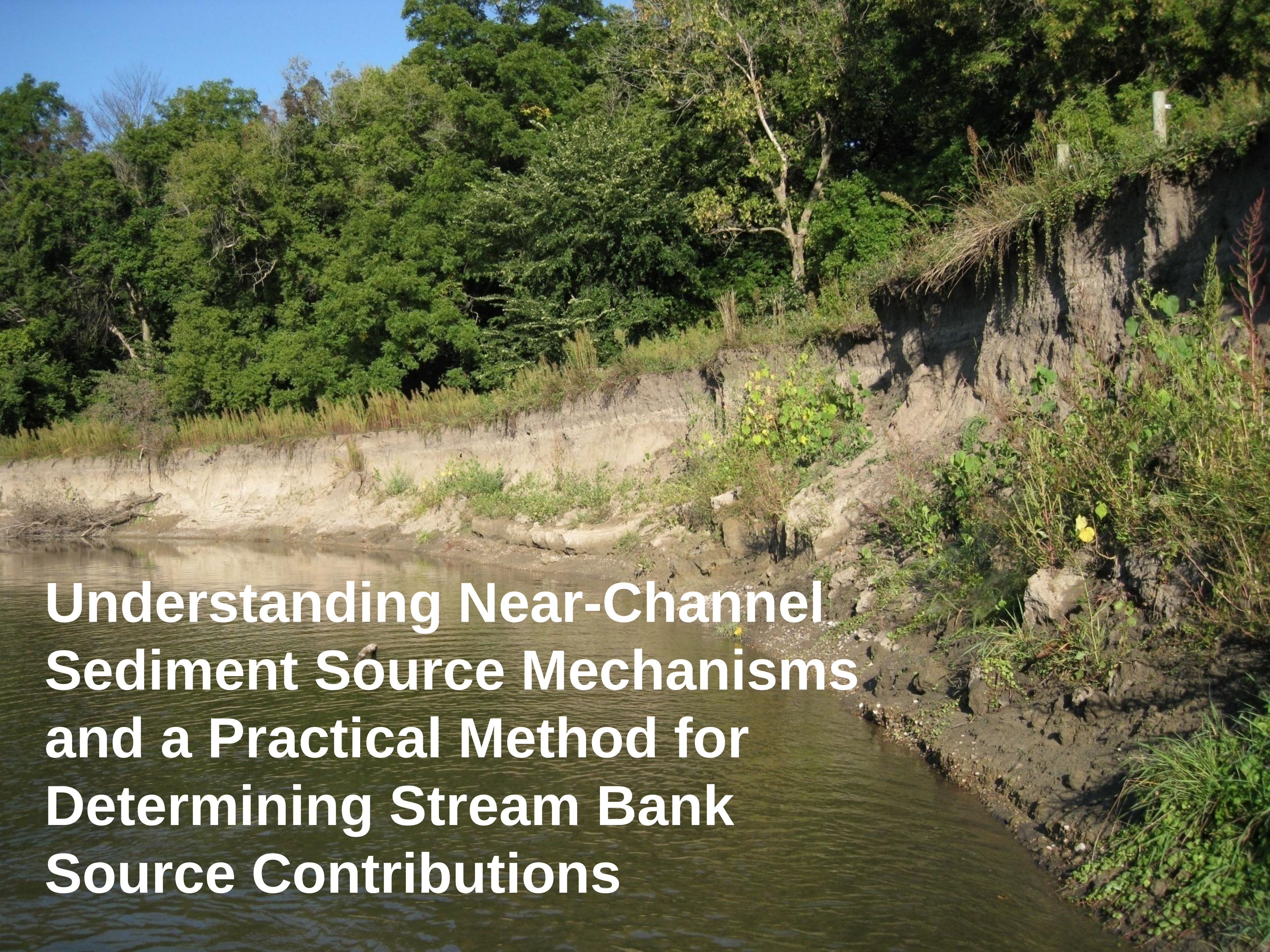
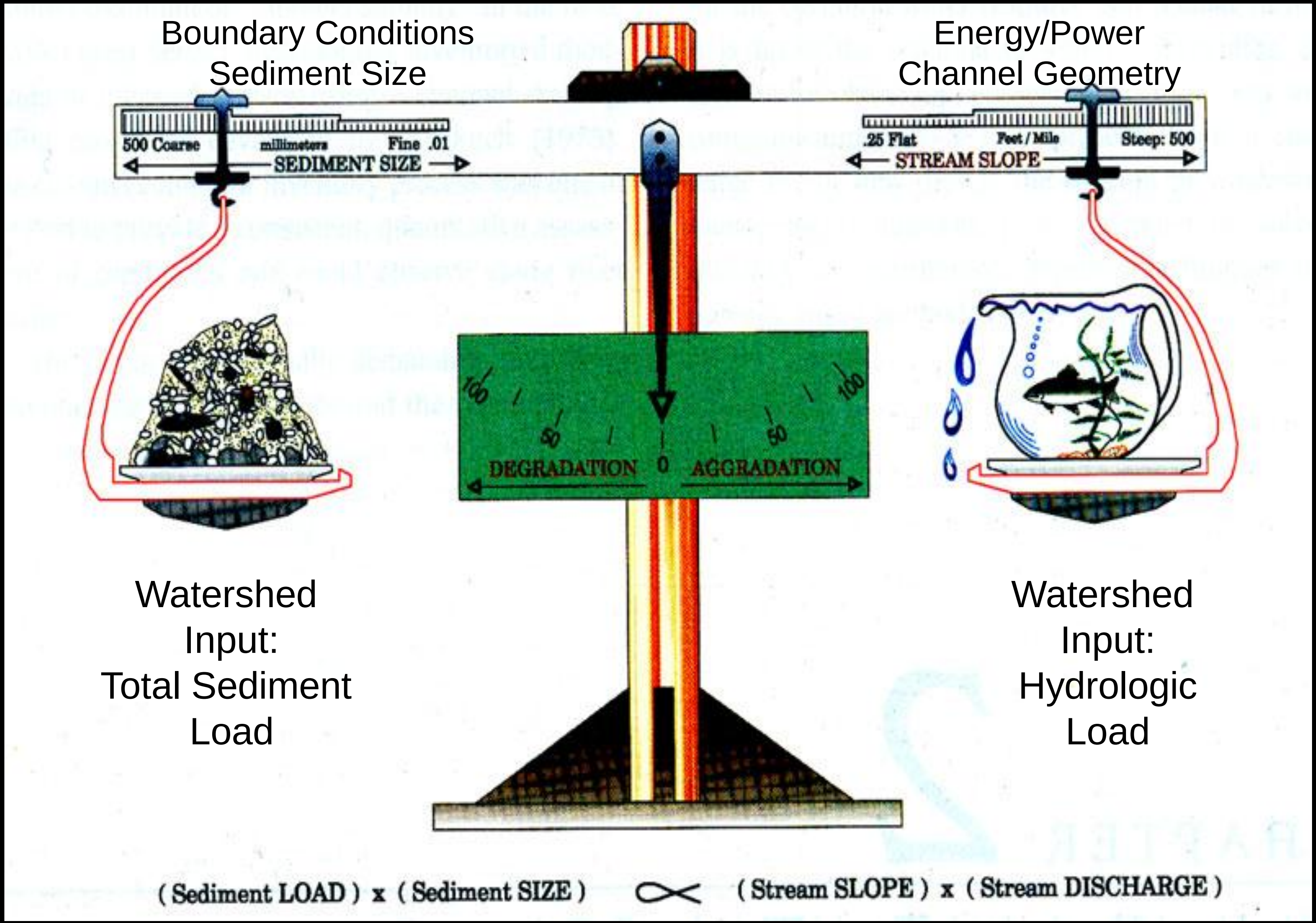


