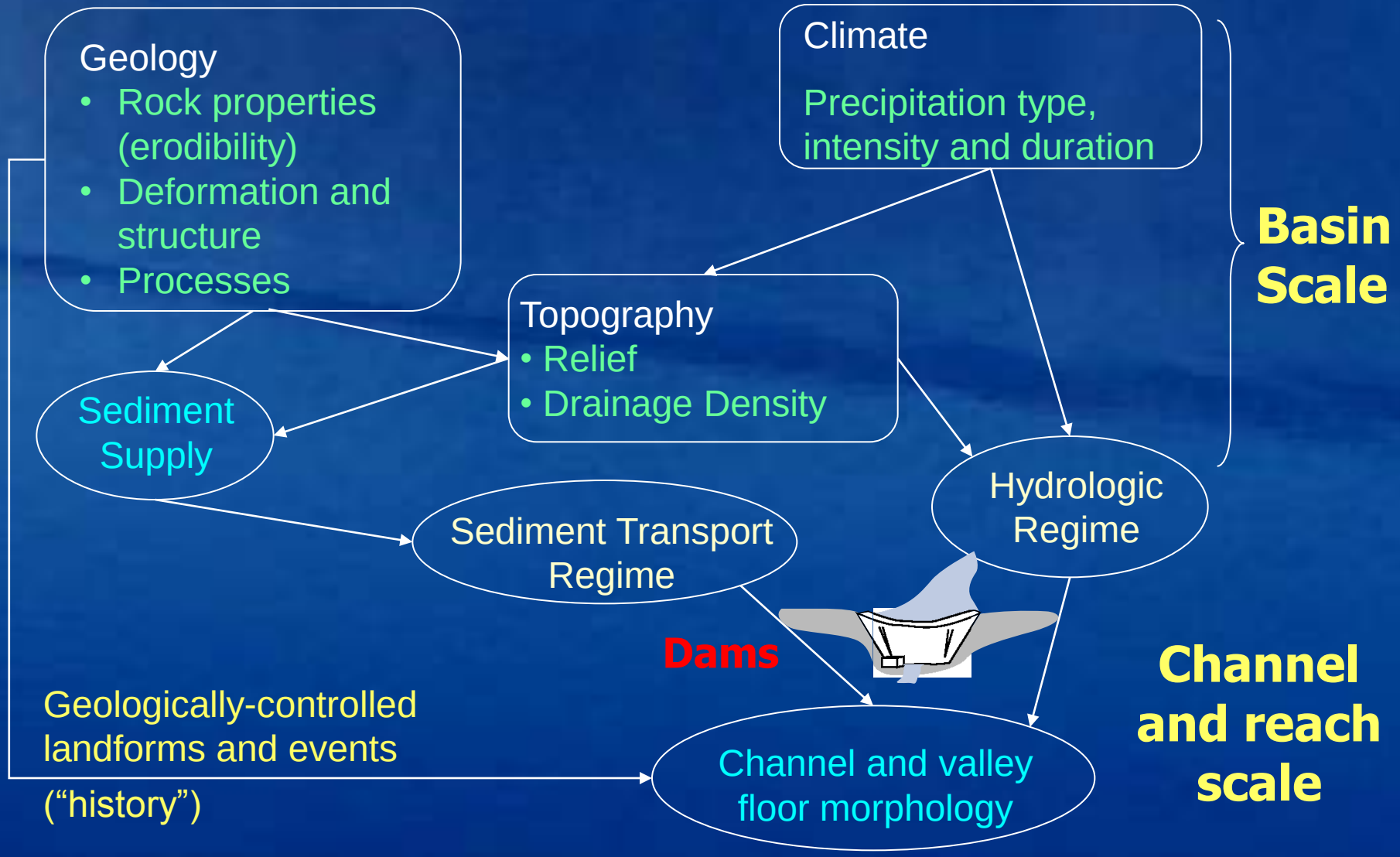


Colorado River

Lodore Canyon, Green River

Grams and Schmidt, 2002

How do we bring hydrologic and sediment transport effects together?



