Beyond Biology – Geomorphic Function and Significance of Wood in Streams

Dan Cenderelli
USDA Forest Service
National Stream and Aquatic Ecology Center

Bob Gubernick
USDA Forest Service
National Stream and Aquatic Ecology Center

Presentation Objectives

Historical context of large wood removal from stream corridors in the United States

General overview of the geomorphic effects of large wood on flow hydraulics and boundary roughness, channel morphology, and channel adjustments and responses

Presentation Outline

- **Historical Context of Large Wood Removal**
- **Geomorphic Effects of Large Wood**
  - **Flow Hydraulics and Boundary Roughness**
  - **Channel Morphology**
  - **Channel Adjustments and Responses**

Historical Context of Large Wood Removal

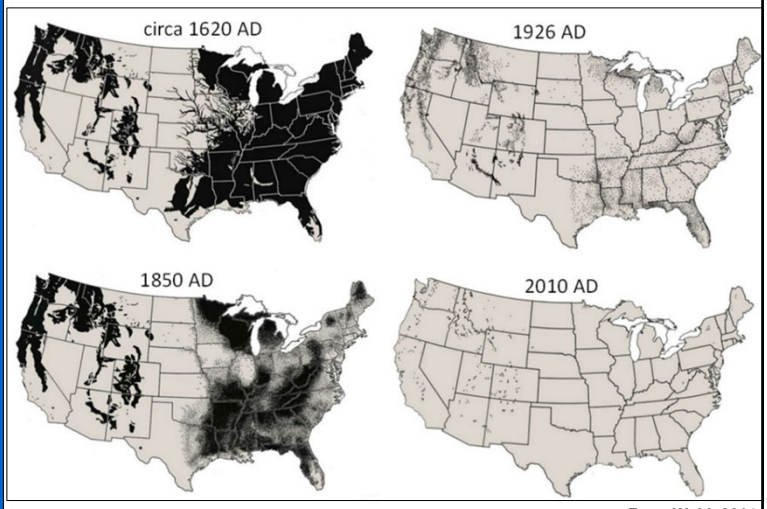
Forest Cover and Wood Loading

Steamboats

Timber Rafting

River Improvements

Implications



From Wohl, 2014

Historical Context of Large Wood Removal

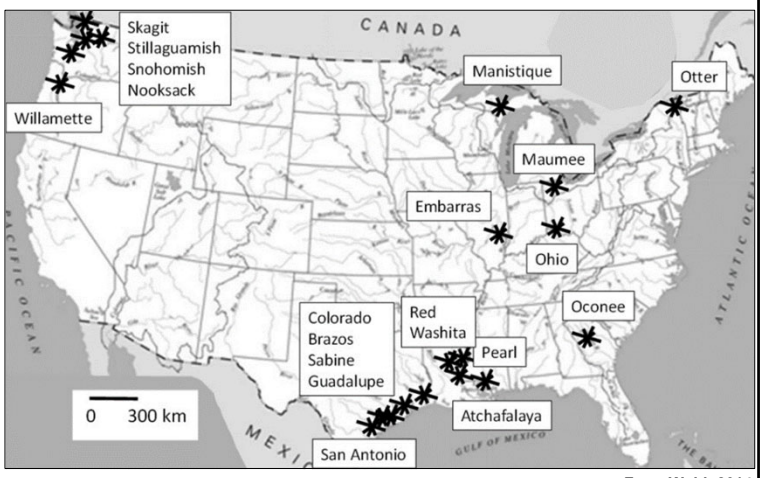
Forest Cover and Wood Loading

Steamboats

Timber Rafting

River Improvements

Implications



From Wohl, 2014

Historical Context of Large Wood Removal

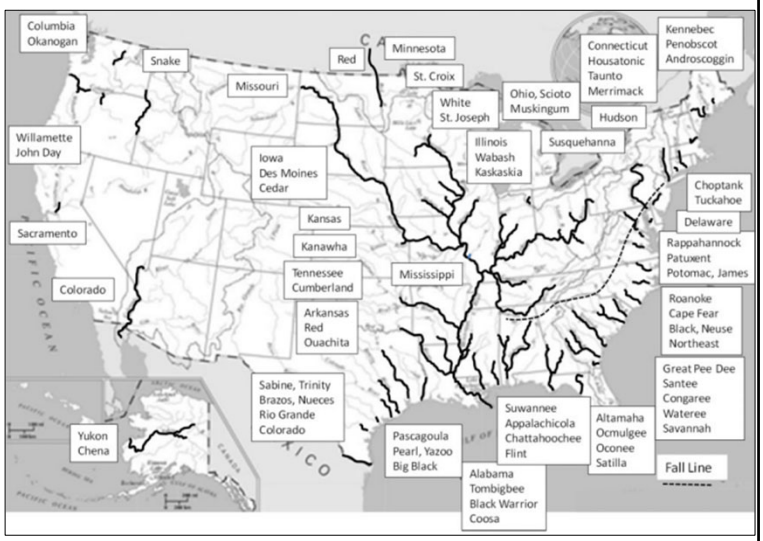
Forest Cover and Wood Loading

Steamboats

Timber Rafting

River Improvements

Implications



From Wohl, 2014

Historical Context of Large Wood Removal

Forest Cover and Wood Loading

Steamboats

Timber Rafting

River Improvements

Implications

- **The *Great Raft* on the Red River, Louisiana**
- **In place from pre-1400 until 1873 A.D.**
- **Removal resulted in 15 ft of channel incision, sediment transport capacity increased by a factor of six**

