A Geomorphologist's Perspective on "Natural Stream" Applications in Mine Reclamation

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Department of Geology & Geography

National Interactive Forum on Geomorphic Reclamation
“Putting a New Face on Mining Reclamation”

September 12-14, 2006
Farmington Civic Center
Farmington, New Mexico

Sponsored by Office of Surface Mining, Western Region, and OSM’s National Technical Training Program

“Natural” Stream & River Restoration: Highly Visible

UTAH RECLAMATION MITIGATION AND CONSERVATION COMMISSION

Provo River Restoration Project

www.mitigationcommission.gov/prrp/prrp.html

NATURE VALLEY GRANOLA BARS

Nature Valley's 2002 “Rescue the Rivers” promotion on Crunchy Granola boxes from June through November 2002.

The Nature Conservancy

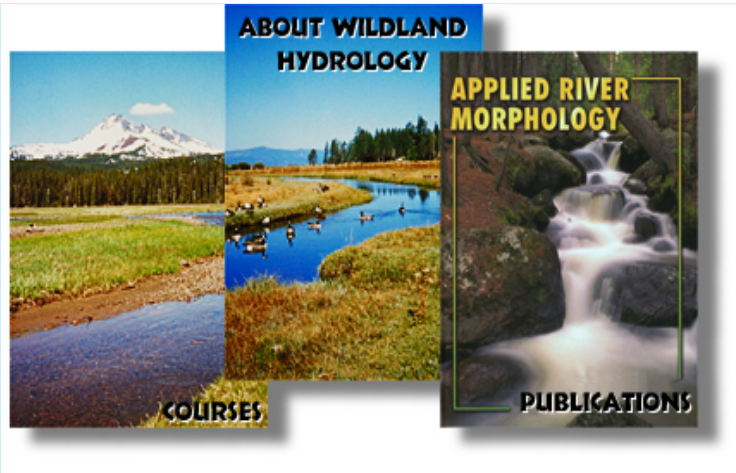
SAVING THE LAST GREAT PLACES ON EARTH

Gila National Forest, NM
© The Nature Conservancy

“Natural Stream Channel Design”

Build Analogs to <u>Stable</u> “Natural” Streams

Wildlandhydrology.com

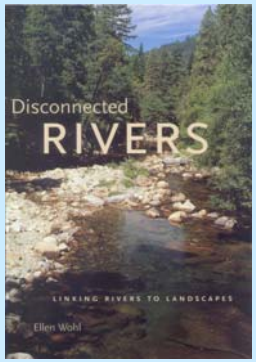


“Packaged” into workshops, teaching materials, and construction by Dave Rosgen

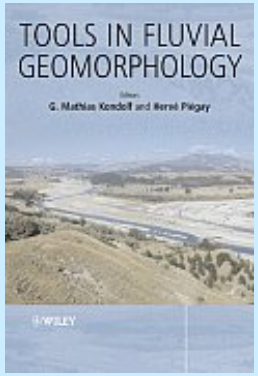
Rosgen, D. L. 1996, Applied River Morphology, Wildland Hydrology, Pagosa Springs, Co.

“Package” relies on classification, references reaches, regional curves (drainage area vs. stream attributes), & in-stream structures

Many Alternative Approaches, Scholars & Practitioners



Ellen Wohl, 2004, Disconnected Rivers Linking Rivers to Landscapes, Yale University Press, 320 p., ISBN: 0300103328



Kondolf, G. Mathias & Piigay, Hervi, editors, Tools in Fluvial Geomorphology, John Wiley & Sons, 696 p. ISBN: 047149142X

"If your only tool is a hammer, every problem looks like a nail."

BLUE Land Water Infrastructure

See downloads at Thomas S. Blue's Website: http://www.blwi.com/

"Stream Restoration" = More Than Just "Rosgen"

Constructive View of “Natural Stream” Science

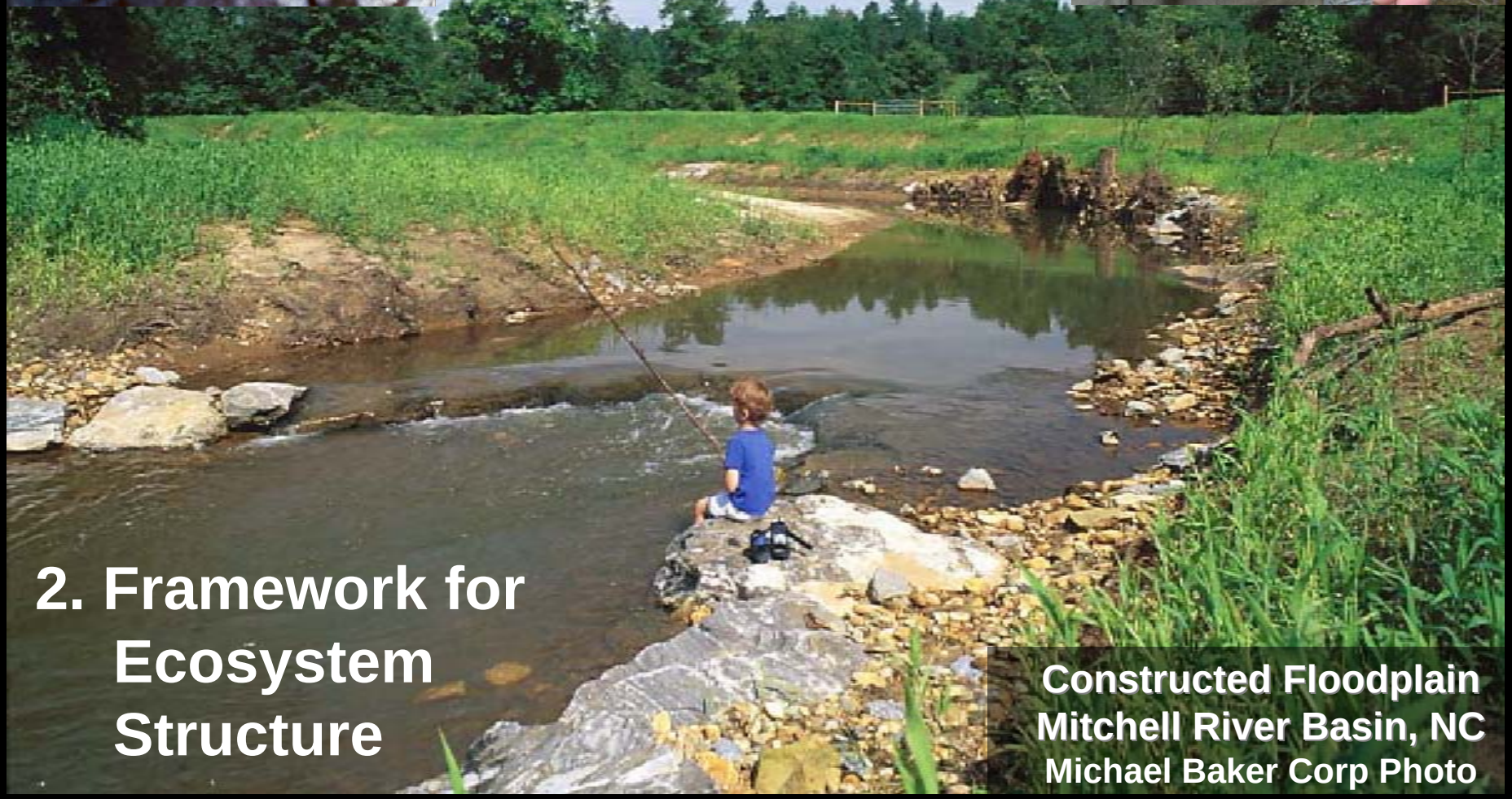
Fluvial Geomorphology & Allied Fields Applied with Goal of Maintaining Channels & Floodplains in Dynamic Equilibrium.

What is a Stream's "Job Description?

Todd Petty Photo

"Work" of a Stream?

Todd Petty Photo

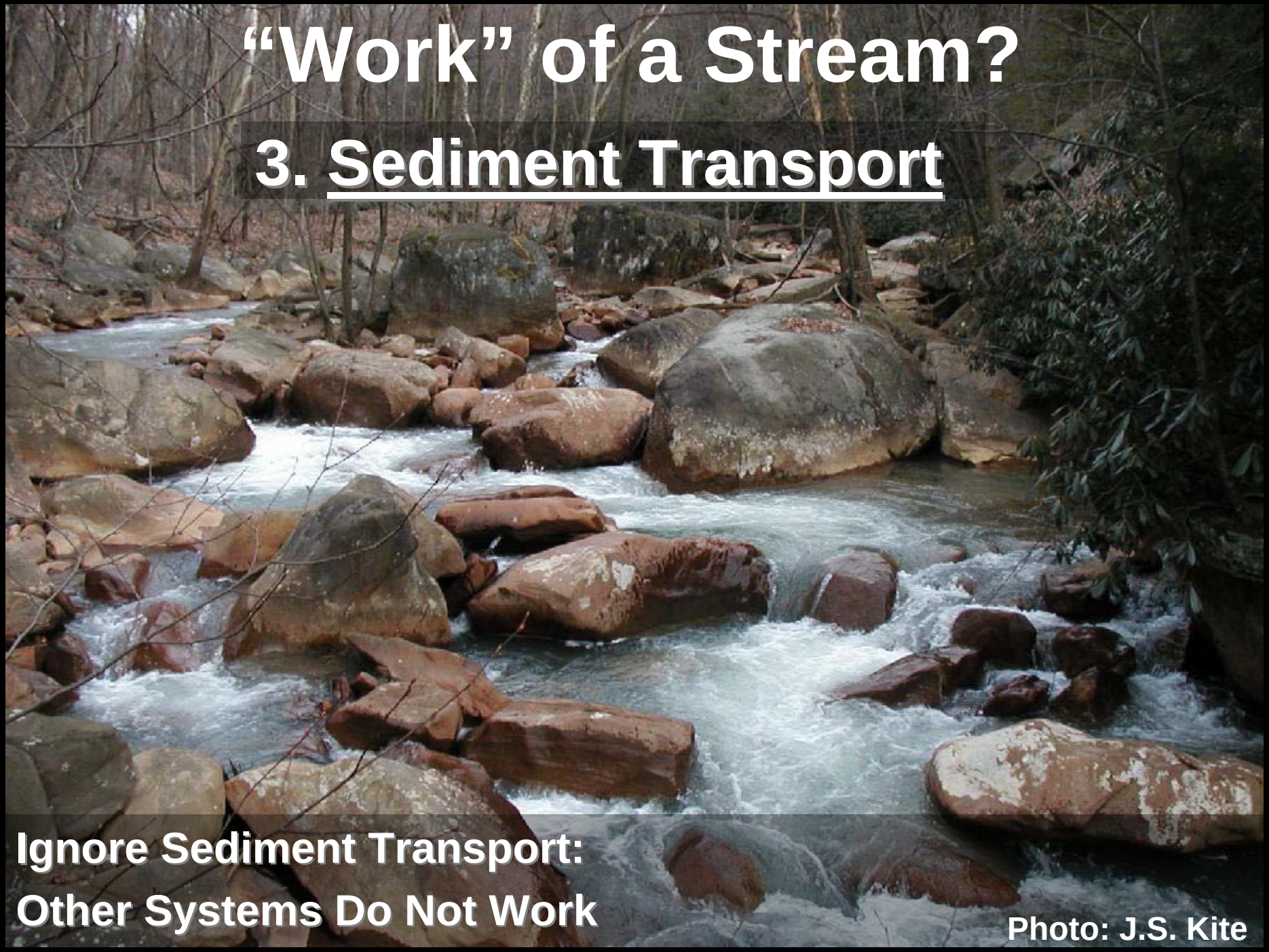


2. Framework for Ecosystem Structure

Constructed Floodplain
Mitchell River Basin, NC
Michael Baker Corp Photo

“Work” of a Stream?