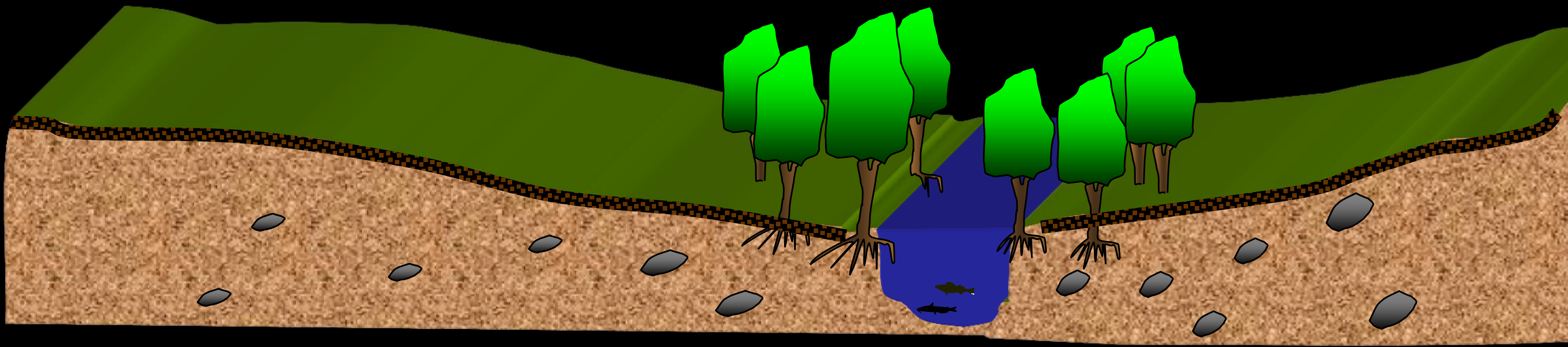
Understanding Near-Channel Sediment Source Mechanisms and a Practical Method for Determining Stream Bank Source Contributions