Transport capacity

$$T = \frac{\sum t_{(Q \geq Q_{cr})}}{\sum t_{Q}}$$

Fraction of time threshold for sediment transport is exceeded (grain size dependent)

Change in transport capacity due to dam

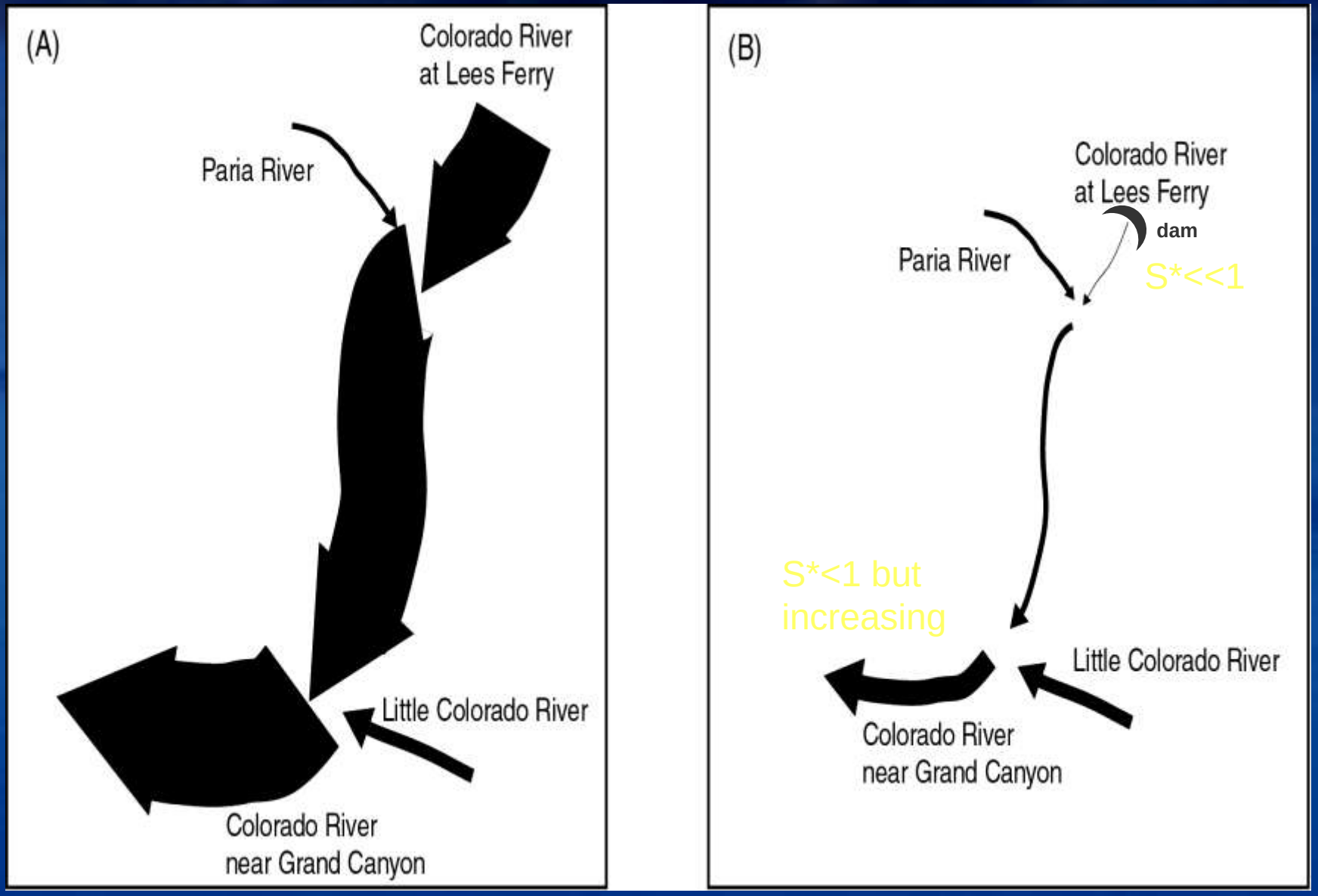
$$T^* = \frac{T_{post}}{T_{pre}}$$

Ratio of post-dam to pre-dam fractional transport time

Change in sediment supply due to dam

$$S^* = \frac{S_B}{S_A}$$

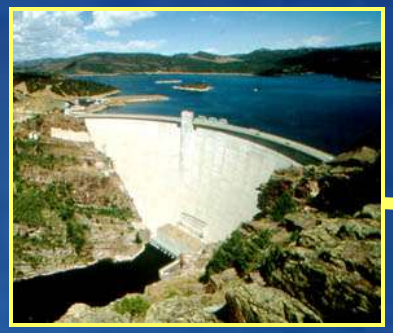
Ratio of below dam to above dam sediment supply