3. Sediment Transport



Ignore Sediment Transport:

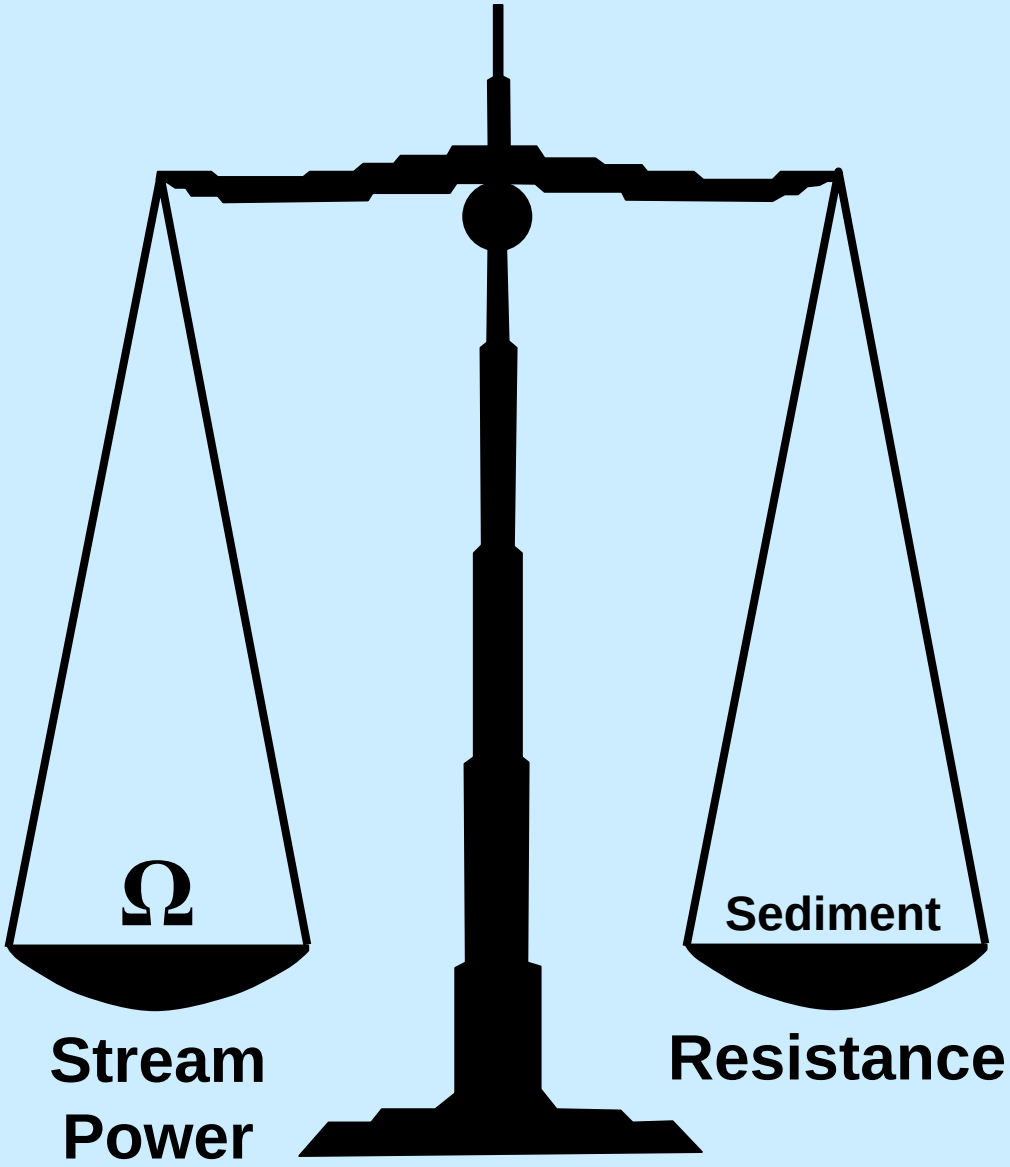
Other Systems Do Not Work

Photo: J.S. Kite

Delicate Balance

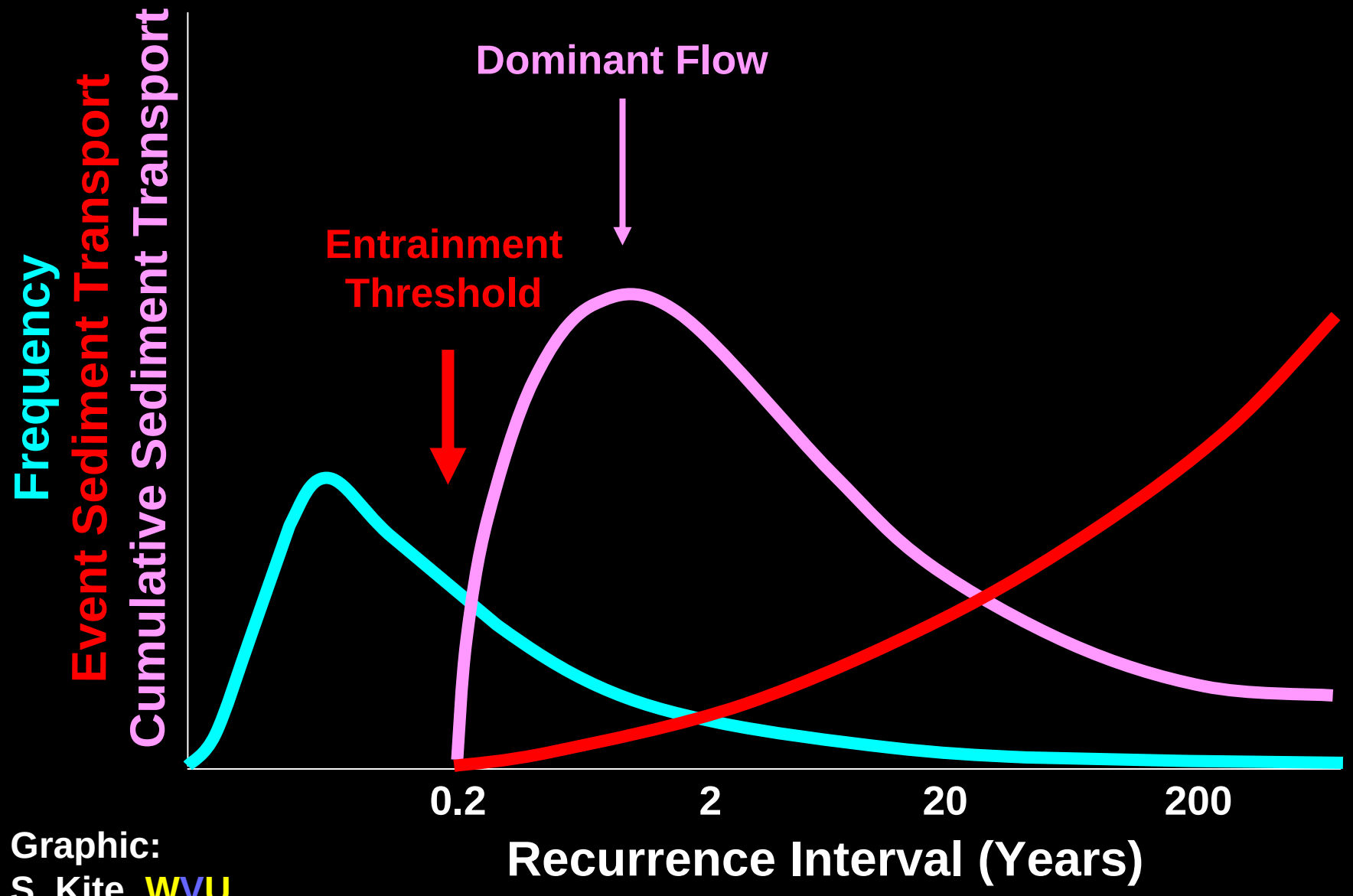
between sediment supply & system's ability to transport sediment

What Size of Flows Determine the Balance?



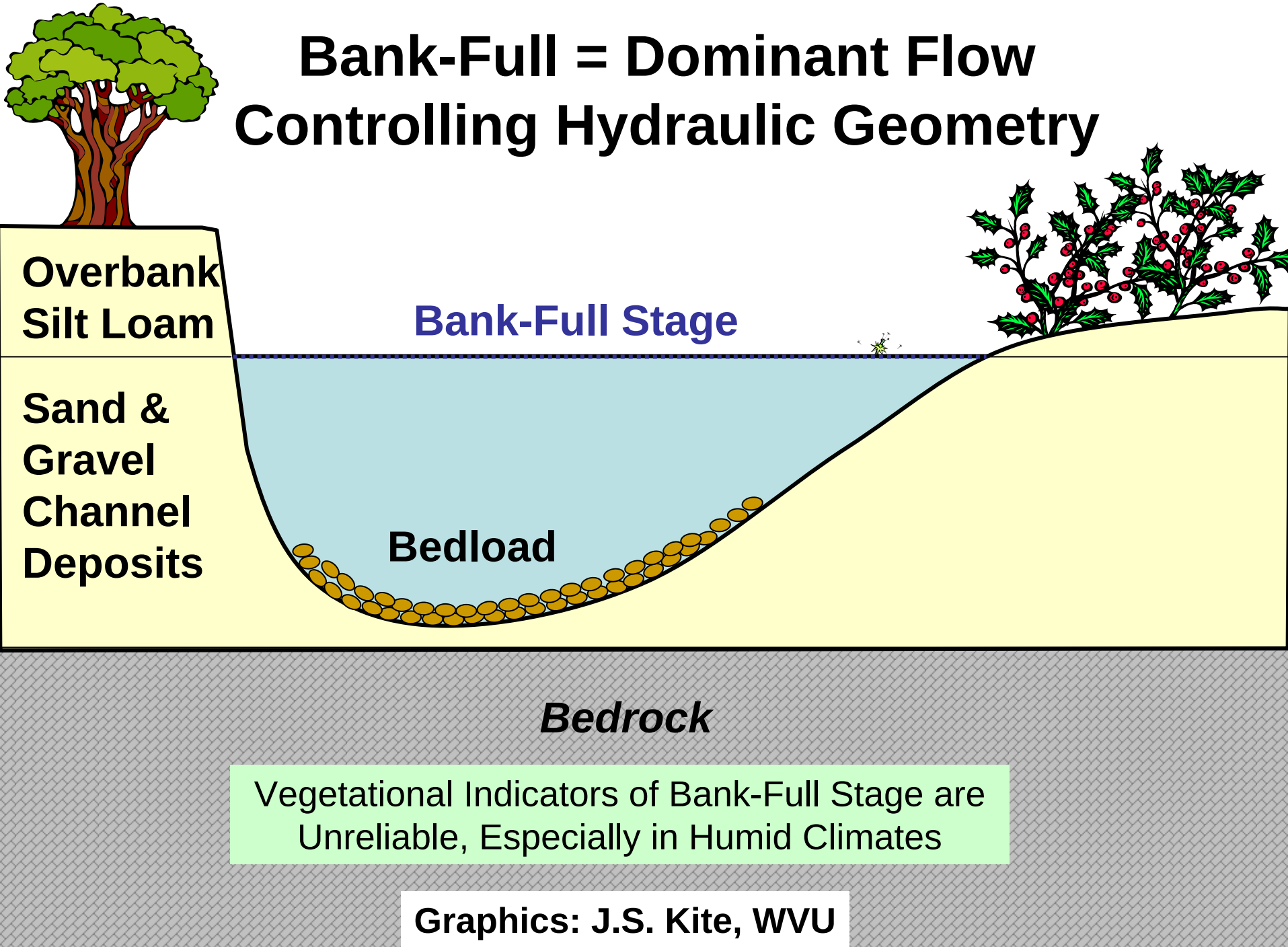
J.S. Kite Graphic

Wolman-Miller Dominant Flow Hypothesis



Graphic:
S. Kite, WVU

Bank-Full = Dominant Flow Controlling Hydraulic Geometry



Vegetational Indicators of Bank-Full Stage are Unreliable, Especially in Humid Climates