River Stability

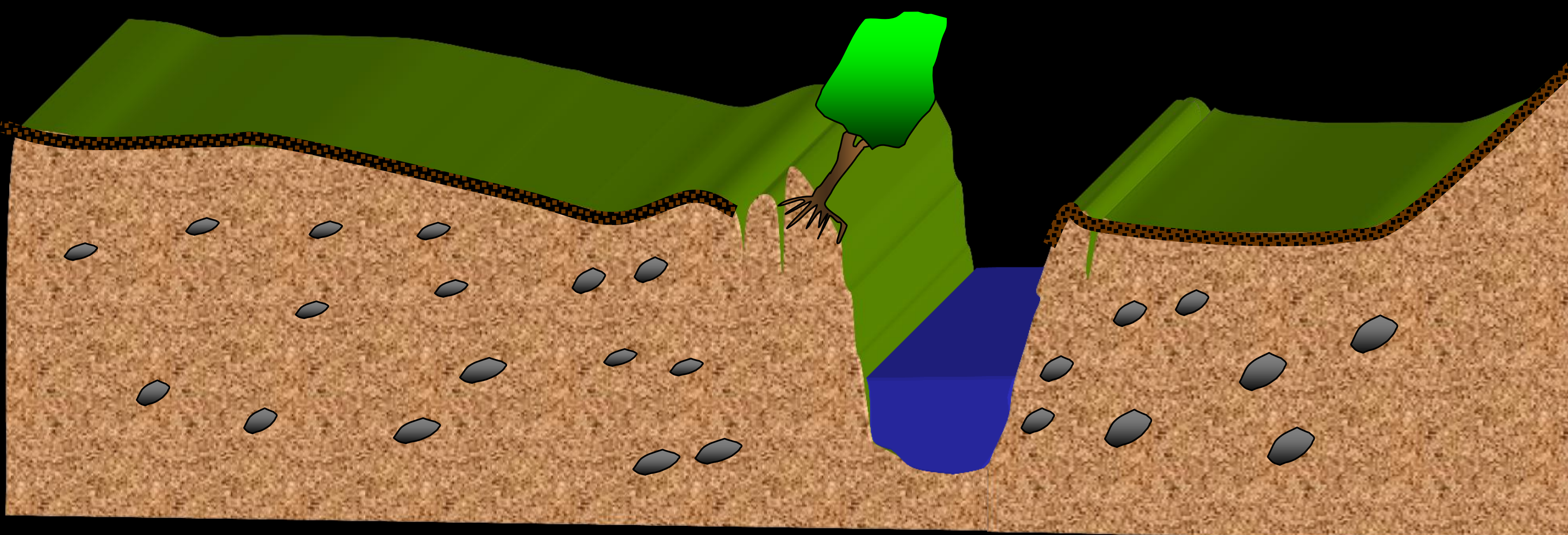
The ability of a stream, to transport the sediment and flows produced by its watershed, while maintaining a consistent dimension, pattern, and profile without aggrading or degrading (Dave Rosgen, 1996).

