...scientific theories are essentially constrained by their associated scales of space and time, and different kinds of theories are appropriate to describe phenomena at different scales.

Michael Church, 1999, in The Scientific Nature of Geomorphology
The search for common empirical attributes of streams
Fluvial geomorphology: 1950s - 1970s

Luna B. Leopold

M. Gordon (“Reds”) Wolman
This channel was identified as being in equilibrium in the 1950s

mid-1950s, Maryland piedmont
local land use = grazed pasture

Watts Branch, Maryland
OVER TIME, THE WATTS BRANCH CHANNEL MIGRATED ACROSS ITS VALLEY, DEPOSITING POINT BARS ON THE INSIDE OF THE MEANDER BENDS. EROSION APPROXIMATELY EQUALED DEPOSITION. THERE WAS NO SIGNIFICANT OVERBANK DEPOSITION.

Construction of point bar whose upper surface is called the active floodplain

Bank retreat

This is an example of a channel in equilibrium
CRITERIA FOR IDENTIFYING BANKFULL STAGE

- Top of the point bar
- Marked by change in vegetation
- Topographic break
- Change in size distribution of surface materials
1953–1960 -- no change in bed elevation
After 1972 -- bed aggradation; widening

(Leopold et al., 2005)

MAGNITUDE AND FREQUENCY OF FORCES IN GEOMORPHIC PROCESSES

M. GORDON WOLMAN AND JOHN P. MILLER
Johns Hopkins University and Harvard University

Fig. 1.—Relations between rate of transport, applied stress, and frequency of stress application.
The watershed steadily urbanized.

In 1999, impervious surfaces made up ~28% of watershed.

During construction of the surrounding suburbs, sediment yield greatly increased because erosion from construction sites was not controlled.

Long recognized below dams: pattern of channel change downstream from Elephant Butte Dam is typical of the pattern of change below all dams.

Downstream from Elephant Butte Dam, the upper river *incised its bed* as much as 1 m within 225 km downstream from Elephant Butte Dam between ~1917 and ~1933. Downstream from El Paso/Juarez, the bed *aggred* about 0.25 m. (Stevens, 1938)

THREE METRICS OF CHANNEL CHANGE CAUSED BY DAMS

- Perturbation of the predam sediment mass balance
  - Assessing shifts towards deficit or surplus

- Likelihood of post-dam bed incision

- Potential for changes in width based on proportional change in annual floods
AT WHAT TEMPORAL SCALE IS IT BEHAVIOR AND AT WHAT SCALE IS IT CHANGE?

• Rivers are in perpetual adjustment, and do not necessarily oscillate about an equilibrium form, or they oscillate about a mean for a short proportion of their history.

• “rivers are seldom in dynamic equilibrium” (C. Thorne, 1997)

• “planning for ‘mean’ conditions is unsympathetic to the natural range of biotic and geomorphic process activity. In many ways, the inherent variability of river behavior and responses to disturbance drives the functioning of aquatic ecosystems. Instability is a key attribute of many systems.” (Brierley and Fryirs, 2005)

Qualitative descriptions of drainage basins

(Davis, 1899)

(Gilbert, 1877)
Generalizations about how the drainage network is organized are longstanding (Horton, 1945).

Horton scheme

Strahler (1952) revision

Generalizations about how the drainage network is organized are longstanding (Horton, 1945)

Measures of planform

Number of channels

Sinuosity

Lateral stability

(a) Number of channels

(b) Sinuosity

Degrees of sinuosity

Smooth

1-1.0 (plagular)

20-100 (low sinuosity)

1.1-3.0 (sinuosity; meandering)

3.1-5.0 (brittle)

>5 (brittleness)

Type of sinuosity

Irregular meanders (passive)

Irregular meanders

Tidal meanders

Confined pattern

(b) Sinuosity

(c) Lateral stability

Meander growth and shift

Degree of braiding

Extension / increasing amplitude

Translation / downstream progression

Rotation

Neck cutoffs

Chute cutoffs

Axial behavior

1st order avulsion

2nd order avulsion

Reconnection

3rd order avulsion

Bending shift

Bromley and Fryirs, 2005
What is adjustable and at what time and space scales?

Knigton, 1998

Changes at a large scale cascade downward to changes at smaller scales

Brierley and Fryers, 2005
From Parsons et al. (2002), after Frissel et al. (1986)

<table>
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<th>STREAM SYSTEM</th>
<th>SEDIMENT SYSTEM</th>
<th>REACH SYSTEM</th>
<th>POOL-RIFFLE SYSTEM</th>
<th>MICROHABITAT SYSTEM</th>
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