Graphics: J.S. Kite, WVU

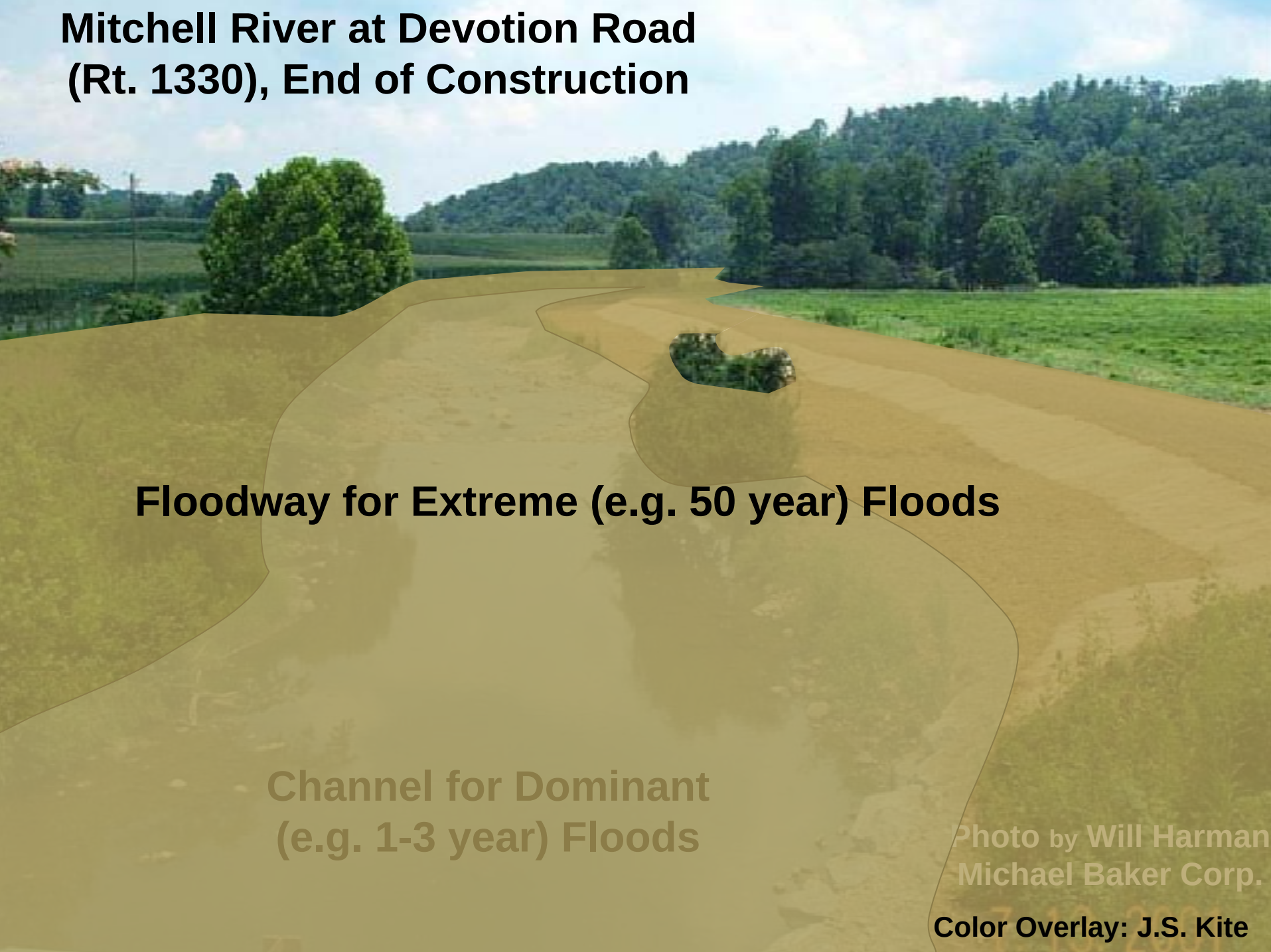
Bank Erosion Hazard
Mitchell River Basin, NC
Michael Baker Corp. Photo

Natural Stream Design May Rely on Structures (e.g. Cross Vein)
Flow Directed to Mid-Channel to Reduce Bank Shear Stress
Constructed Reach
WVU Stream Design Workshop
Mitchell River Basin, NC
Photo: J.S. Kite

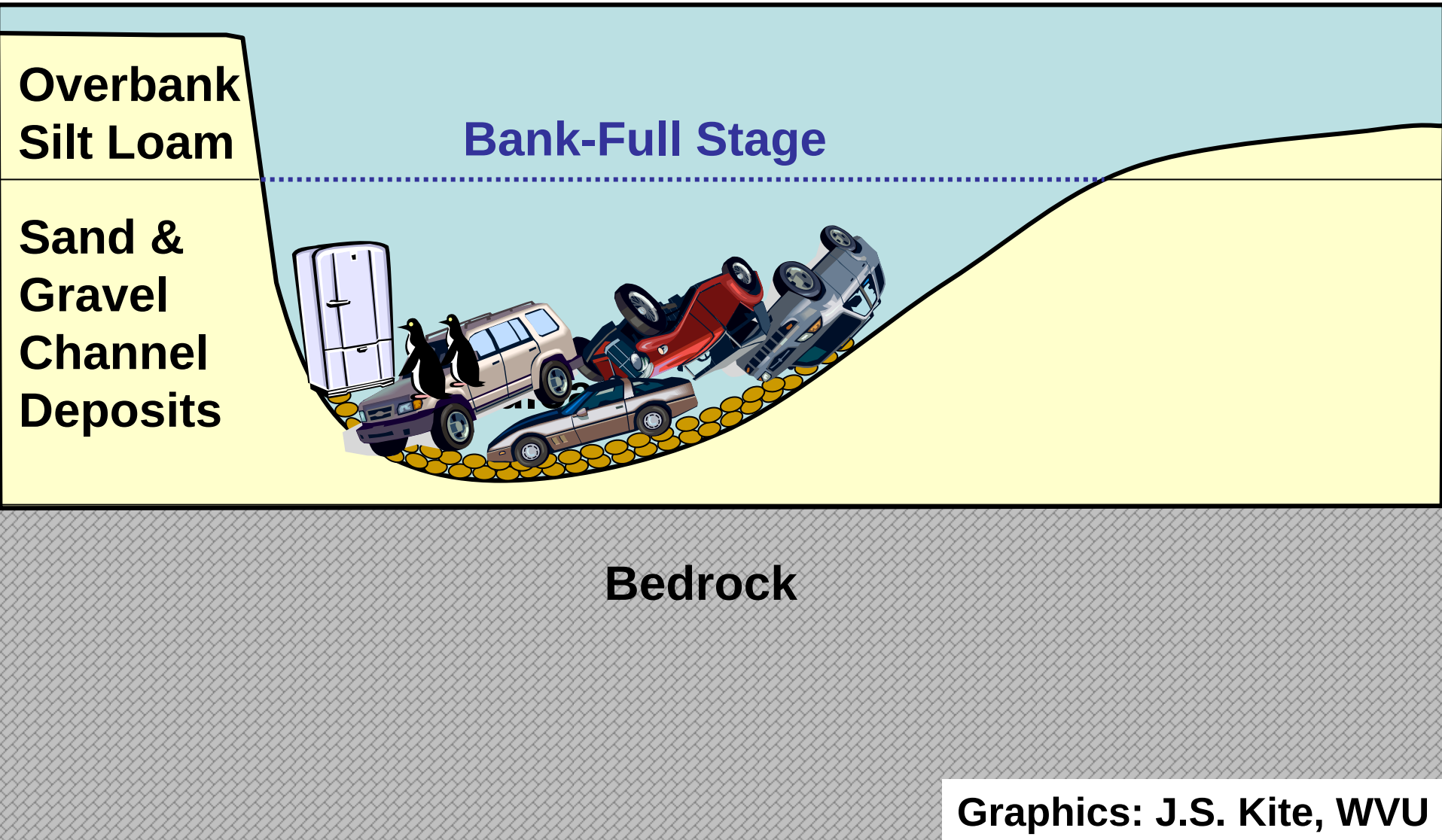
Good “Design” Must Address Dominant (1-3 Year) Flow, Not Just Big (10-200 Year) Floods

Constructed Channel Reach
WVU Stream Design Workshop,
Mitchell River Basin, North Carolina
J.S. Kite, WVU