Understanding Sediment Transport and Capacity

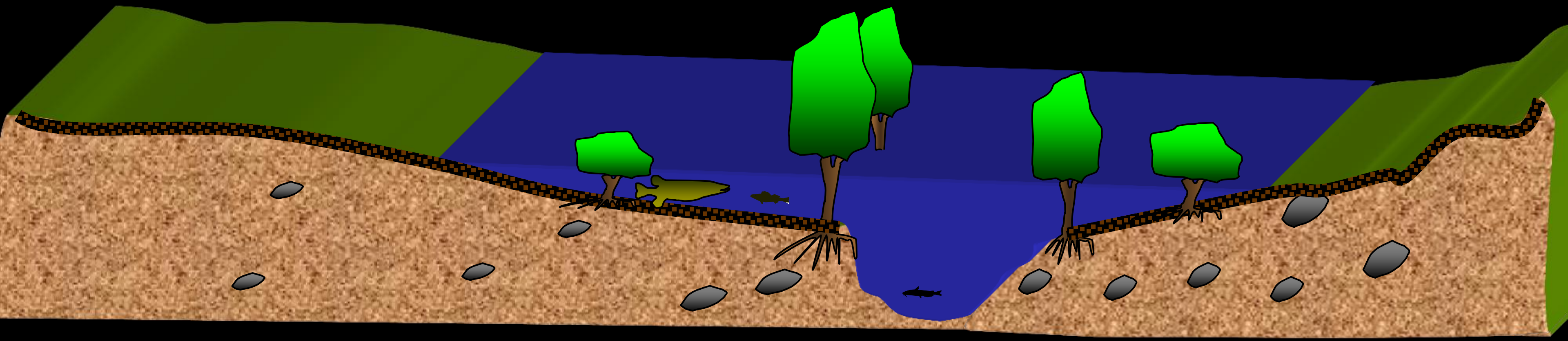




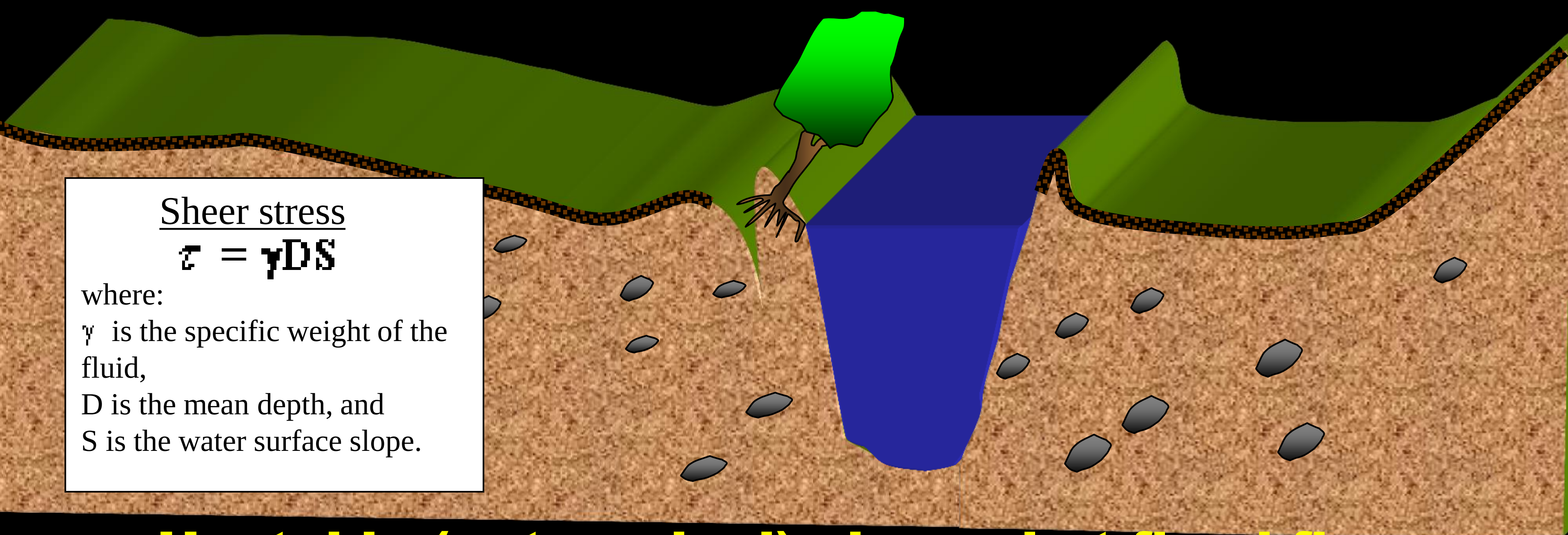