Pre-dam

Post-dam

Downstream Changes in Flow and Sediment Flux, Green River Utah



Flaming Gorge Dam

100% decrease
(-3.3 x 10^6 Mg)

Red Creek*

Greendale Gage

Vermillion Creek*

Change in mean annual sediment flux

57% decrease

Change in mean annual flood

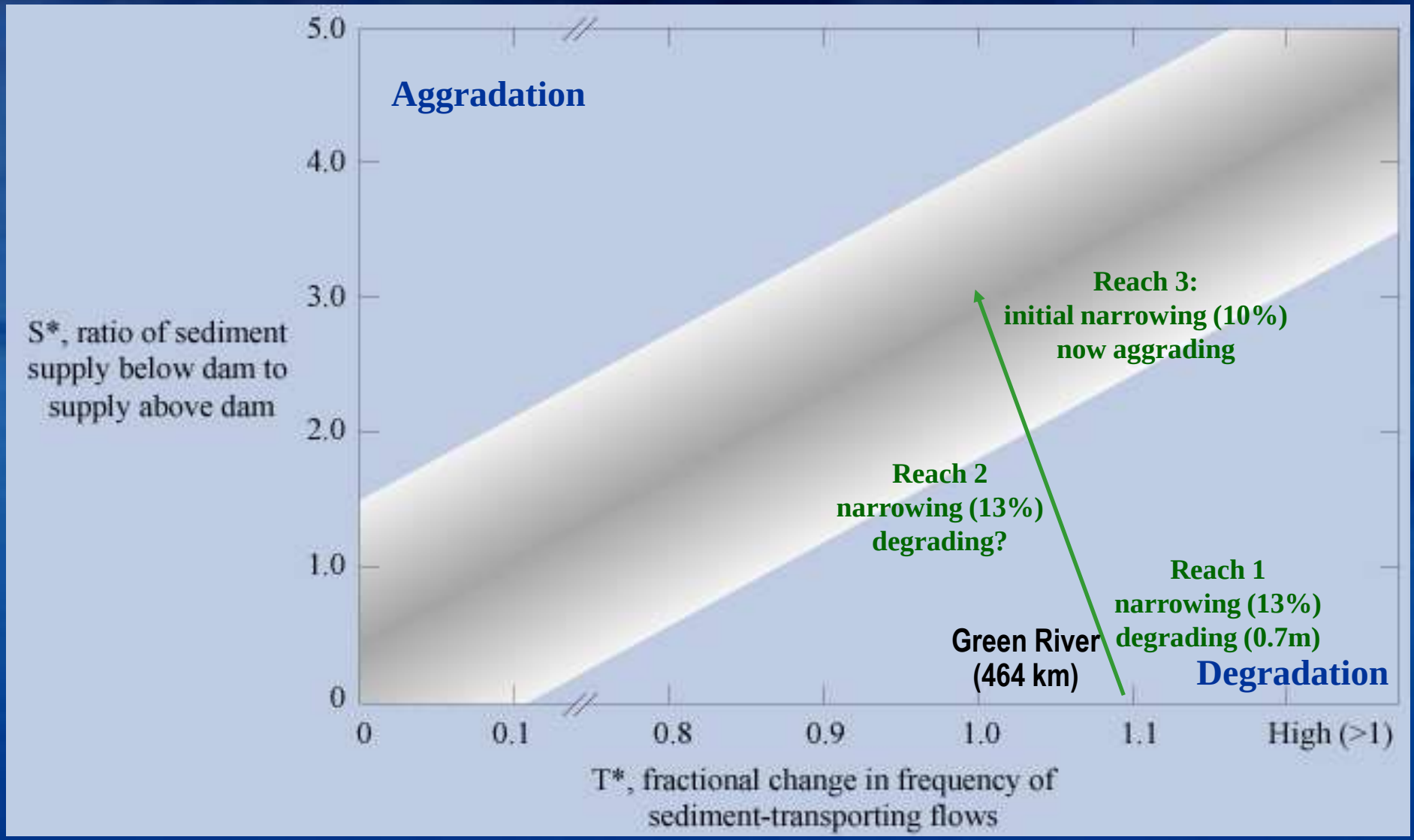
Green River

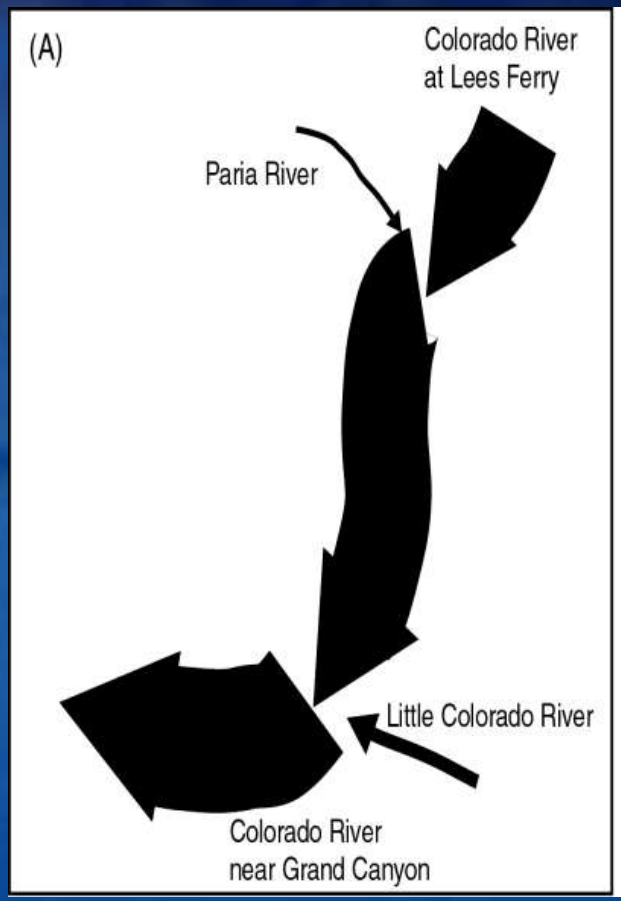
23% decrease

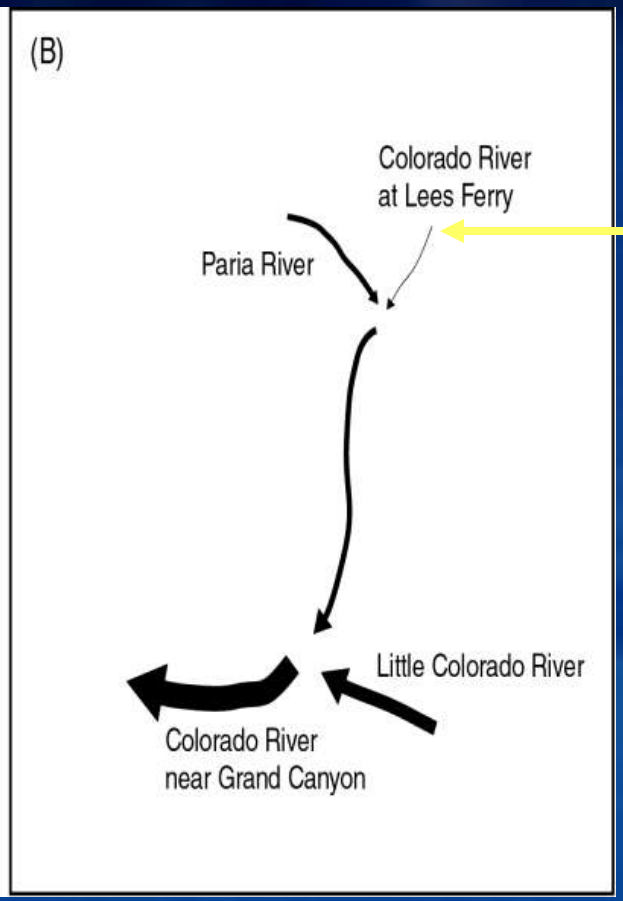
Yampa River*

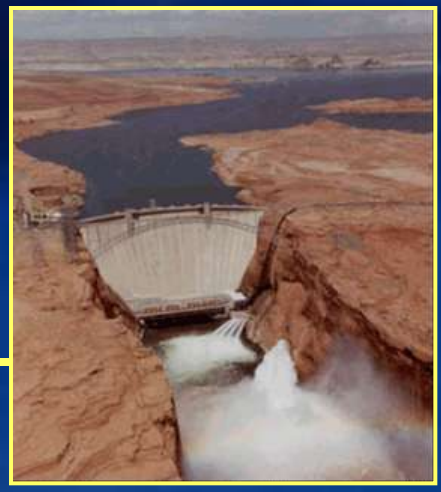
Jensen Gage
57% decrease
(-3.7 x 10^6 Mg)