Mitchell River at Devotion Road (Rt. 1330), End of Construction

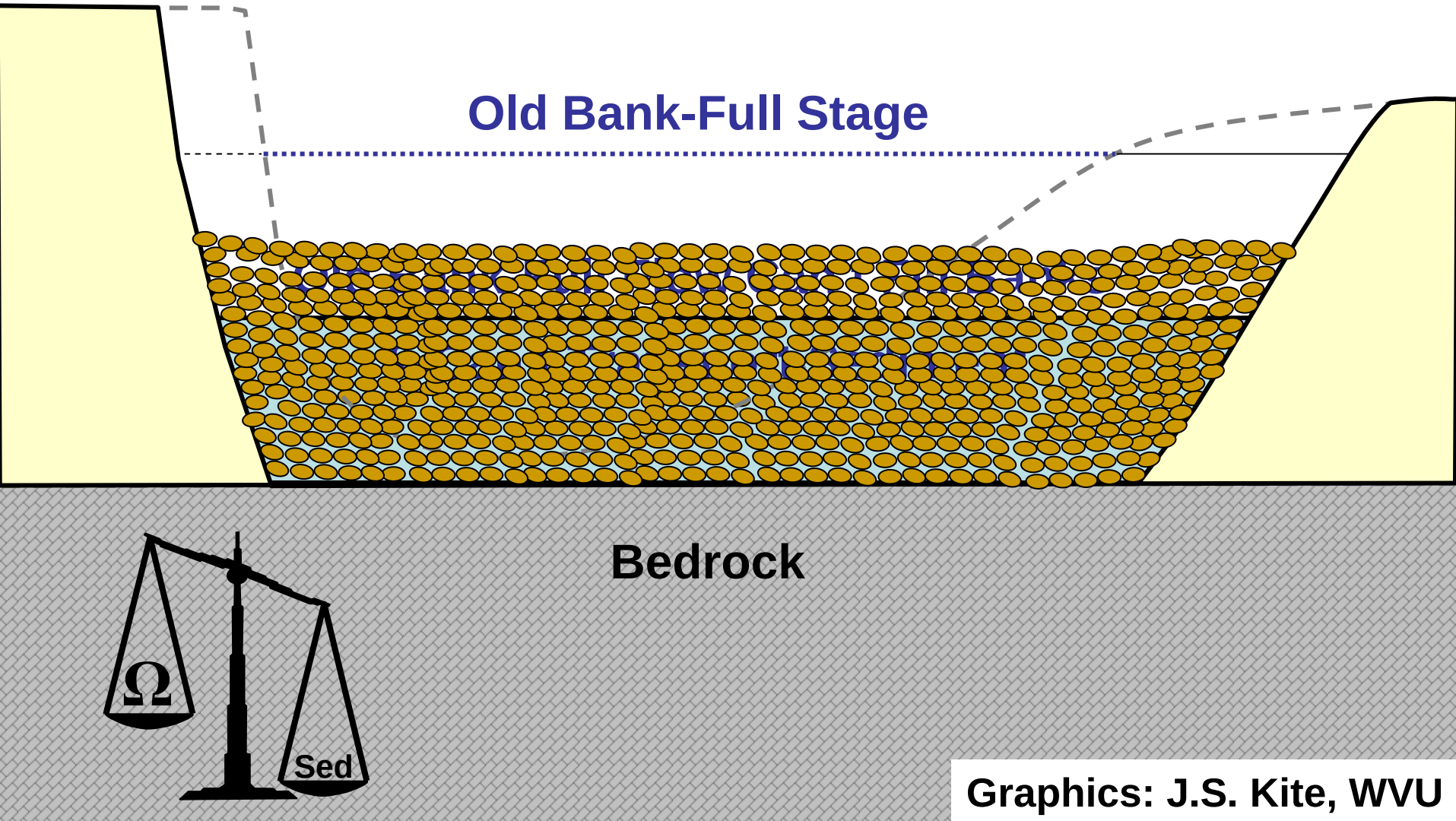


Common Flood Mitigation Error – Over-Widening of Channel



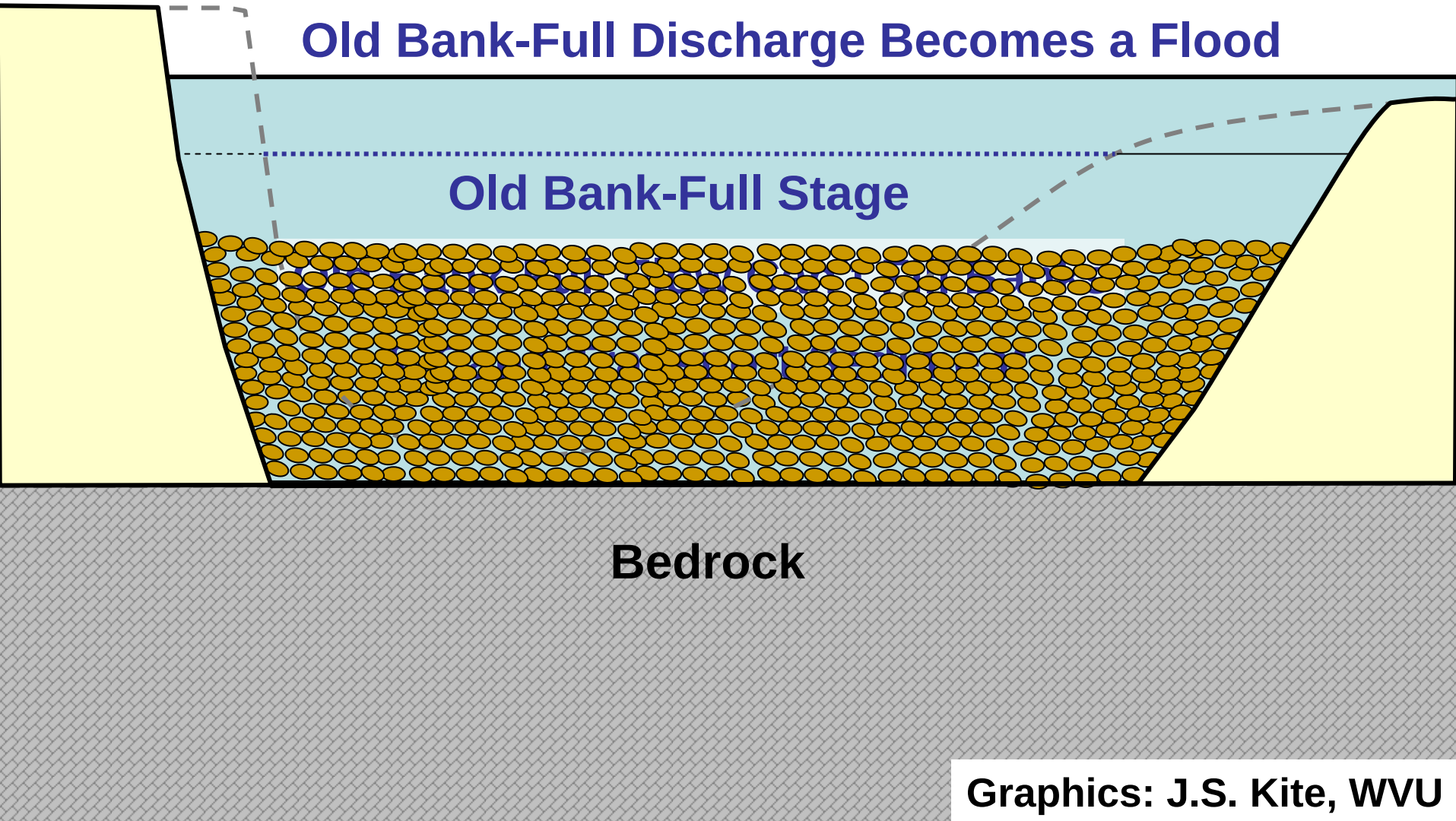
Graphics: J.S. Kite, WVU

Common Flood Mitigation Error – Over-Widening of Channel



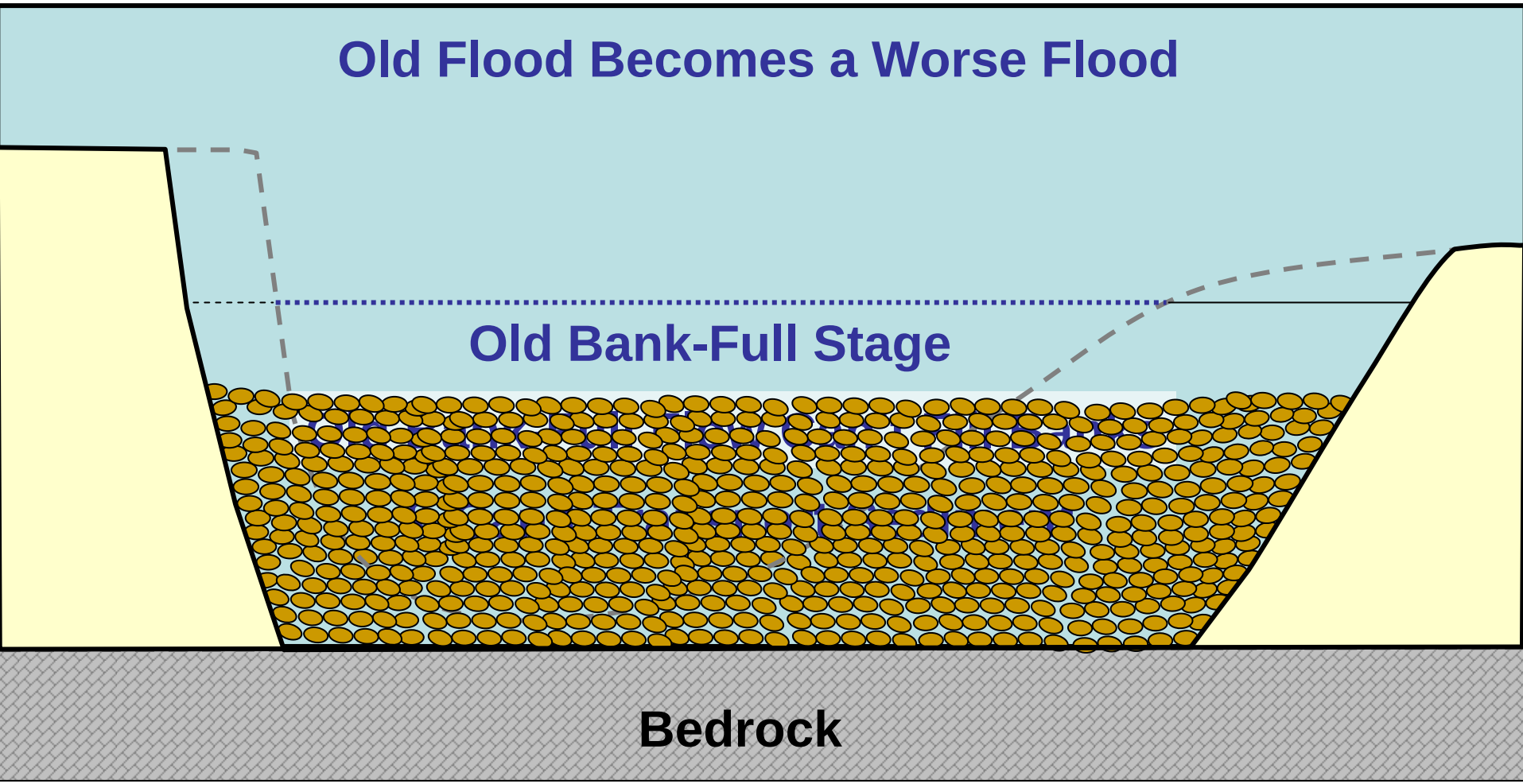
Graphics: J.S. Kite, WVU

Common Flood Mitigation Error – Over-Widening of Channel



Graphics: J.S. Kite, WVU

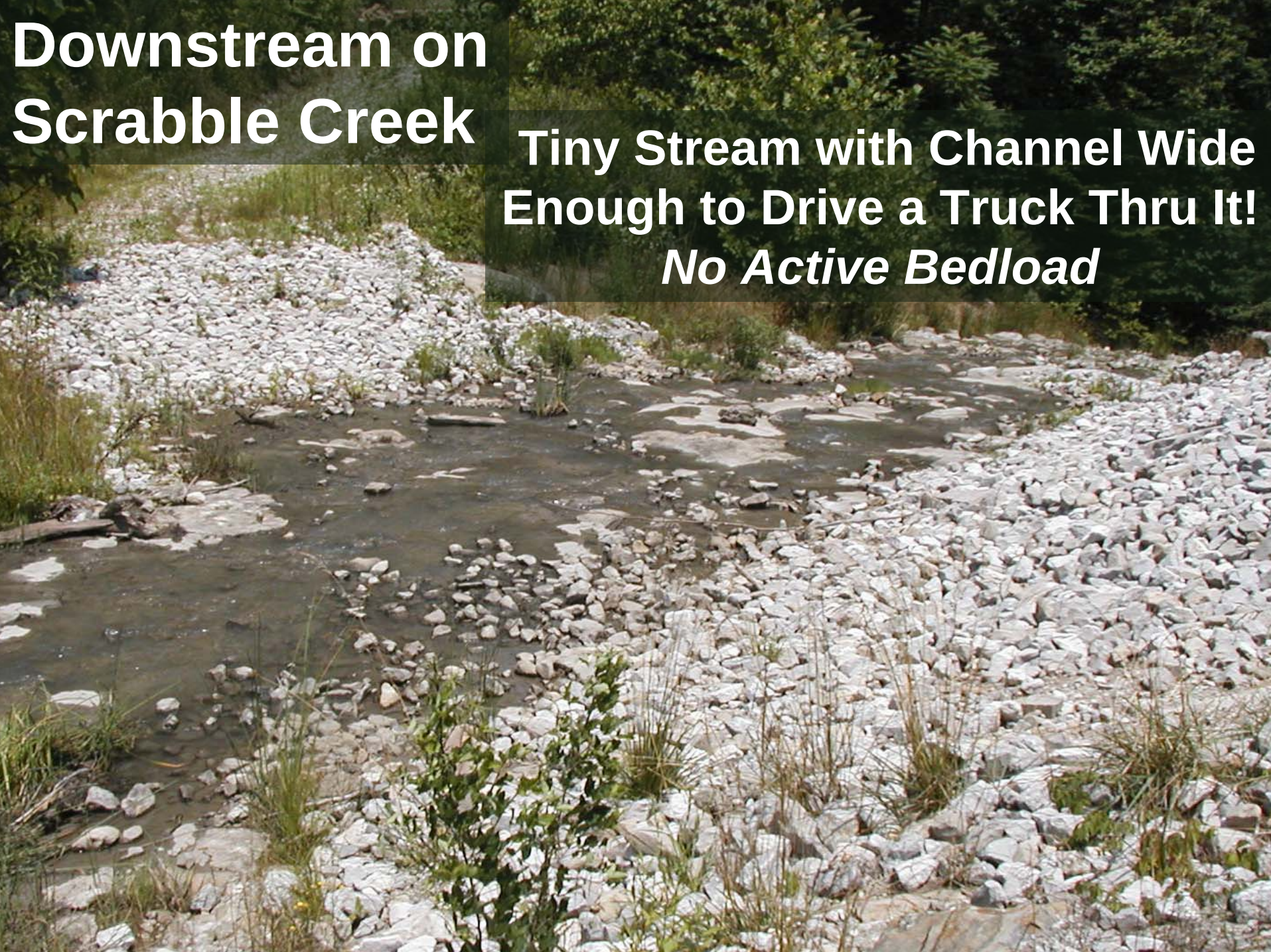
Common Flood Mitigation Error –