Stable channel at bankfull flow



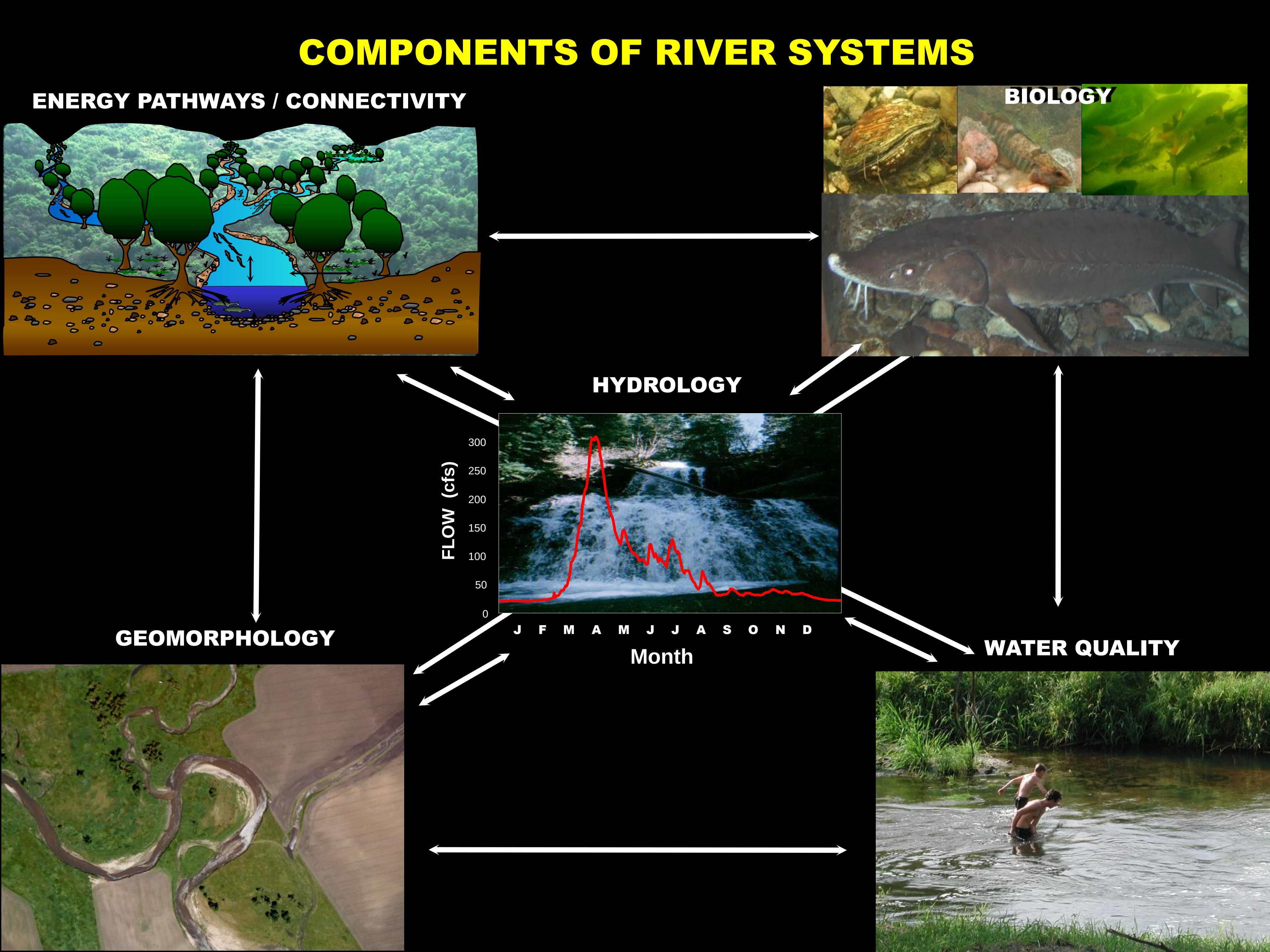
Unstable (entrenched) channel at bankfull flow