Historical Context of Large Wood Removal

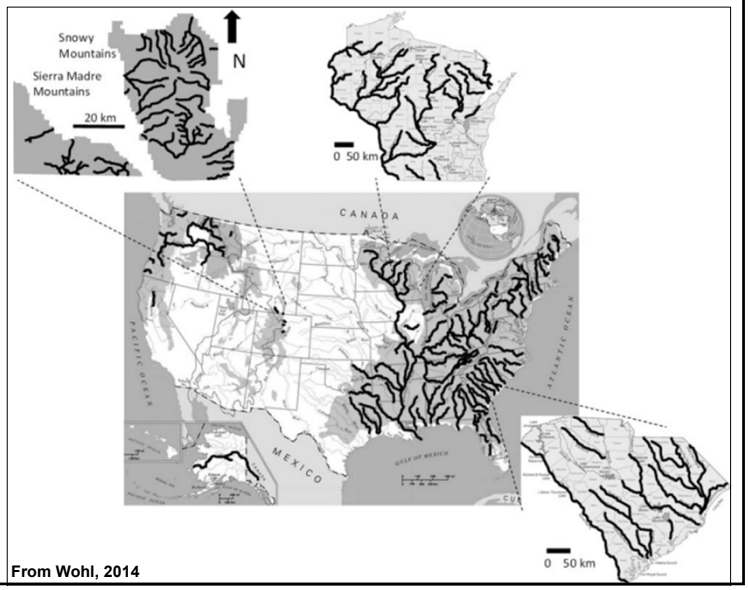
Forest Cover and Wood Loading

Steamboats

Timber Rafting

River Improvements

Implications



From Wohl, 2014

Historical Context of Large Wood Removal

Forest Cover and Wood Loading

Steamboats

Timber Rafting

River Improvements

Implications

Historical Context of Large Wood Removal

Forest Cover and Wood Loading

Steamboats

Timber Rafting

River Improvements

Implications

River Improvements

- **Initially focused on removing instream wood via snagging to improve boat transportation**
- **Expanded the work to include other activities:**
  - ***Blasting of rock obstructions***
  - ***Dredging***
  - ***Bank stabilization***
  - ***Levee construction***
  - ***Canal construction***
  - ***Channelization via cutting off bends***
  - ***Flow regulation***

Historical Context of Large Wood Removal

Forest Cover and Wood Loading

Steamboats

Timber Rafting

River Improvements

Implications

Implications

- **Increase in flow energy and sediment transport**
- **Single-thread channel with reduced sinuosity**
- **Channel incision**
- **Decrease in channel/floodplain connectivity**
- **Decrease in and degradation of aquatic and riparian habitat**

Presentation Outline

- **Historical Context of Large Wood Removal**
- **Geomorphic Effects of Large Wood**
  - **Flow Hydraulics and Boundary Roughness**
  - **Channel Morphology**
  - **Channel Adjustments and Responses**

Geomorphic Effects of Large Wood

Flow Hydraulics and Boundary Roughness
- *Flow Resistance*
- *Hydraulic Diversity*
- *Bed Scour*
- *Bank Scour*

Channel Morphology

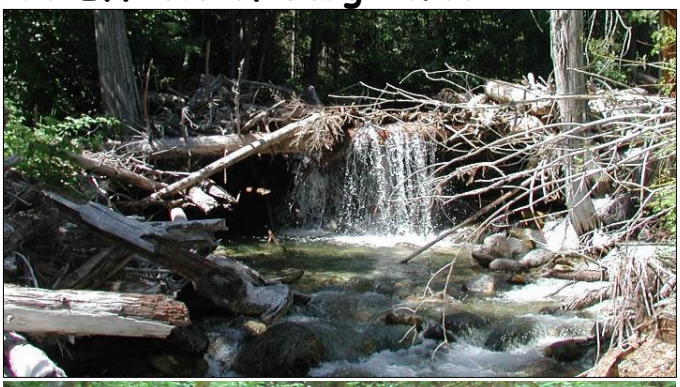
Channel Responses and Adjustments

Geomorphic Effects of Large Wood

Flow Hydraulics and Boundary Roughness
- *Flow Resistance*
- *Hydraulic Diversity*
- *Bed Scour*
- *Bank Scour*

Channel Morphology

Channel Responses and Adjustments



Geomorphic Effects of Large Wood

Flow Hydraulics and Boundary Roughness
- *Flow Resistance*
- *Hydraulic Diversity*
- *Bed Scour*
- *Bank Scour*

Channel Morphology

Channel Responses and Adjustments

Geomorphic Effects of Large Wood

Flow Hydraulics and Boundary Roughness
- *Flow Resistance*
- *Hydraulic Diversity*
- *Bed Scour*
- *Bank Scour*