Don't Over-Widen Channels to "Pass" the next Flood.
Re-Construct Bank-Full Channel Dimensions
for Sediment Transport

J.S. Kite, WVU

Scrabble Creek
Too-Wide Channel
Not Transporting Bedload

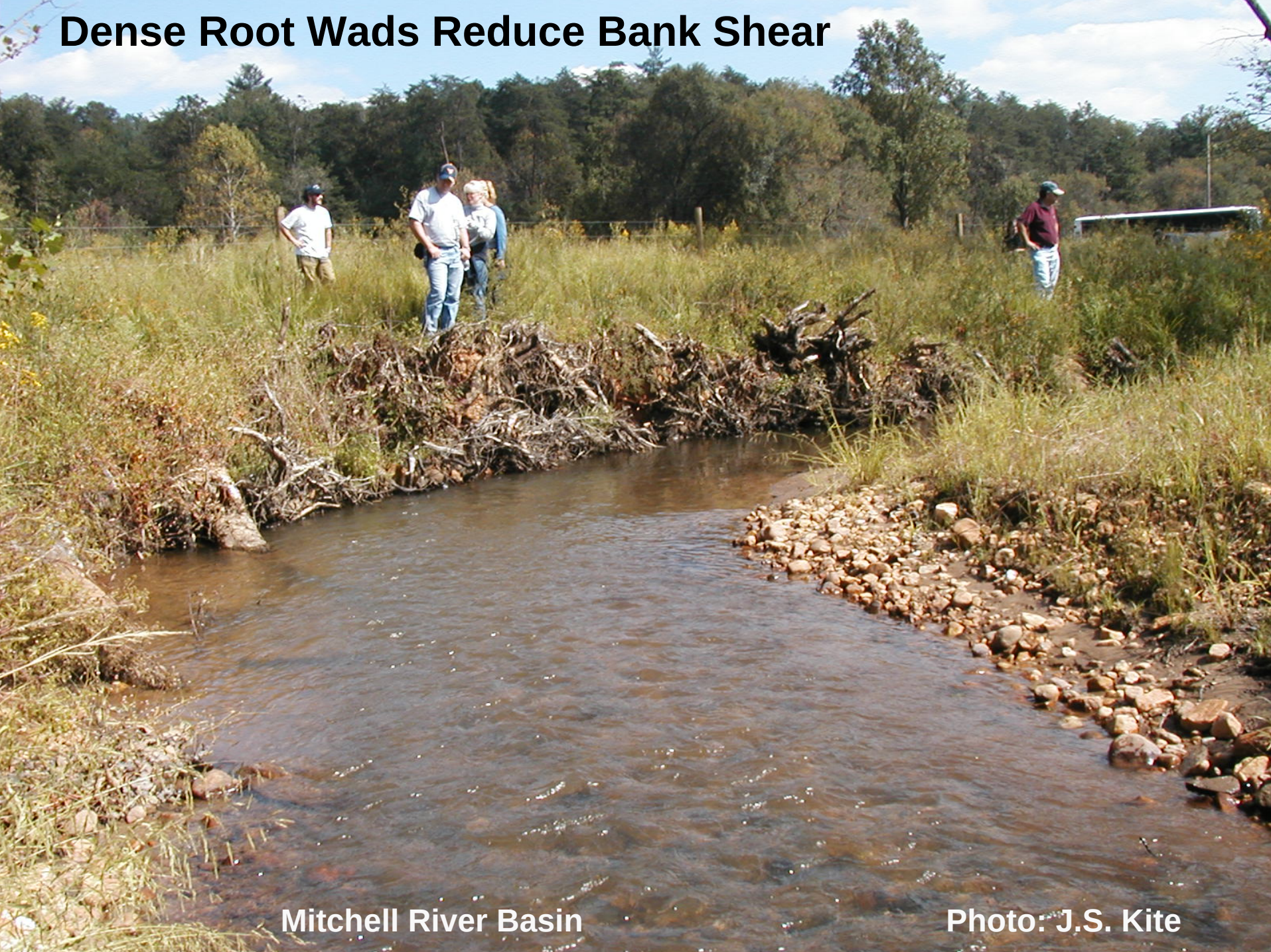

Downstream on Scrabble Creek
Tiny Stream with Channel Wide Enough to Drive a Truck Thru It!
No Active Bedload

Much Larger NC Stream Showing Proper Dimensions & Importance of Plantings

Photo by Will Harman,
Michael Baker Corp.

Vegetation = Nature's Bank Protection Stabilized by Cross-Vane
Image from Will Harman, Michael Baker Corp.