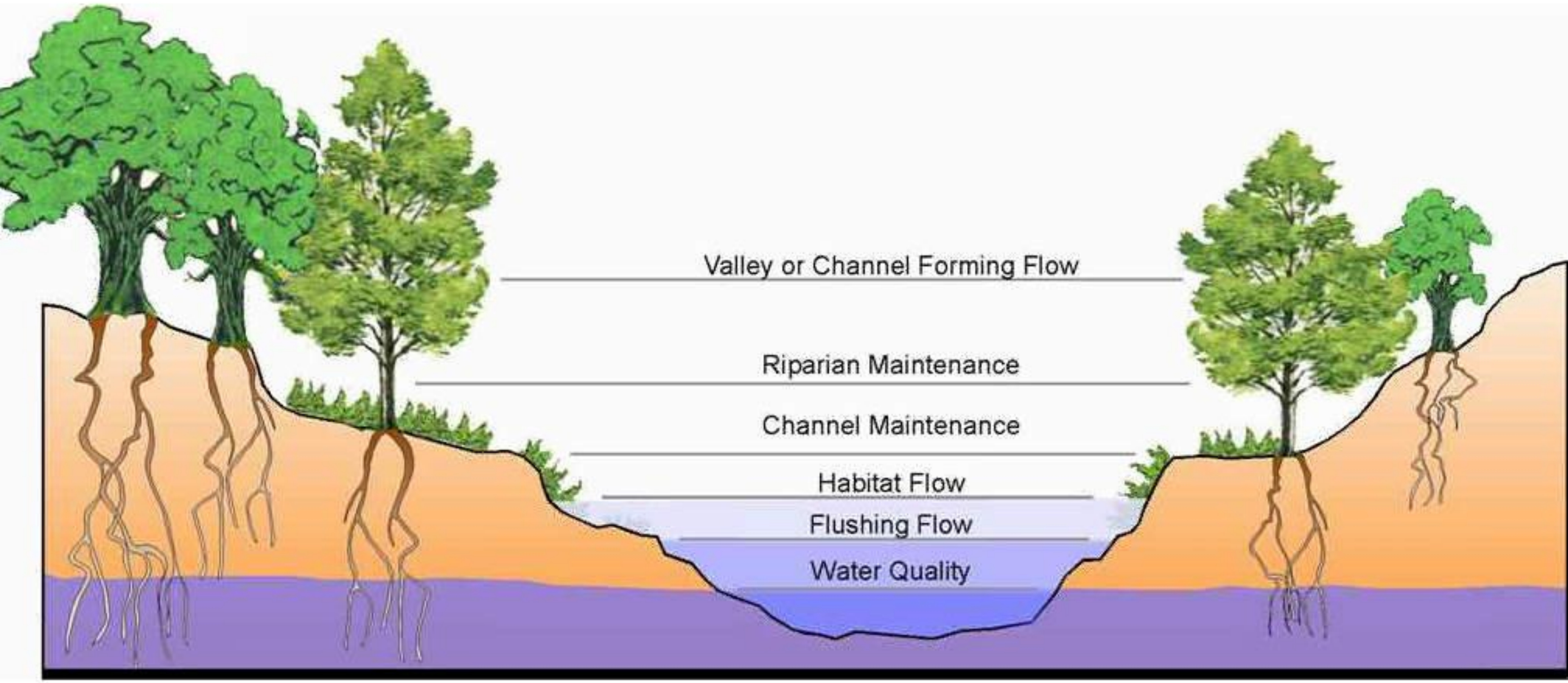
Stable channel at flood flow



Unstable (entrenched) channel at flood flow


COMPONENTS OF RIVER SYSTEMS
ENERGY PATHWAYS / CONNECTIVITY
BIOLOGY
HYDROLOGY
FLOW (cfs)
300
250
200
150
100
50
0
J F M A M J J A S O N D
Month
GEOMORPHOLOGY
WATER QUALITY

Principles of a Healthy River (Hydrology)



All flows (parts of the hydrograph), are essential to the ecological functioning of the river system