Channel Morphology

Channel Responses and Adjustments

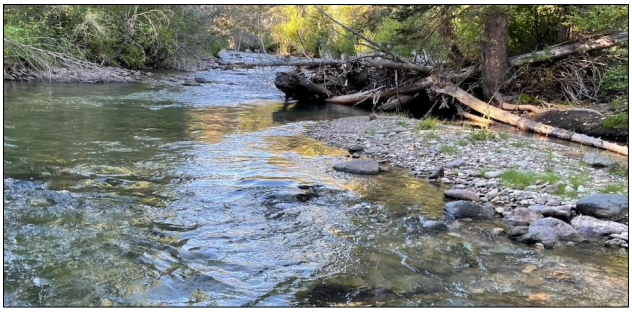
From Abbe et al., National Large Wood Manual 2016

Geomorphic Effects of Large Wood

Flow Hydraulics and Boundary Roughness

Channel Morphology
- *Bar Deposition and Sediment Storage*
- *Sediment Sorting*
- *Irregular Bed and Bank Topography*
- *Frequency of Pools and Bar Deposits*
- *Channel Width*
- *Channel Sinuosity*

Channel Responses and Adjustments



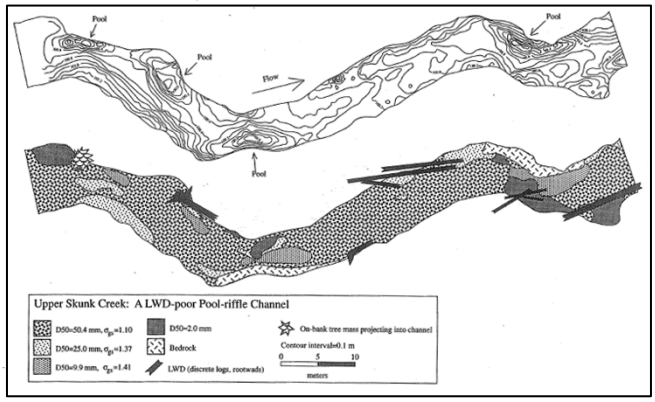
Geomorphic Effects of Large Wood

Flow Hydraulics and Boundary Roughness

Channel Morphology
- *Bar Deposition and Sediment Storage*
- *Sediment Sorting*
- *Irregular Bed and Bank Topography*
- *Frequency of Pools and Bar Deposits*
- *Channel Width*
- *Channel Sinuosity*

Channel Responses and Adjustments

Channels with Low Wood Loading



From Buffington and Montgomery 1999

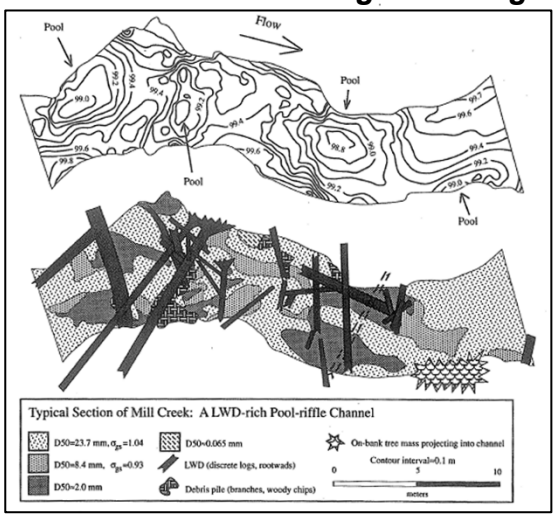
Geomorphic Effects of Large Wood

Flow Hydraulics and Boundary Roughness

Channel Morphology
- *Bar Deposition and Sediment Storage*
- *Sediment Sorting*
- *Irregular Bed and Bank Topography*
- *Frequency of Pools and Bar Deposits*
- *Channel Width*
- *Channel Sinuosity*

Channel Responses and Adjustments

Channels with Low High Loading



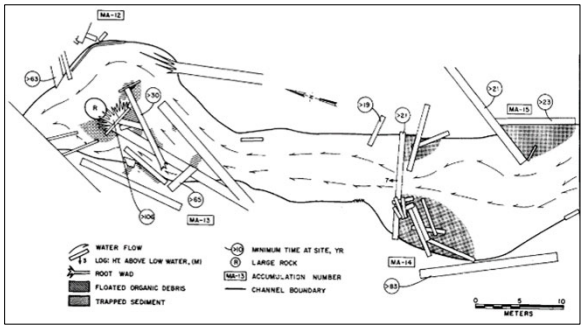
From Buffington and Montgomery 1999

Geomorphic Effects of Large Wood

Flow Hydraulics and Boundary Roughness

Channel Morphology
- *Bar Deposition and Sediment Storage*
- *Sediment Sorting*
- *Irregular Bed and Bank Topography*
- *Frequency of Pools and Bar Deposits*
- *Channel Width*
- *Channel Sinuosity*