Dense Root Wads Reduce Bank Shear

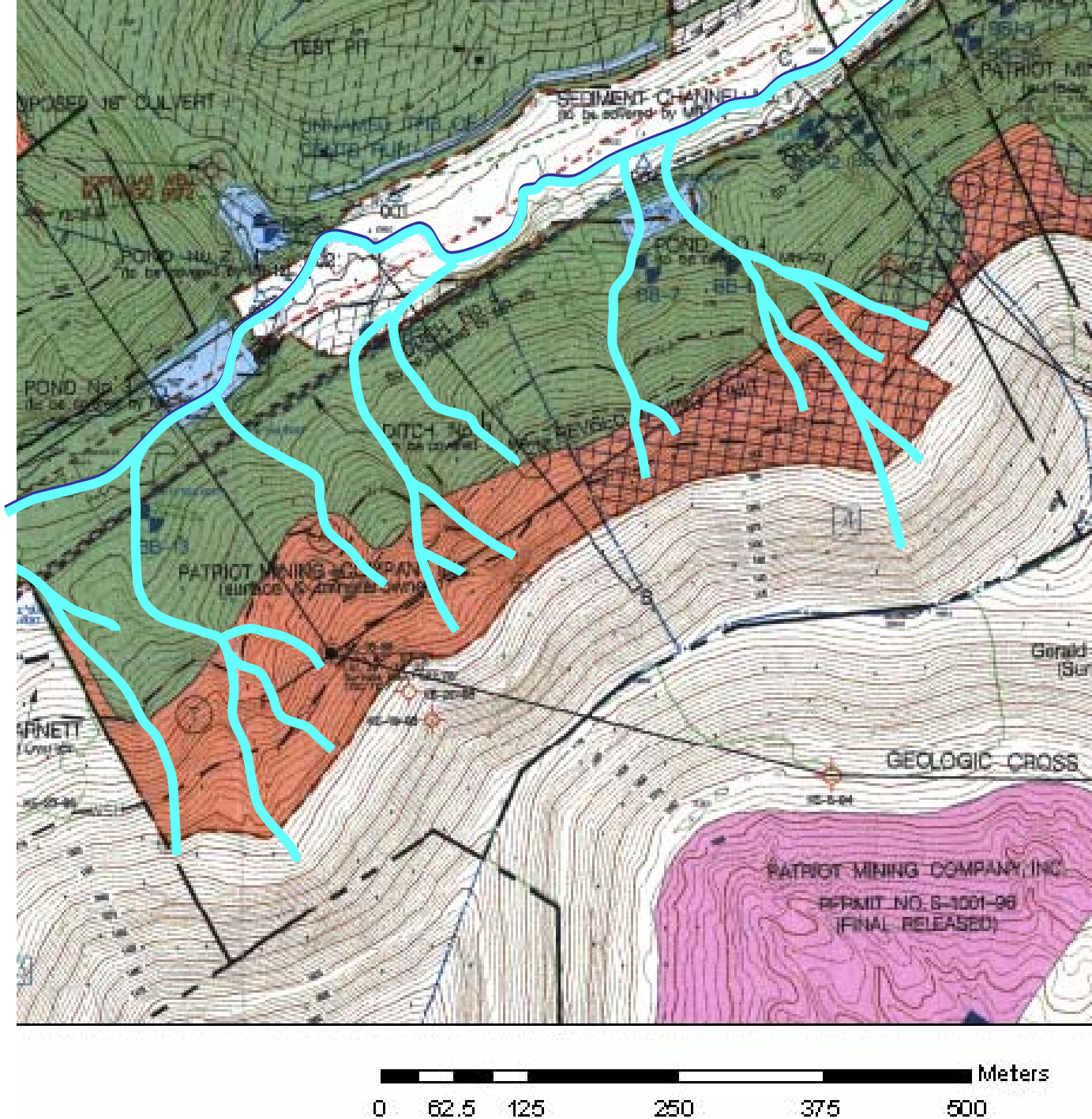


Pre-Mining Drainage Network

Green = Mined & Reclaimed Area

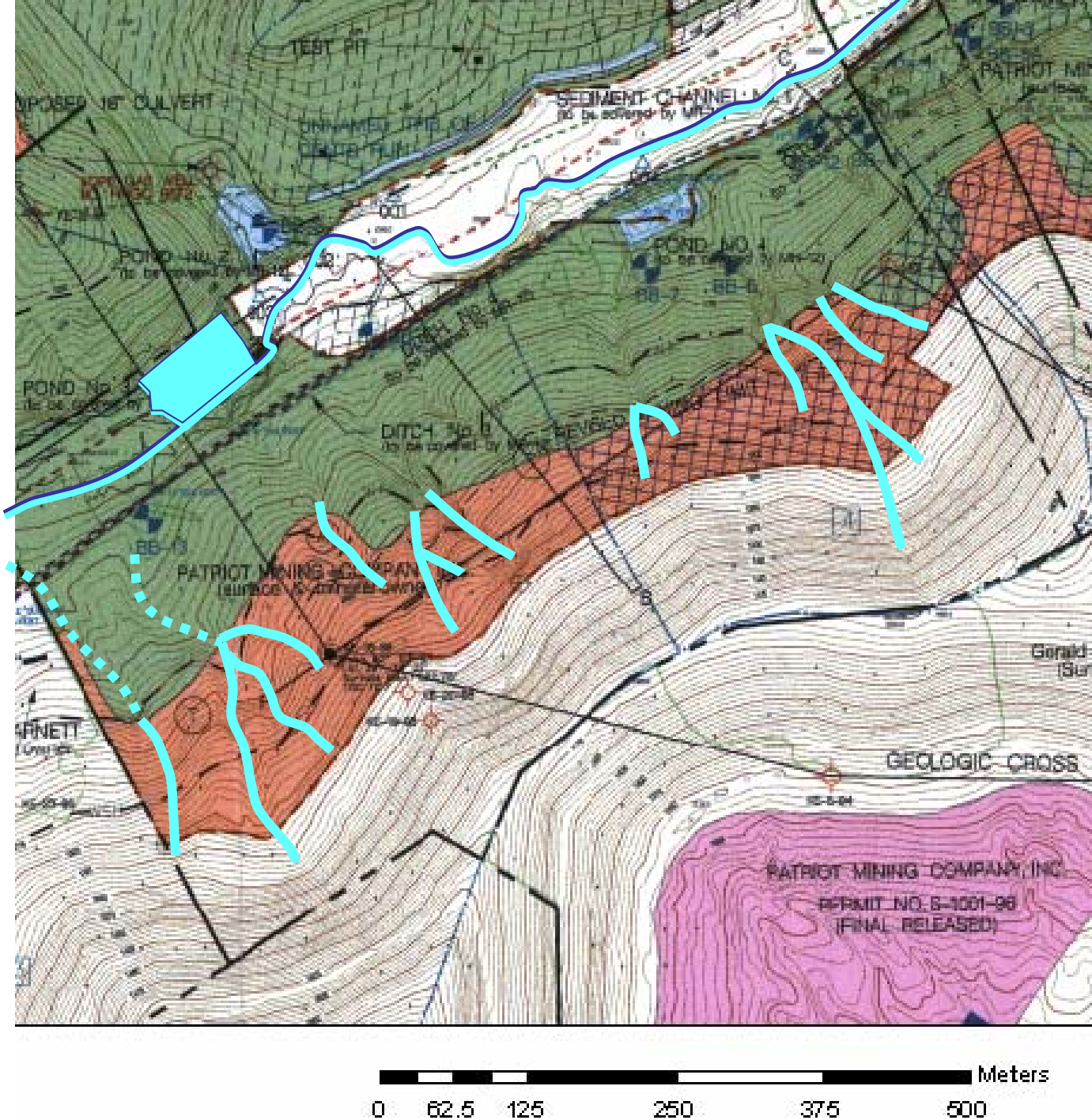
Orange = Undisturbed in Permit Area

Pink = Adjacent Permit Areas.



Post-Reclamation Drainage

1st and 2nd Order Streams Decapitated from Rest of Drainage Network.



Pre-Mining *vs*. Post-Reclamation Drainage for Three Surface Mine Sites in Northern WV

	Pre-Mining (Map Based)	Post-Reclamation (Field Based)	Net Change
Total Channel Lengths			
3 Sites	**11,623 m**	**7384 m**	**- 36.4 %**
Control	*1866 m*	*1882 m*	*- 0.1%*
1st Order: 2nd Order Bifurcation Ratios			
3 Sites	**3.38**	***7.89***	**+133.4 %**
Control	*2.60*	*3.17*	*+ 22%*

Decrease in Drainage Density and Integration

Gullies Downslope of Truncated Stream, North-Central WV

Nearly Random Boulders are Little Protection for Substrate

1st Order Stream Bed Mobilization on Reclaimed Mine Wastes

Minden AML Site, after 115 cm Rainfall, July 2001

Oversized Rock-Lined Slope-Perpendicular 2nd Order Channel Incapable of Most Stream Functions

Permit Area #80-80, 2002,
North Central WV

Unlined Sub-Horizontal 1st Order "Stream" (Sediment Trenches) Designed NOT to Transport Sediment

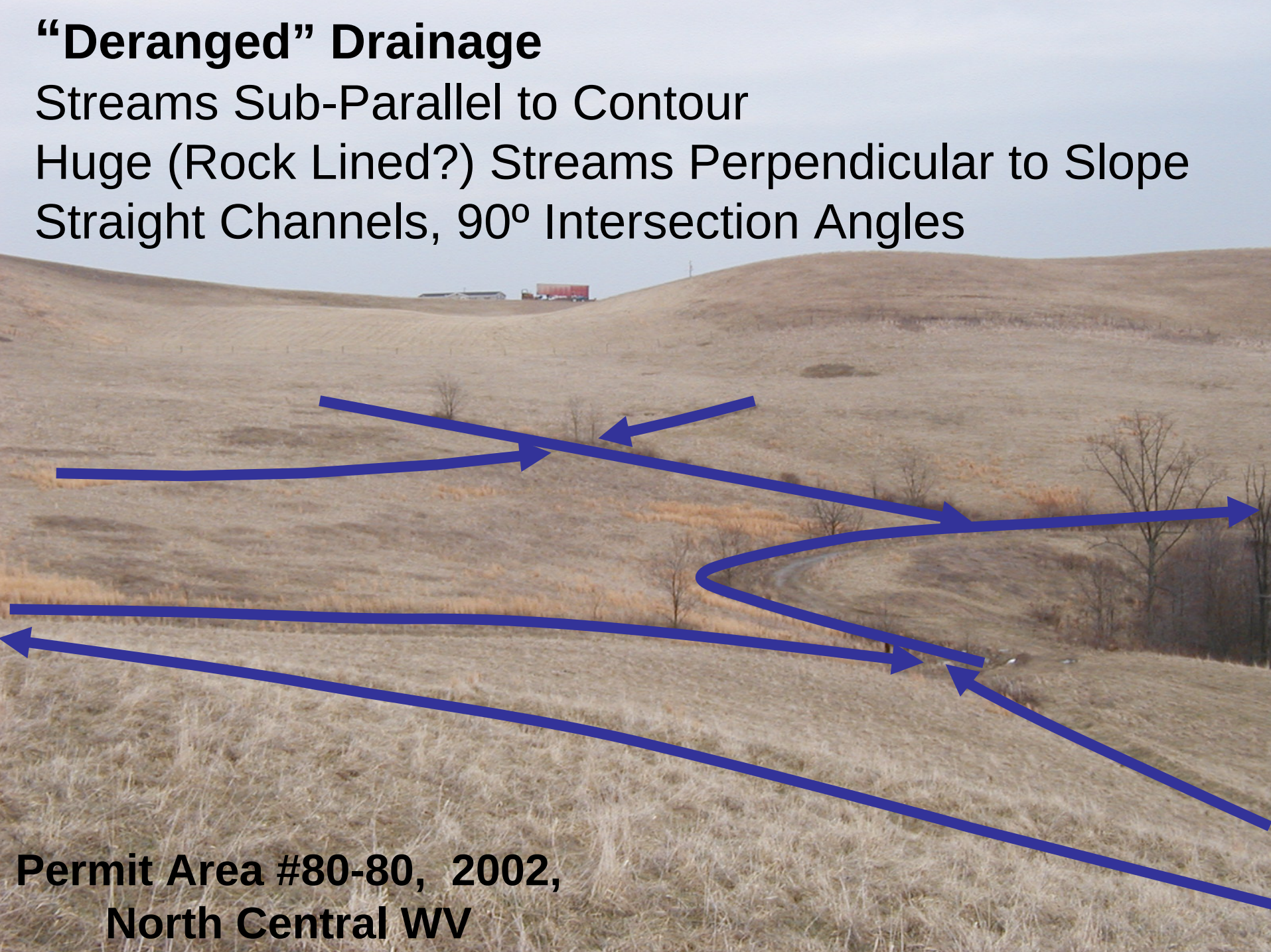
Permit Area #80-80, 2002, North Central WV

“Deranged” Drainage

Streams Sub-Parallel to Contour

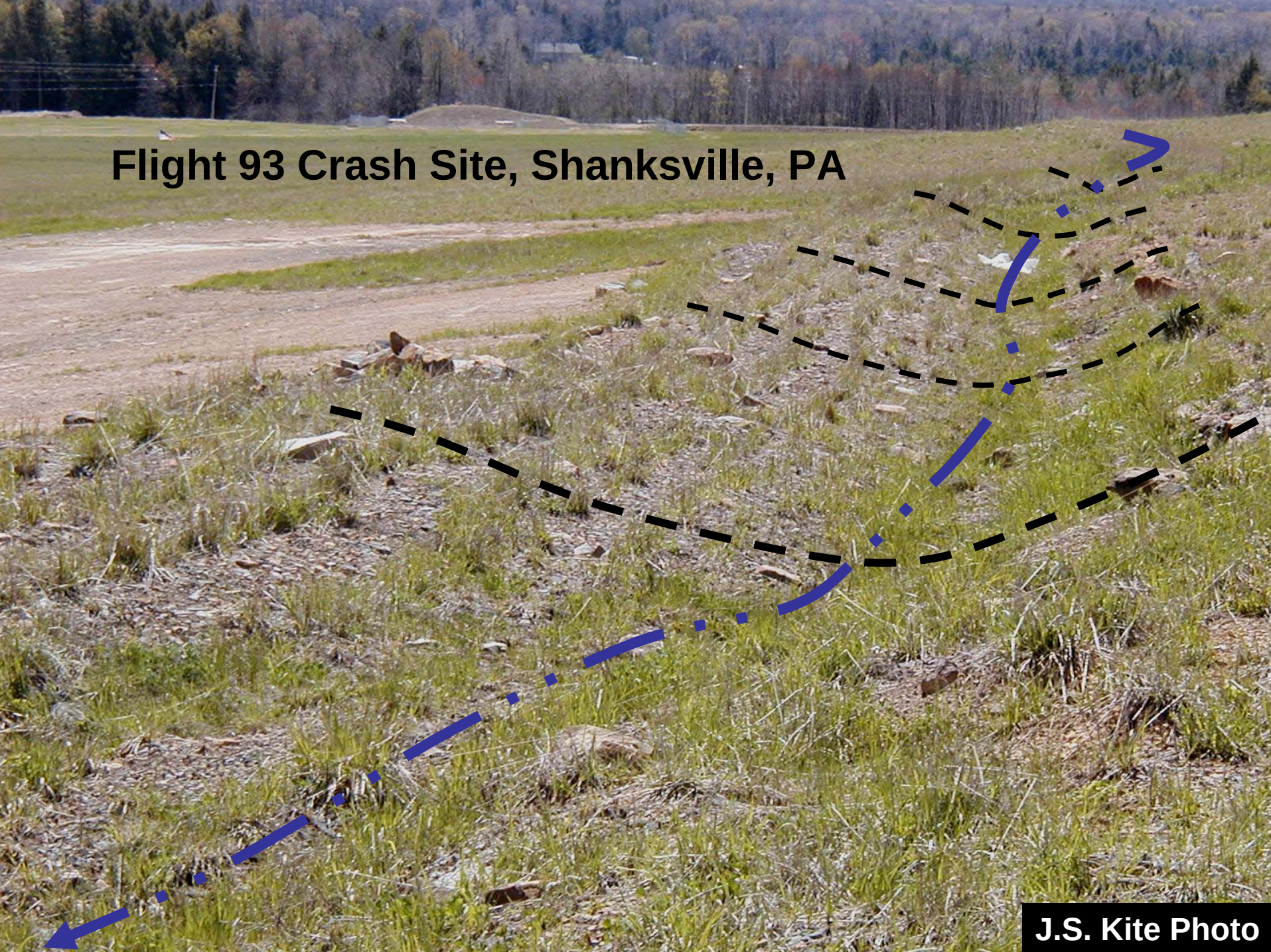
Huge (Rock Lined?) Streams Perpendicular to Slope