** no change in tributary sediment supply*


Aggradation
Degradation
Reach 3:
initial narrowing (10%)
now aggrading
Reach 2
narrowing (13%)
degrading?
Reach 1
narrowing (13%)
degrading (0.7m)
Green River
(464 km)
S*, ratio of sediment supply below dam to supply above dam
5.0
4.0
3.0
2.0
1.0
0
0
0.1
0.8
0.9
1.0
1.1
High (>1)
T*, fractional change in frequency of sediment-transporting flows



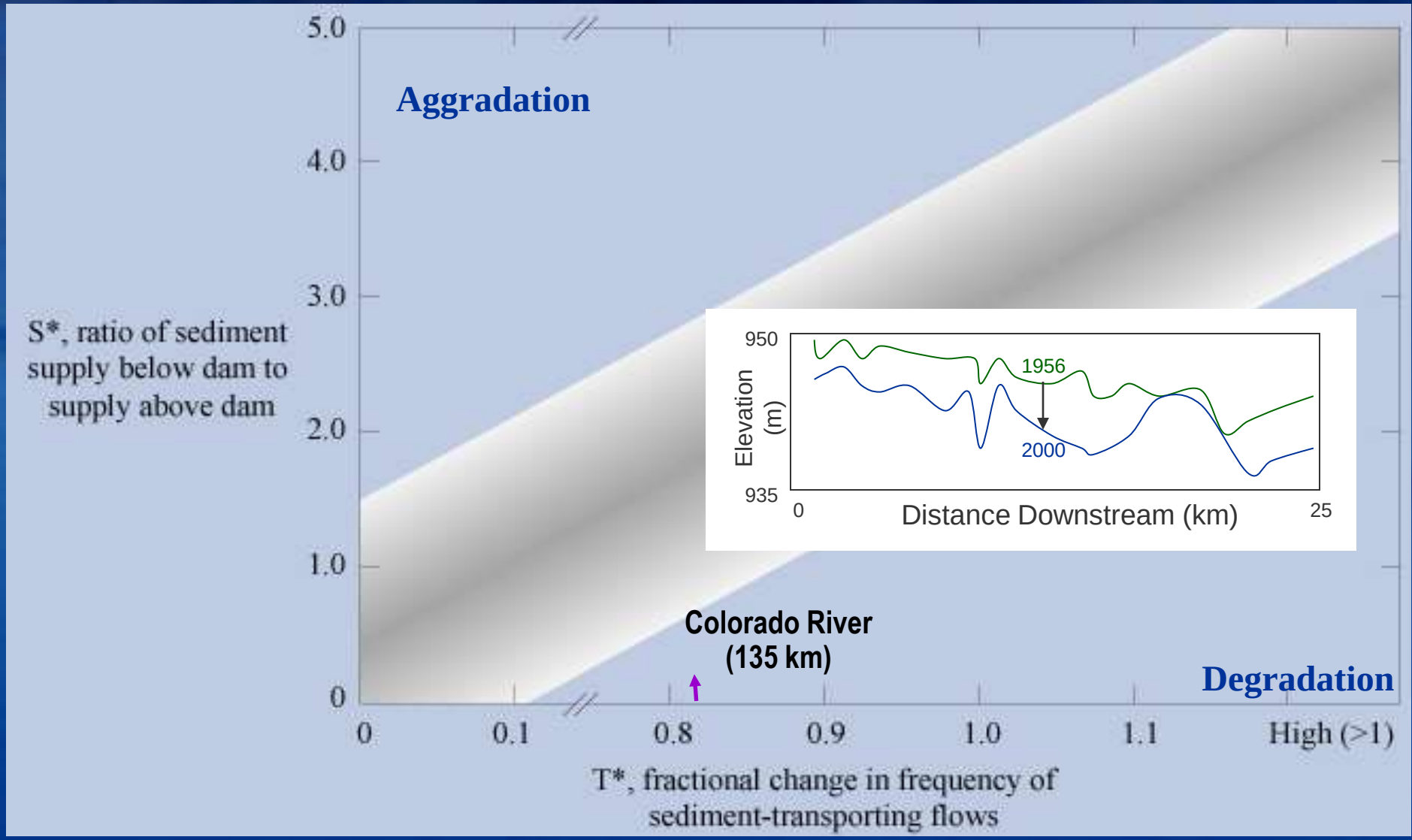




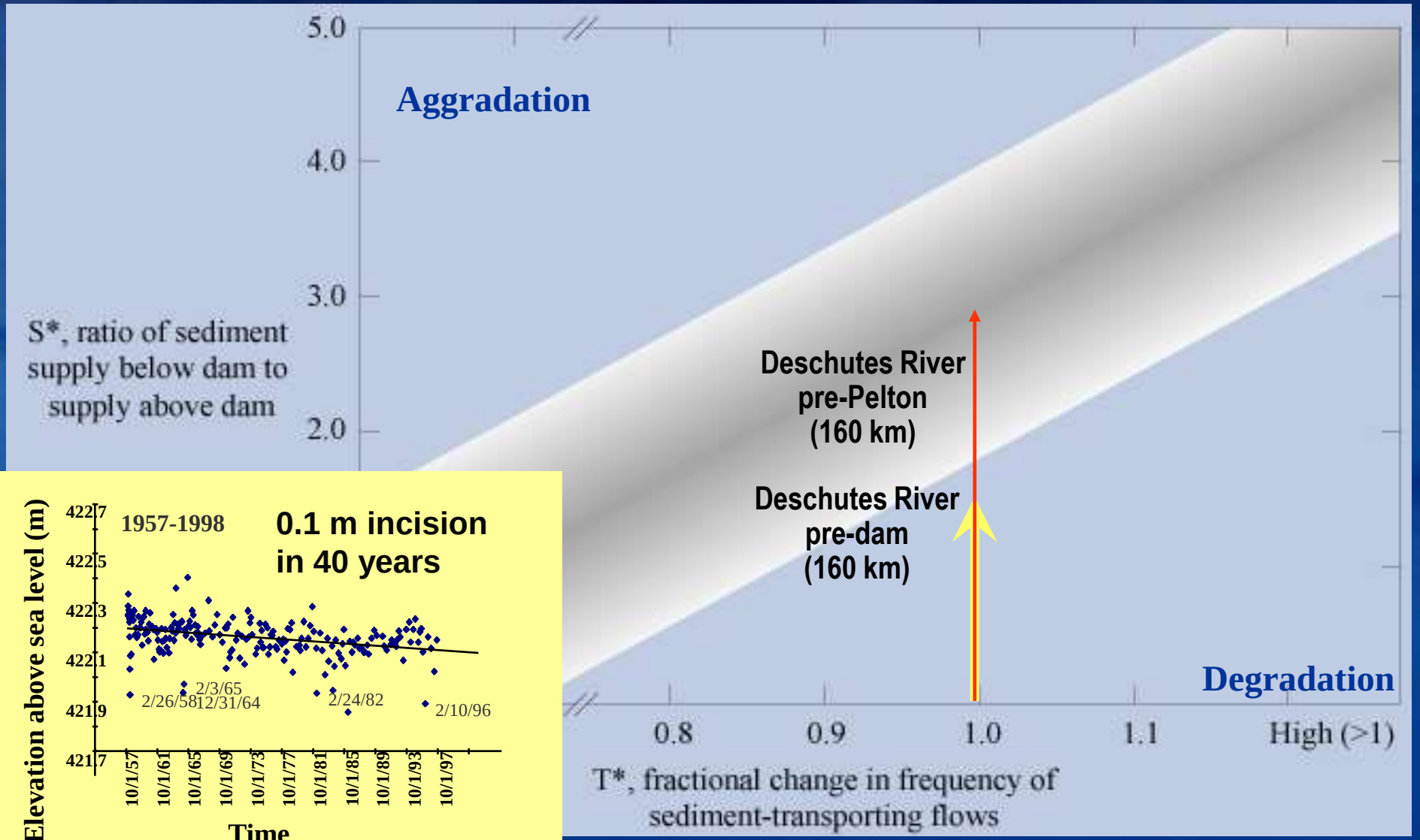
Glen Canyon Dam
Colorado River

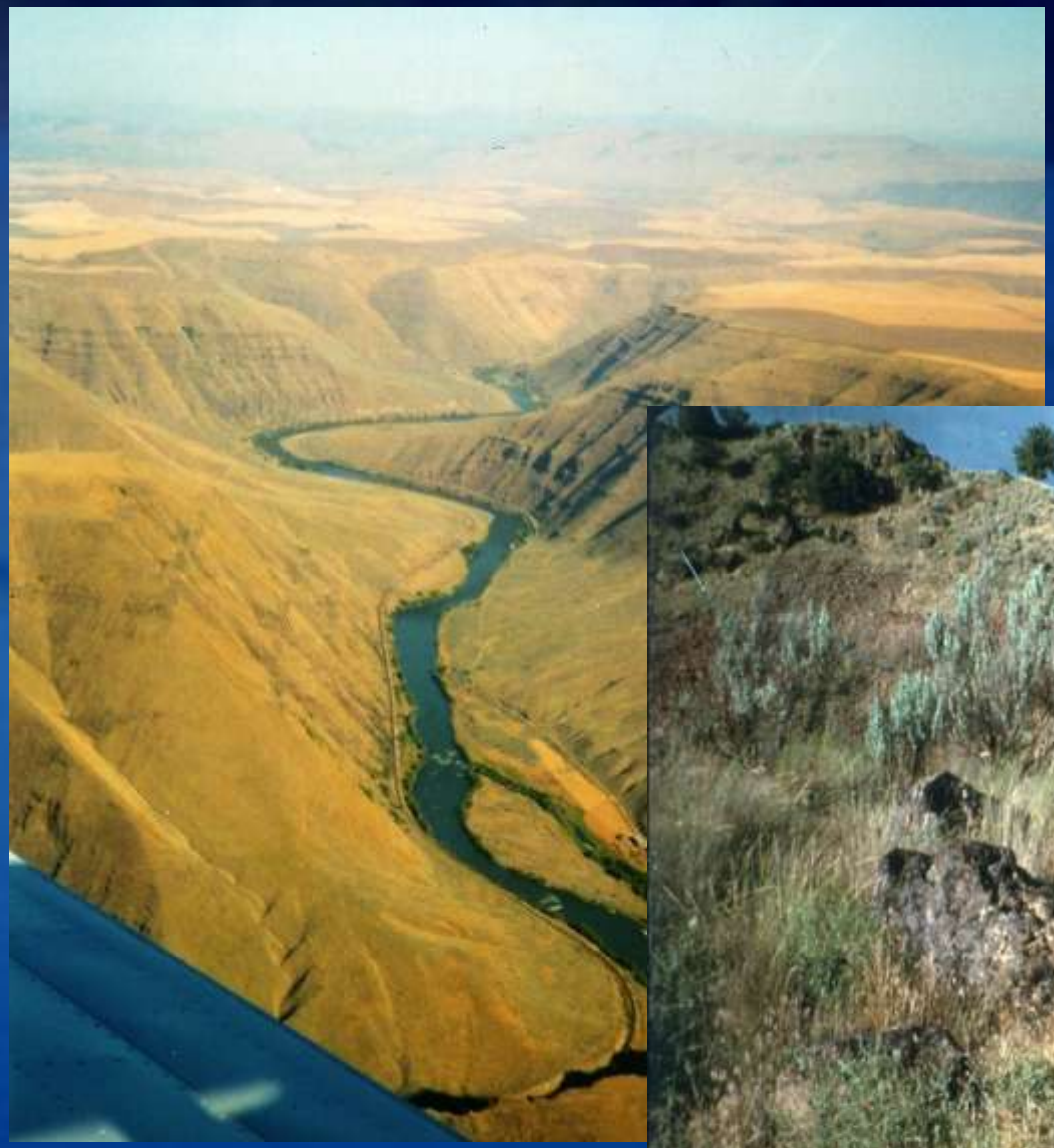
Pre-dam loads were 35-40% sand

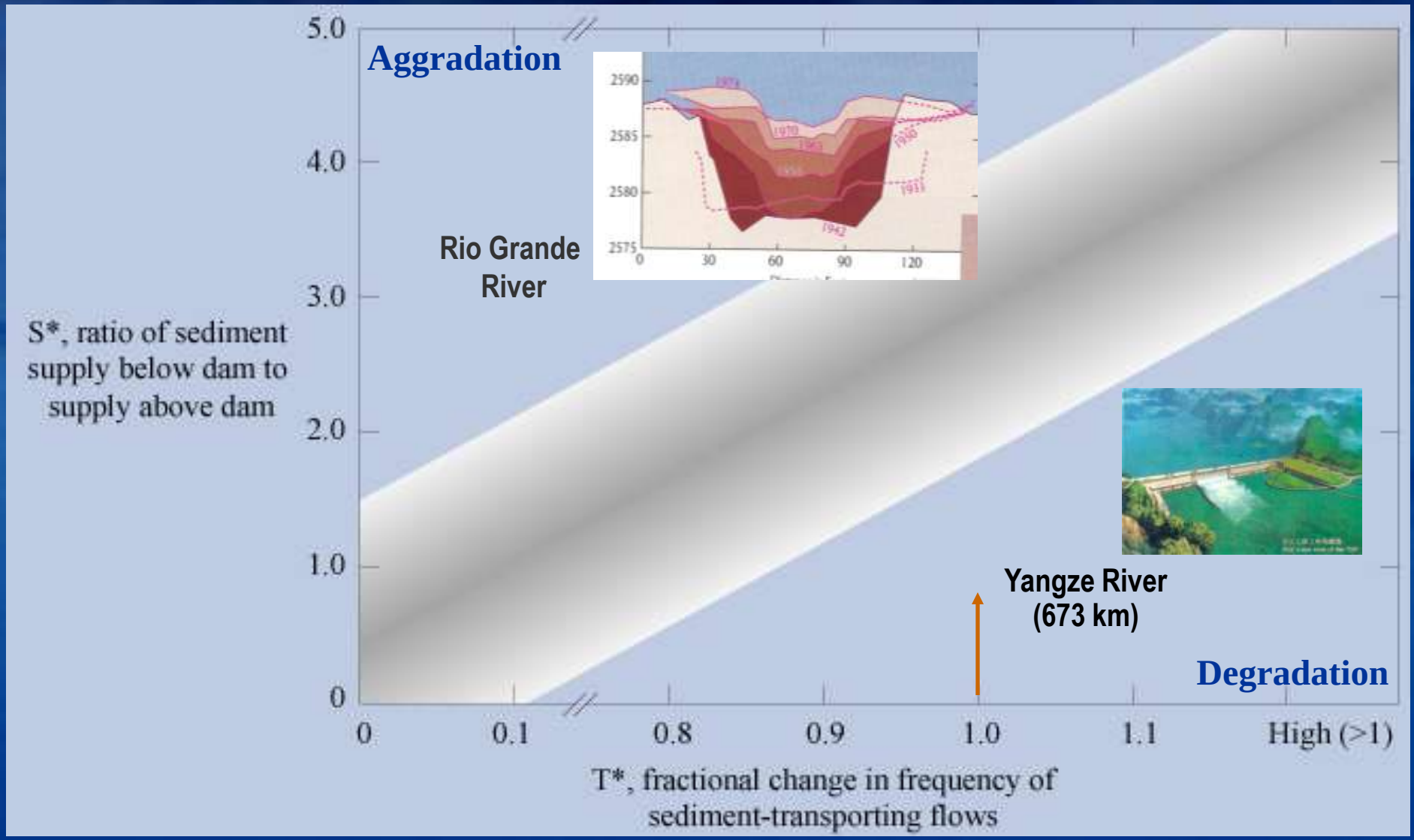
(Topping et al., 2000)


Aggradation
Degradation
S*, ratio of sediment supply below dam to supply above dam
5.0
4.0
3.0
2.0
1.0
0
0
0.1
0.8
0.9
1.0
1.1
High (>1)
T*, fractional change in frequency of sediment-transporting flows
Colorado River
(135 km)
950
935
Elevation (m)
1956
2000
0
25
Distance Downstream (km)

Deschutes River, Oregon






Aggradation
Rio Grande River
2590
2585
2580
2575
0
30
60
90
120
1970
1942
1911
Yangze River (673 km)
Degradation
S*, ratio of sediment supply below dam to supply above dam
5.0
4.0
3.0
2.0
1.0
0
0
0.1
0.8
0.9
1.0
1.1
High (>1)
T*, fractional change in frequency of sediment-transporting flows

Evaluating altered sediment regimes

- Pre-dam as reference point
  - Reservoir sedimentation rates
- Magnitude/frequency of sediment transport
- Ratio of above dam to below dam sediment supply
  - Volume
  - Timing/mechanisms of supply
  - Caliber

Linking hydrograph changes to geomorphic response