Channel Responses and Adjustments



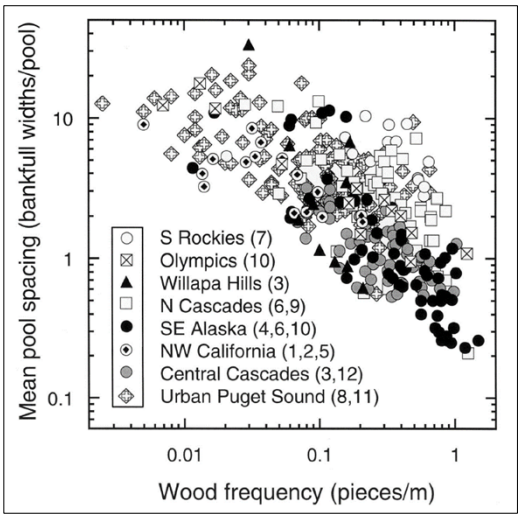
From Keller and Swanson 1978

Geomorphic Effects of Large Wood

Flow Hydraulics and Boundary Roughness

Channel Morphology
- *Bar Deposition and Sediment Storage*
- *Sediment Sorting*
- *Irregular Bed and Bank Topography*
- *Frequency of Pools and Bar Deposits*
- *Channel Width*
- *Channel Sinuosity*

Channel Responses and Adjustments



From Buffington and others 2003

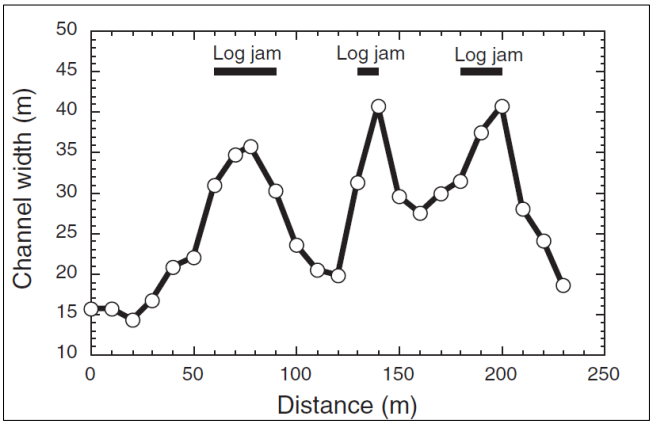
- **The spacing between pools and bars decreases as the frequency of wood pieces increases**
- **Pool spacing is variable reflecting the influence regional and site-specific factors**

Geomorphic Effects of Large Wood

Flow Hydraulics and Boundary Roughness

Channel Morphology
- *Bar Deposition and Sediment Storage*
- *Sediment Sorting*
- *Irregular Bed and Bank Topography*
- *Frequency of Pools and Bar Deposits*
- *Channel Width*
- *Channel Sinuosity*

Channel Responses and Adjustments



From Montgomery and other 2003

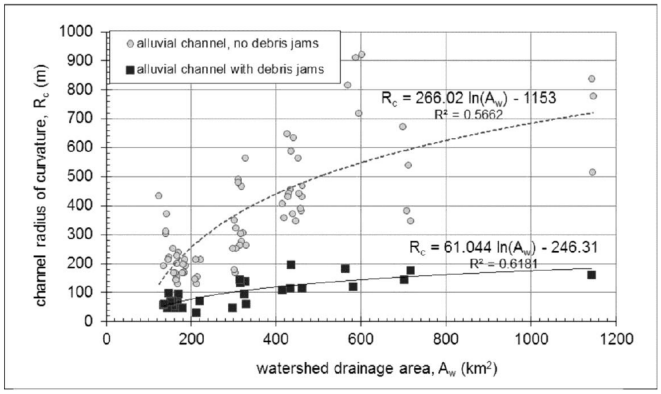
- **Wood loading influences the variability or range of channel widths along the channel**

Geomorphic Effects of Large Wood

Flow Hydraulics and Boundary Roughness

Channel Morphology
- *Bar Deposition and Sediment Storage*
- *Sediment Sorting*
- *Irregular Bed and Bank Topography*
- *Frequency of Pools and Bar Deposits*
- *Channel Width*
- *Channel Sinuosity*

Channel Responses and Adjustments



From Abbe 2000

- **Channels with high wood loading have a more sinuous channel planform pattern and tighter channel bends compared to channels with low wood loading**

Geomorphic Effects of Large Wood

1. Diversity of stable main and perennial secondary channel habitats
2. Abundant, high-quality edge habitat
3. Large trees entrained by river at eroding banks
4. Stable jams at flow splits and secondary channel inlets
5. Deep scour pools associated with stable jams
6. Forest age and species patch diversity, including mature conifer patches on stable "hard points"

1. Braided, unstable main channel and shifting, ephemeral secondary channels
2. Low quality of edge habitat
3. Riparian forest recruitment limited to small wood
4. Unstable pieces and accumulations of fluvial wood
5. Fewer pools that are shallow
6. Low forest patch age and species diversity, dominantly ephemeral, young stands of pioneer tree species