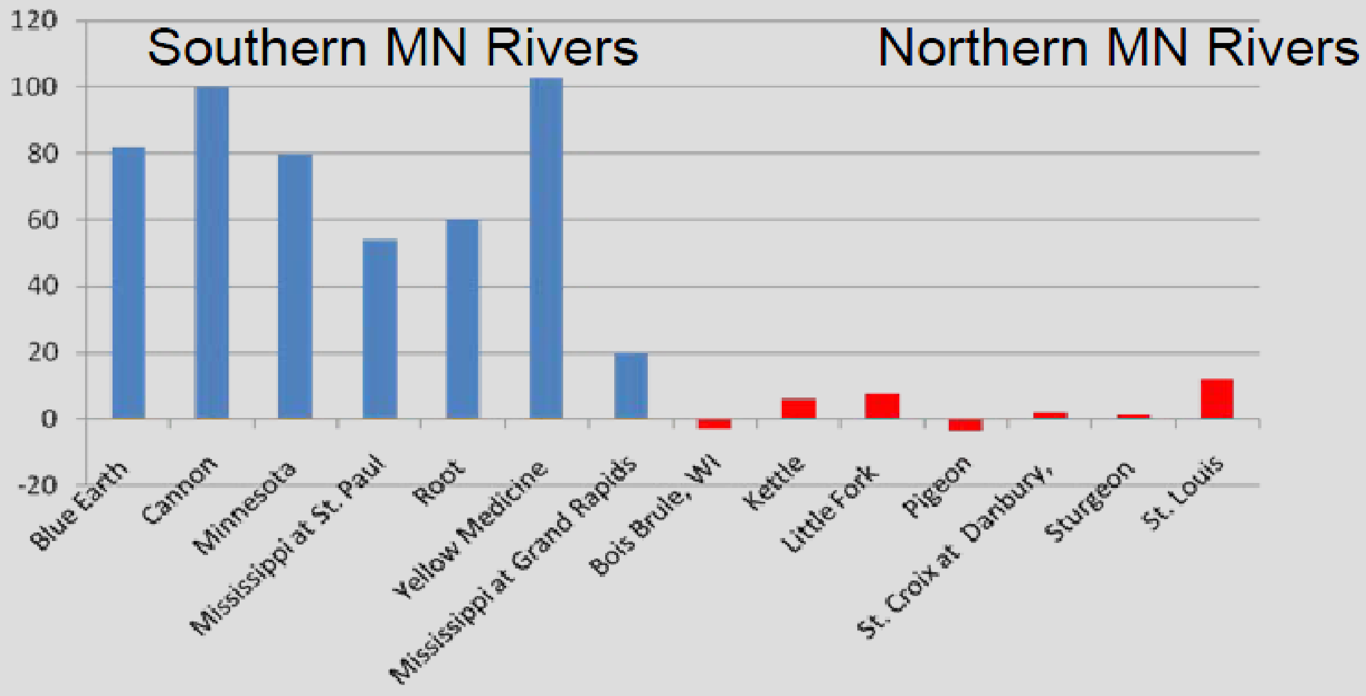
Annual Stream Runoff and Climate in Minnesota's River Basins

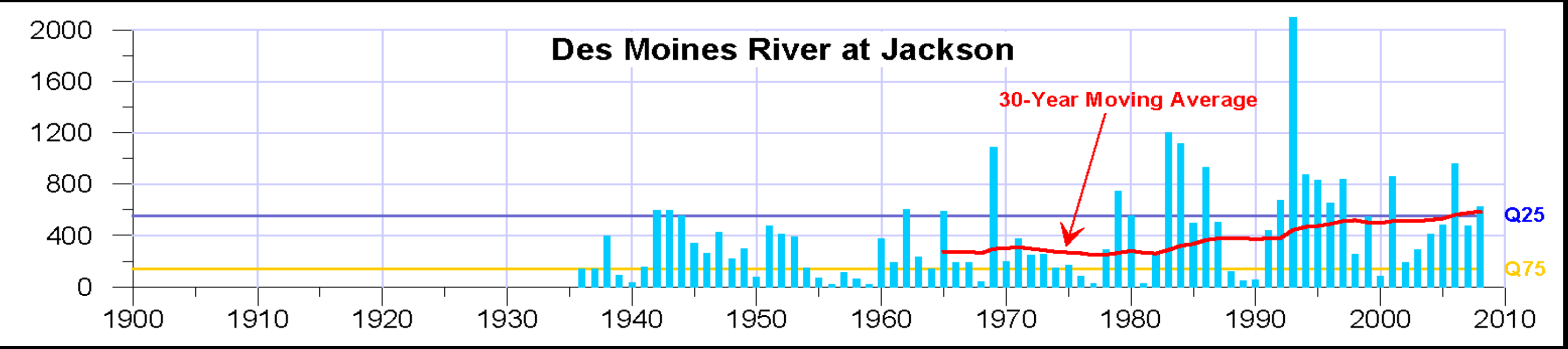
In Minnesota, peak flows and annual run-off have been increasing for as long as gaging has existed (back to 1926). Increases in the MN River basin and Red River basins have shown the greatest increases.