Straight Channels, 90º Intersection Angles



Permit Area #80-80, 2002,
North Central WV

Sediment Trenches Head Cutting at Intersection
Permit Area #80-80, 2002,
North Central WV


Flight 93 Crash Site, Shanksville, PA
J.S. Kite Photo

Stream "Restoration" Issues Related to Reclaimed Contour Surface Mines

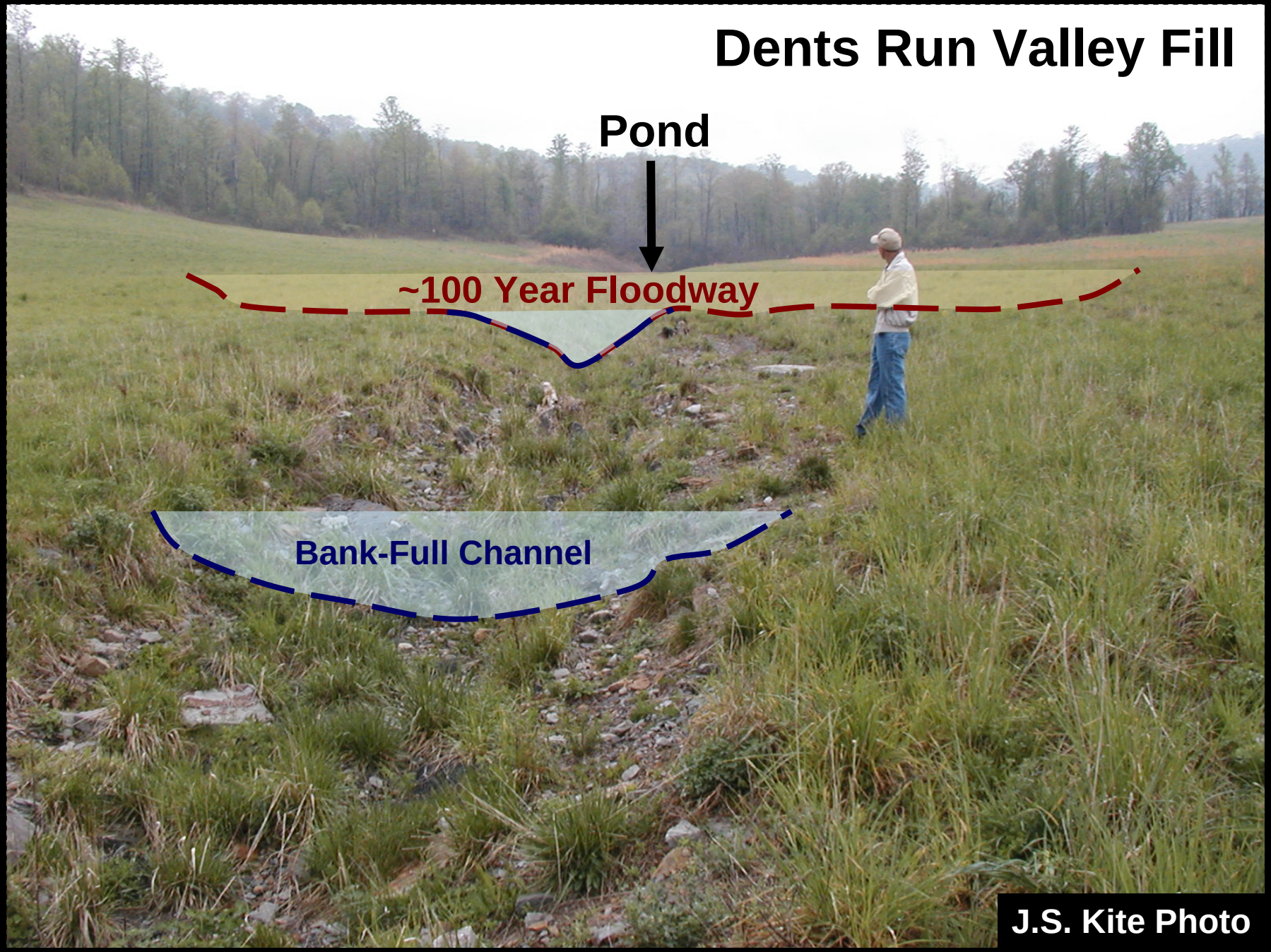
- Ecological Integrity
- Drainage Integration
  - Bank-Full and Flood Flows?
- Sediment Supply & Transport
- Natural Stream Design Cost-Benefits vs. Currently Used "Structures"
  - Over What Time Frame?

J.S. Kite Photo

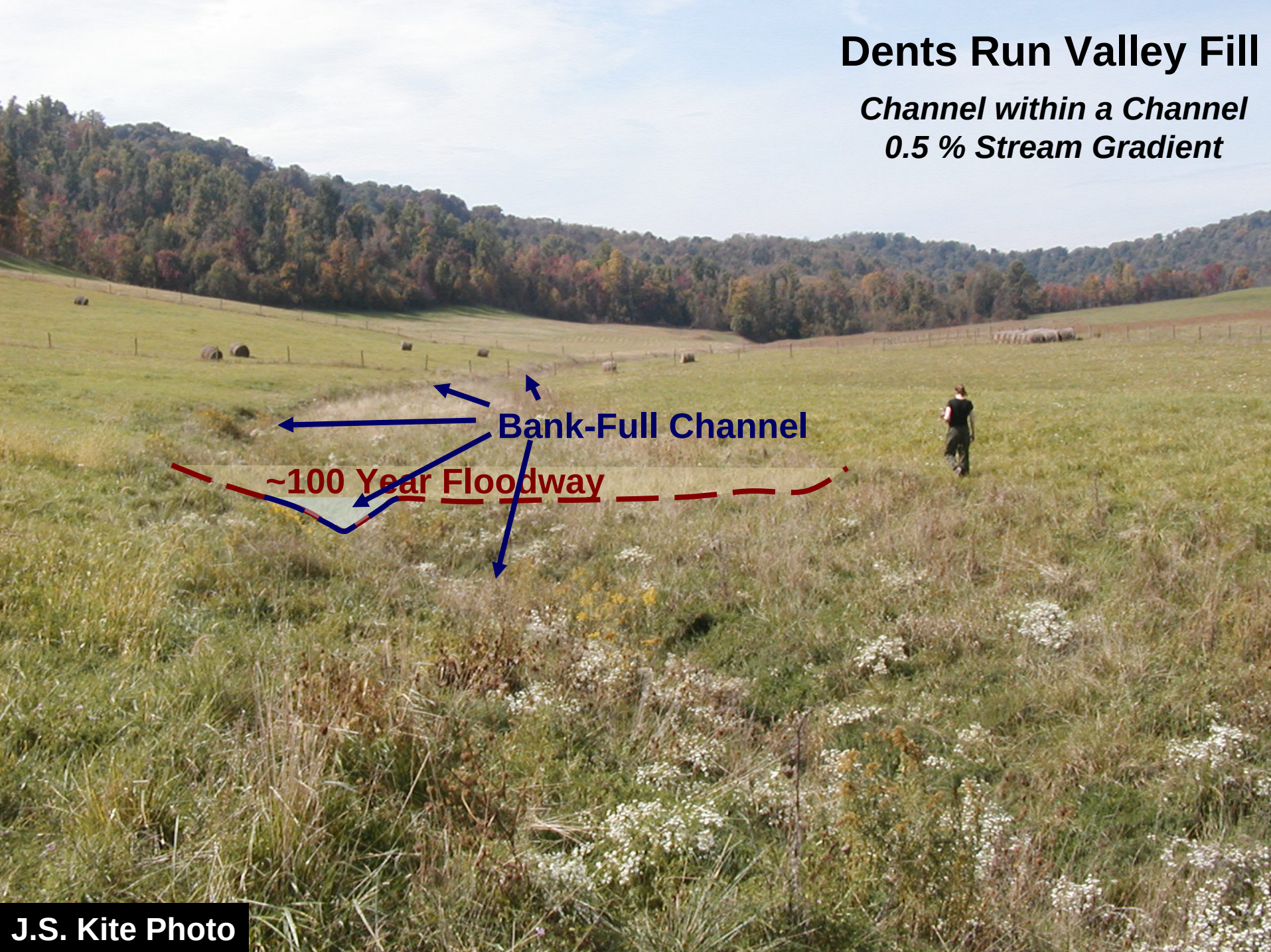
Flight 93 Crash Site, Shanksville, PA

Dents Run Valley Fill
Northern WV

Flow Ends at Pond >99% of Time
What About other 1%

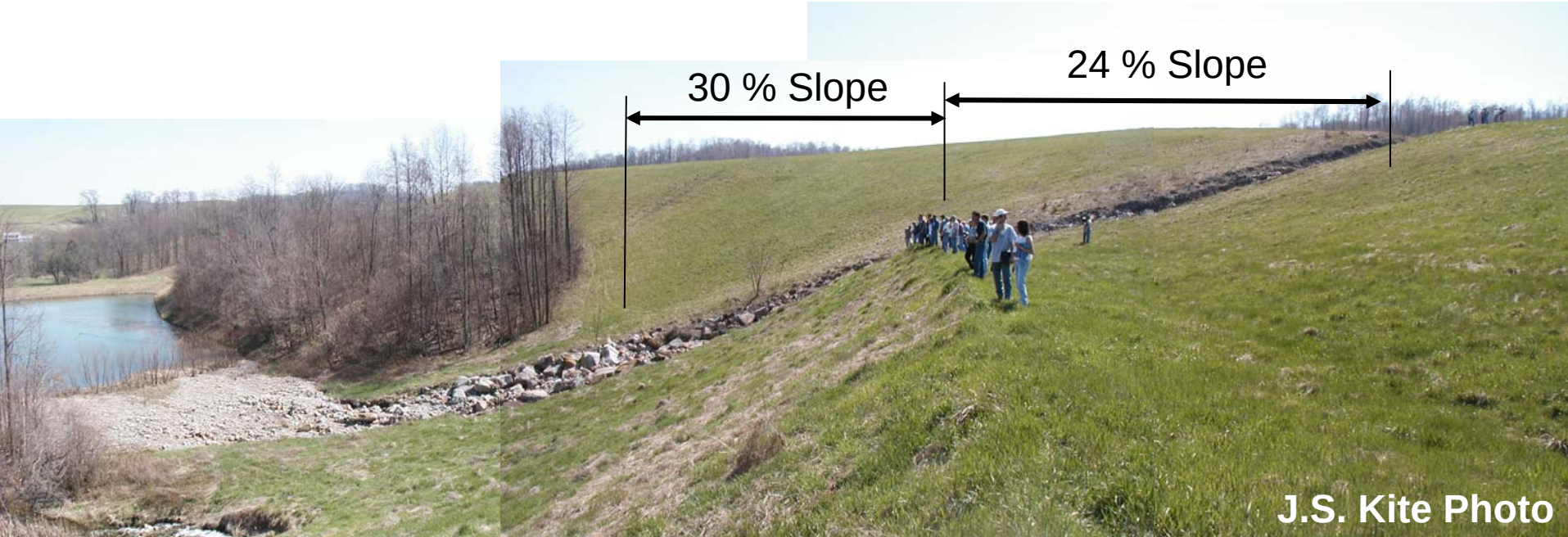

Dents Run Valley Fill
Pond
~100 Year Floodway
Bank-Full Channel
J.S. Kite Photo

Dents Run Valley Fill
J.S. Kite Photo


Dents Run Valley Fill
Channel within a Channel
0.5 % Stream Gradient
Bank-Full Channel
~100 Year Floodway
J.S. Kite Photo

Steep Channel at End of Dents Run Valley Fill

Tremendous Stream Power When Flow Reaches Steep End of Valley Fill



Dents Run Valley Fill
J.S. Kite Photo

Dents Run Valley Fill
J.S. Kite Photo

Dents Run Valley Fill
J.S. Kite Photo

Large “Durable” Rock Valley Fill

End-Dump Produces Low-Cost Internal Drainage

What About Long-Term Stability?