High Wood Loading
Higher Channel Complexity
Higher Aquatic Diversity

Low Wood Loading
Lower Channel Complexity
Lower Aquatic Diversity

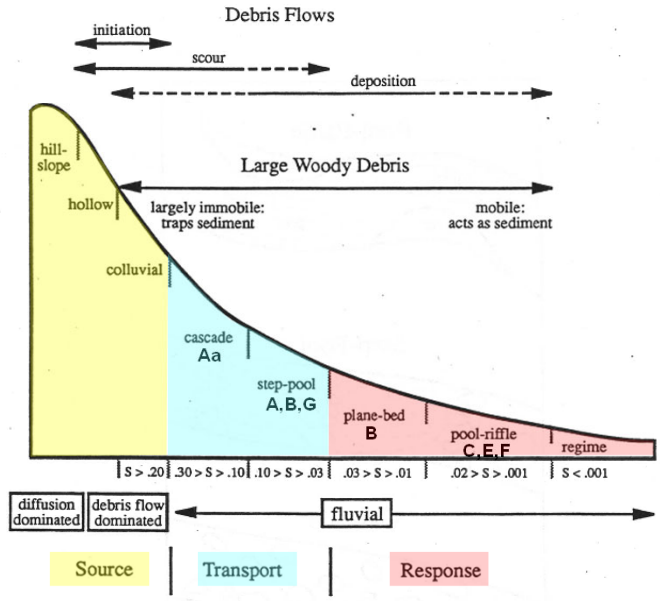
From Collins and others 2012

Geomorphic Effects of Large Wood

Flow Hydraulics and Boundary Roughness

Channel Morphology

Channel Responses and Adjustments
- *Channel Type*
- *Channel Evolution*



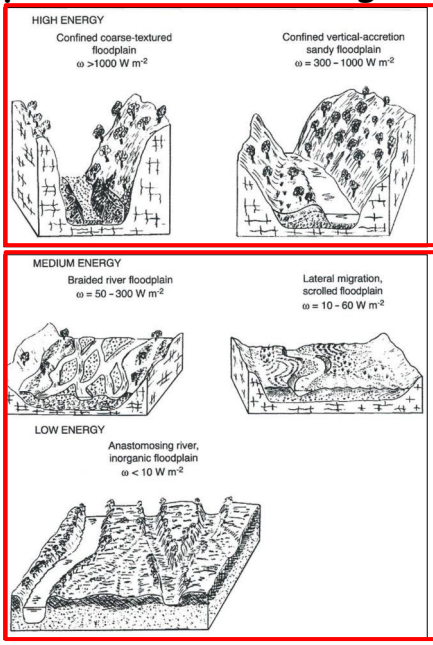
From Montgomery & Buffington, 1993

Geomorphic Effects of Large Wood

Flow Hydraulics and Boundary Roughness

Channel Morphology

Channel Responses and Adjustments
- *Channel Type*
- *Channel Evolution*



Confined Channels
- Transport Reaches
  - step-pool, cascade channels
- High energy
- Straight, high gradient channels
- Minimal floodplain development
- Channel migration low
- Slope interactions high

Unconfined Channels
- Response Reaches
  - plane bed, pool-riffle channels
- Low to medium energy
- Sinuous, low gradient channels
- Well-developed floodplain
- Lateral channel migration high
- Slope interactions low