Stream “Restoration” and Valley Fills

Habitat Loss & Ecological Integrity

Flood & Baseflow Hydrograph

- **Enhancement or Attenuation?**

Balanced Sediment Transport

Selection of Reference Reaches

- **Stable Pre-SMCRA Mines?**

USGS Photo

Scour of Colluvial Slope in Valley Fill “Groin,” July 2001

Scoured Colluvium
Valley Fill Groin
Valley Fill
Colluvium
J.S. Kite Photo

“Natural” Valley-Fill Design?

- **Materials:**
  - Wrong Geology Yields Bad Fill
- **Water Flow Must Be Carefully Routed**
  - Channels, Groins, & Toe-Slopes Must Be Protected to Avoid Run-Away Erosion
  - Cross-Vanes, J-Hooks, Other In-Stream Structures Can Direct Shear Stress Away from Banks & Toe-Slopes & Permit Steep Gradient

Cyprus Kanawha Mine Valley Fills: Completed & Under Construction
Photo by Lawrence Pierce, Charleston Gazette, 1998

Conventional valley fills, include costly chimney drain, constructed from valley bottom up, may be more amenable to “Natural Stream Design” approach.

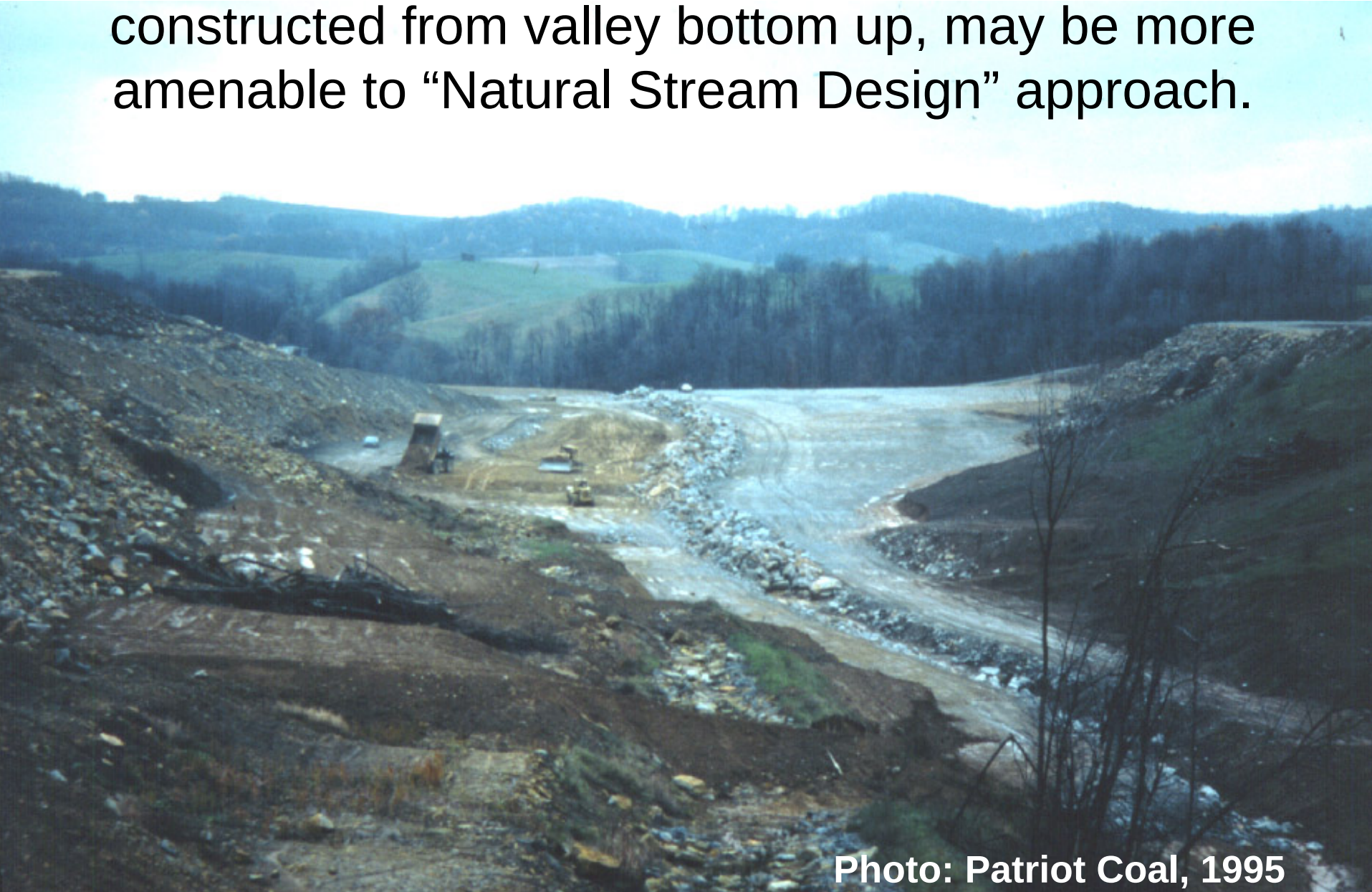


Photo: Patriot Coal, 1995

Where is Stream “Restoration” Need Greatest?

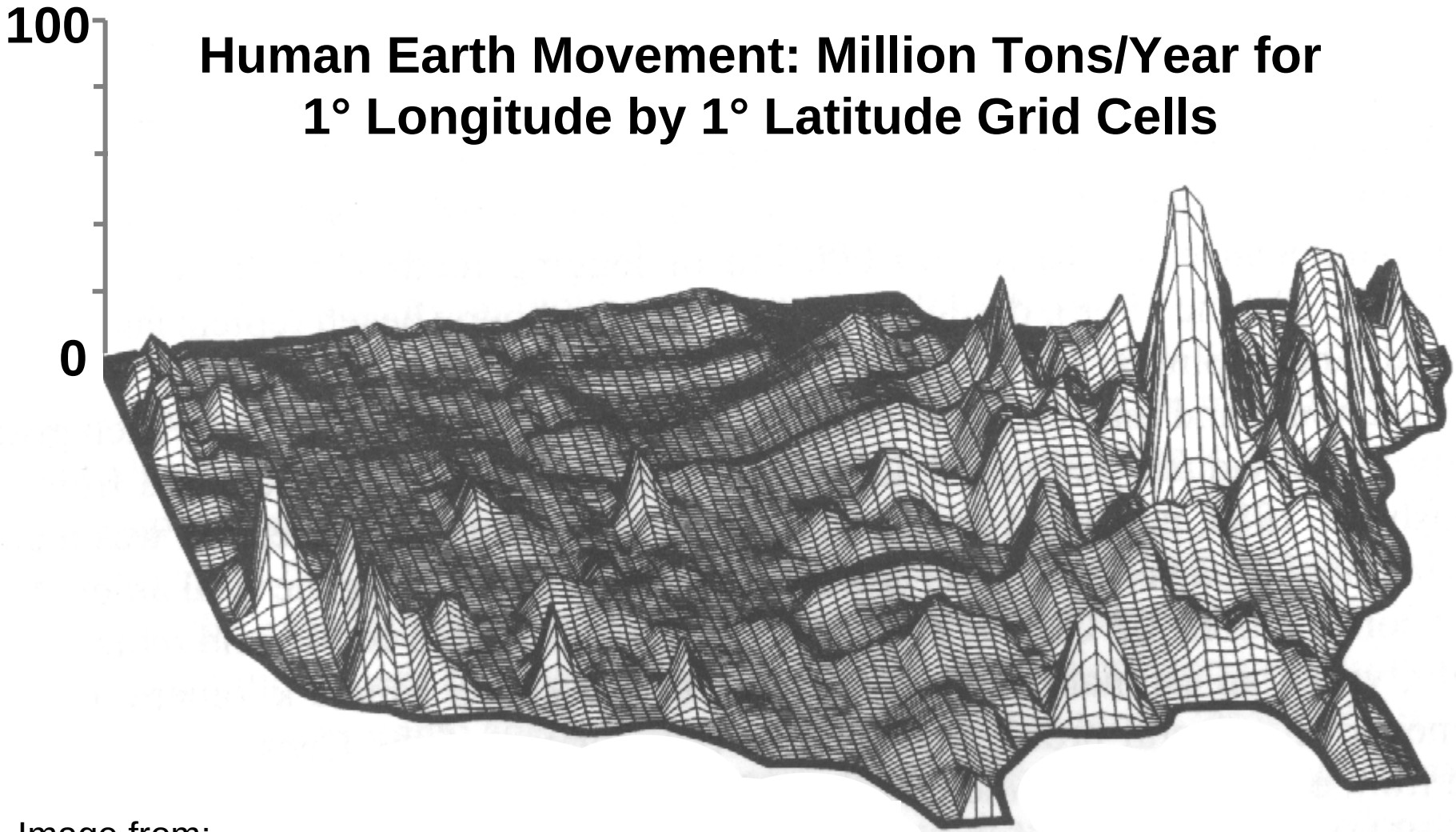


Image from:

Hooke, R. L., 1999, Spatial distribution of human geomorphic activity in the United States; comparison with rivers: Earth Surface Processes and Landforms, v. 24, p. 687-692.

Potential Problems

Photo: Greene County (NY) Soil & Water Conservation District Stream Restoration Program
www.gcswcd.com/stream

- Conservatism in Face of New Ideas
- Some Regulations are Disincentives to Best Engineering Practices
- Uncertainty Over Best Methods
- Cost Effectiveness is Long Term –Mine Industry Works on Short-Term Economics

Reclaimed Landscapes Present Great Opportunity for Natural Stream Design

1. Costly, Large-Scale Stream Modification Already Occurs.
2. Industry Must Address Aesthetics & Ecology to Maintain Public Support.
3. Reduce Erosion & Sedimentation Problems
4. Flood Hazard Reduction.
5. Cost Effective Long-Term, (vs. “Bond Period”?)

Image from Will Harman, Michael Baker Corp.