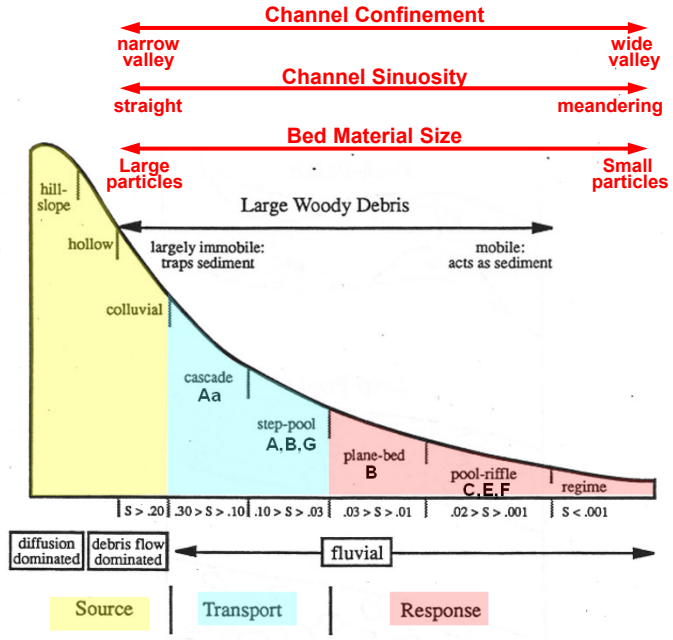
From Knighton, 1998

Geomorphic Effects of Large Wood

Flow Hydraulics and Boundary Roughness

Channel Morphology

Channel Responses and Adjustments
- *Channel Type*
- *Channel Evolution*



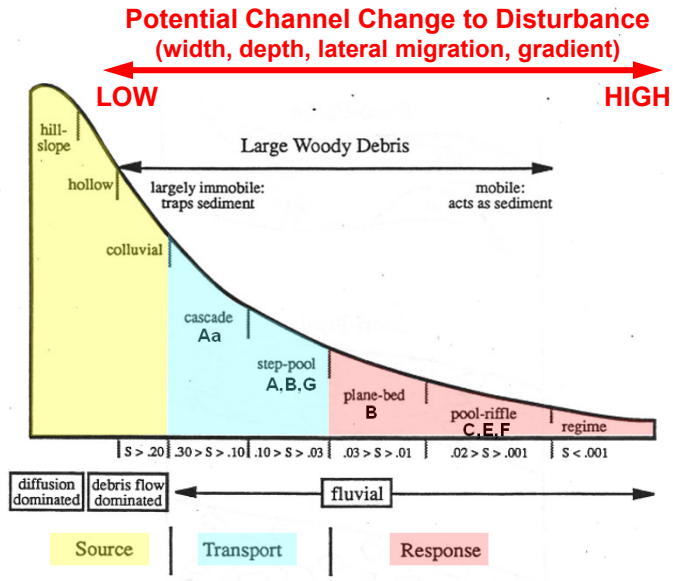
From Montgomery & Buffington, 1993

Geomorphic Effects of Large Wood

Flow Hydraulics and Boundary Roughness

Channel Morphology

Channel Responses and Adjustments
- *Channel Type*
- *Channel Evolution*



From Montgomery & Buffington, 1993

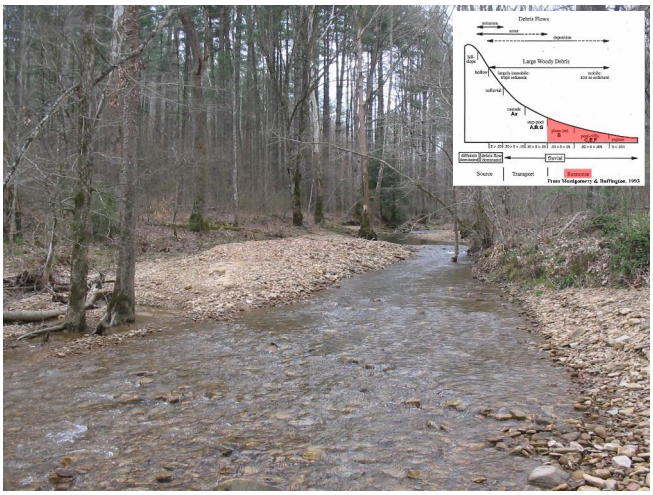
Geomorphic Effects of Large Wood

Flow Hydraulics and Boundary Roughness

Channel Morphology

Channel Responses and Adjustments
- *Channel Type*
- *Channel Evolution*

Response Reach, Pool-Riffle (C) channel



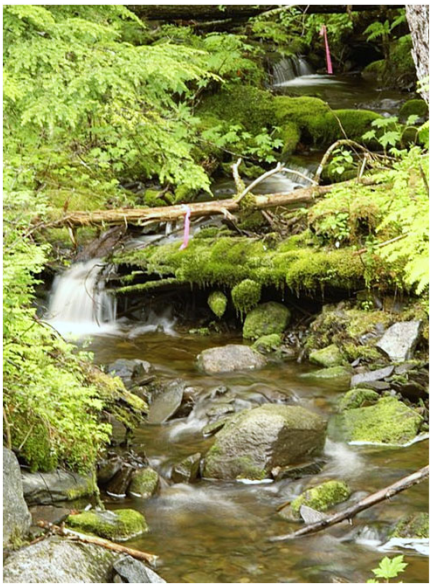
Geomorphic Effects of Large Wood

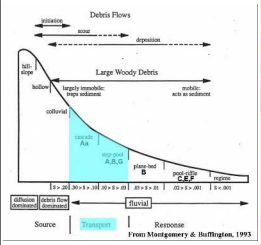
Flow Hydraulics and Boundary Roughness

Channel Morphology

Channel Responses and Adjustments
- *Channel Type*
- *Channel Evolution*

Transport Reach, Step-Pool (A) channel





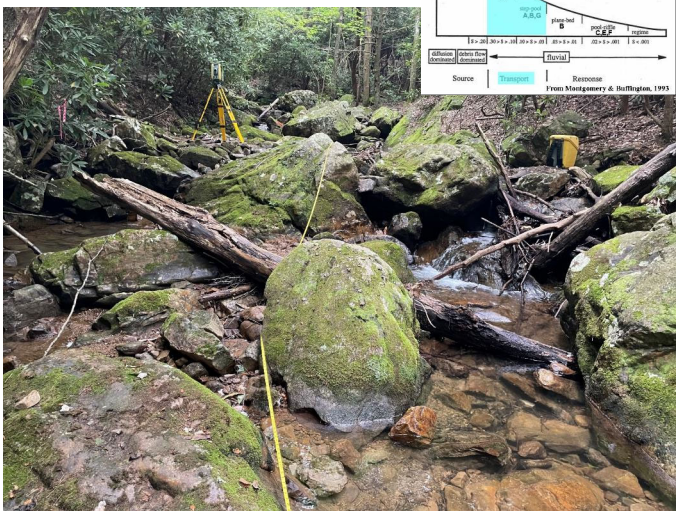
Geomorphic Effects of Large Wood

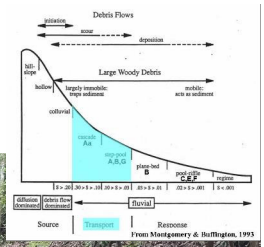
Flow Hydraulics and Boundary Roughness

Channel Morphology

Channel Responses and Adjustments
- *Channel Type*
- *Channel Evolution*

Transport Reach, Cascade (A) channel





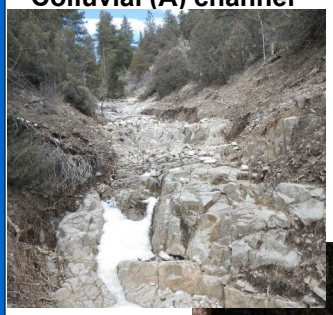
Geomorphic Effects of Large Wood

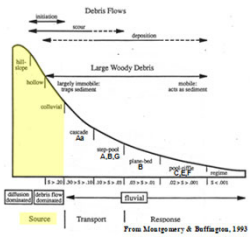
Flow Hydraulics and Boundary Roughness

Channel Morphology

Channel Responses and Adjustments
- *Channel Type*
- *Channel Evolution*

Source Reach, Colluvial (A) channel





Geomorphic Effects of Large Wood

Flow Hydraulics and Boundary Roughness

Channel Morphology

Channel Responses and Adjustments
- *Channel Type*
- *Channel Evolution*

Type of channel	Typical bed material	Typical slope	Dominant roughness elements	Pool spacing (channel widths)	Typical Confine-ment	Typical reach type	Typical sediment supply conditions	Typical transport capacity of stream	Frequency of effective bedload transport (mobile bed)
nonalluvial									
-colluvial	variable	> 0.20	grains, LWD	variable	confined	source	high	high	infrequent
-bedrock	bedrock	variable	not applicable	variable	confined	transport	low	high	not applicable
alluvial									
-cascade	boulder	0.10 to 0.30	grains, banks	< 1	confined	transport	low	high	infrequent
-step-pool	cobble, boulder	0.03 to 0.10	bedforms, grains, LWD,	1 to 4	confined	transport	low	high	infrequent
-plane bed 1	cobble	0.01 to 0.03	grains, banks	none	variable	transport	low	high	infrequent
-plane bed 2	gravel	0.01 to 0.03	grains, banks	none	variable	response	moderate	moderate	frequent
-pool-riffle 1	cobble	0.01 to 0.04	bedforms, grains, LWD,	5 to 7	variable	transport	low	high	infrequent
-pool-riffle 2	gravel	0.001 to 0.02	bedforms, grains, LWD, sinuosity,	5 to 7	unconfined	response	moderate	moderate	frequent
-dune-ripple	sand	< 0.001	sinuosity, bedforms	5 to 7	unconfined	response	high	low	very frequent

Geomorphic Effects of Large Wood

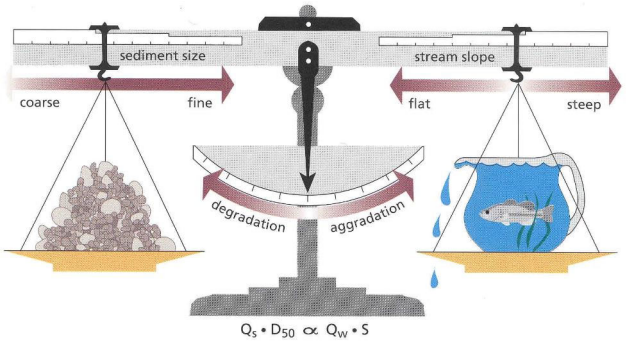
Flow Hydraulics and Boundary Roughness

Channel Morphology

Channel Responses and Adjustments
- *Channel Type*
- *Channel Evolution*

Channel Adjustments and Responses

Sediment (LOAD) X (SIZE) **α** **Stream (SLOPE) X (DISCHARGE)**

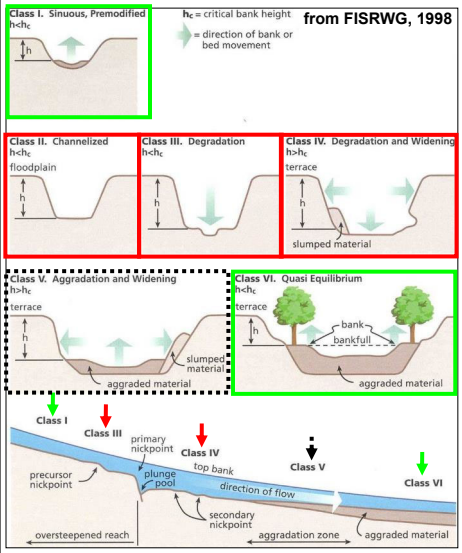


Geomorphic Effects of Large Wood

Flow Hydraulics and Boundary Roughness

Channel Morphology

Channel Responses and Adjustments
- *Channel Type*
- *Channel Evolution*



Restoring Channel Function Based on Altered Channel Conditions
- ***Channel Evolution Model***
- ***Stream Evolution Model***

Geomorphic Effects of Large Wood

Flow Hydraulics and Boundary Roughness

Channel Morphology

Channel Responses and Adjustments
- *Channel Type*
- *Channel Evolution*

Class		Dominant Processes		Characteristic Forms	Geobotanical Evidence
No.	Name	Fluvial	Hillslope		
I	Premodified	Sediment transport - mild aggradation; basal erosion on outside bends; deposition on inside bends.		Stable, alternate channel bars; convex top-bank shape; flow line high relative to top bank; channel straight or meandering.	Vegetated banks to flow line.
II	Constructed			Trapezoidal cross section; linear bank surfaces; flow line lower relative to top bank.	Removal of vegetation.
III	Degradation	Degradation; basal erosion on banks.	Pop-out failures.	Heightening and steepening of banks; alternate bars eroded; flow line lower relative to top bank.	Riparian vegetation high relative to flow line and may lean toward channel.
IV	Threshold	Degradation; basal erosion on banks.	Slab, rotational and pop-out failures.	Large scallops and bank retreat; vertical face and upper-bank surfaces; failure blocks on upper bank; some reduction in bank angles; flow line very low relative to top bank.	Riparian vegetation high relative to flow line and may lean toward channel.
V	Aggradation	Aggradation; development of meandering thalweg; initial deposition of alternate bars; reworking of failed material on lower banks.	Slab, rotational and pop-out failures; low-angle slides of previously failed material.	Large scallops and bank retreat; vertical face, upper bank, and slough line; flattening of bank angles; flow line low relative to top bank; development of new floodplain.	Tilted and fallen riparian vegetation; reestablishing vegetation on slough line; deposition of material above root collars of slough line vegetation.
VI	Restabilization	Aggradation; further development of meandering thalweg; further deposition of alternate bars; reworking of failed material; some basal erosion on outside bends deposition of flood-plain and bank surfaces.	Low-angle slides; some pop-out failures near flow line.	Stable, alternate channel bars; convex-short vertical face on top bank; flattening of bank angles; development of new floodplain; flow line high relative to top bank.	Reestablishing vegetation extends up slough line and upper bank; deposition of material above root collars of slough-line and upper-bank vegetation; some vegetation establishing on bars.

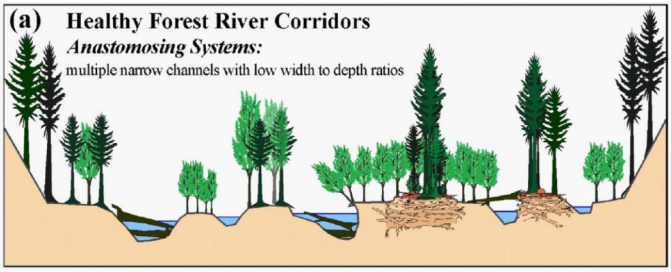
from FISRWG, 1998

Geomorphic Effects of Large Wood

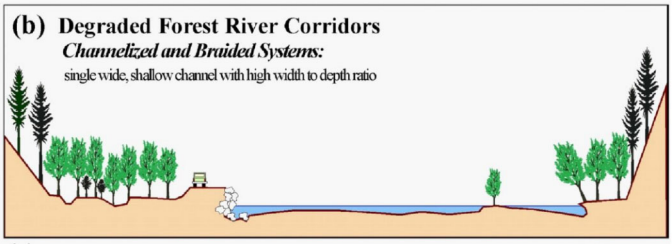
Flow Hydraulics and Boundary Roughness

Channel Morphology

Channel Responses and Adjustments
- *Channel Type*
- *Channel Evolution*



A. Multiple channels within a riparian forest valley bottom; high channel complexity because of numerous large wood structures



B. A degraded channel with less complexity because of the removal of large wood from channel and harvesting of the riparian area

From Abbe 2000

Geomorphic Effects of Large Wood

Flow Hydraulics and Boundary Roughness

Channel Morphology

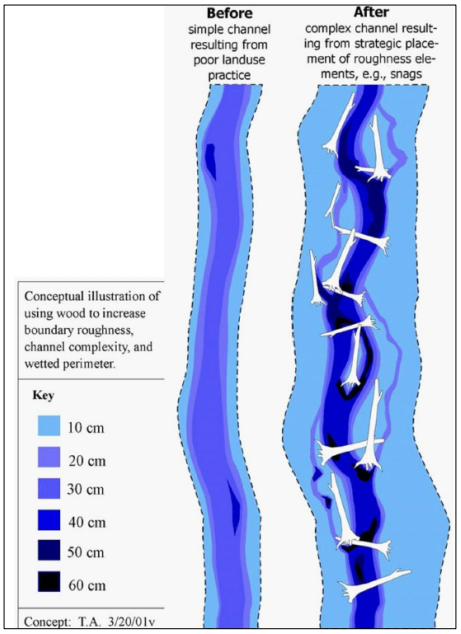
Channel Responses and Adjustments
- *Channel Type*
- *Channel Evolution*

Geomorphic Effects of Large Wood

Flow Hydraulics and Boundary Roughness

Channel Morphology

Channel Responses and Adjustments
- *Channel Type*
- *Channel Evolution*



From Abbe et al., National Large Wood Manual 2016

Thank You!
QUESTIONS?