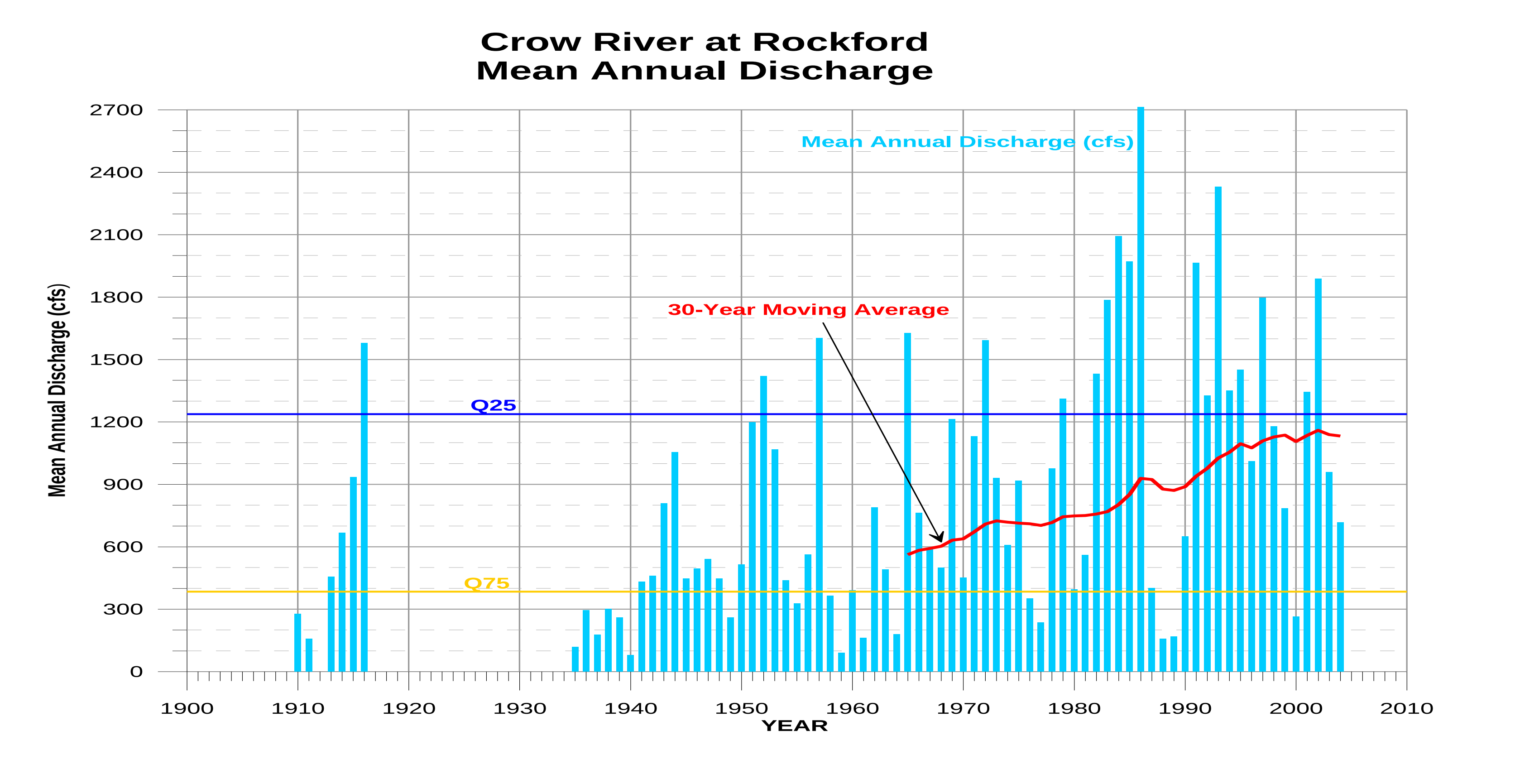
Novotny and Stefan 2007

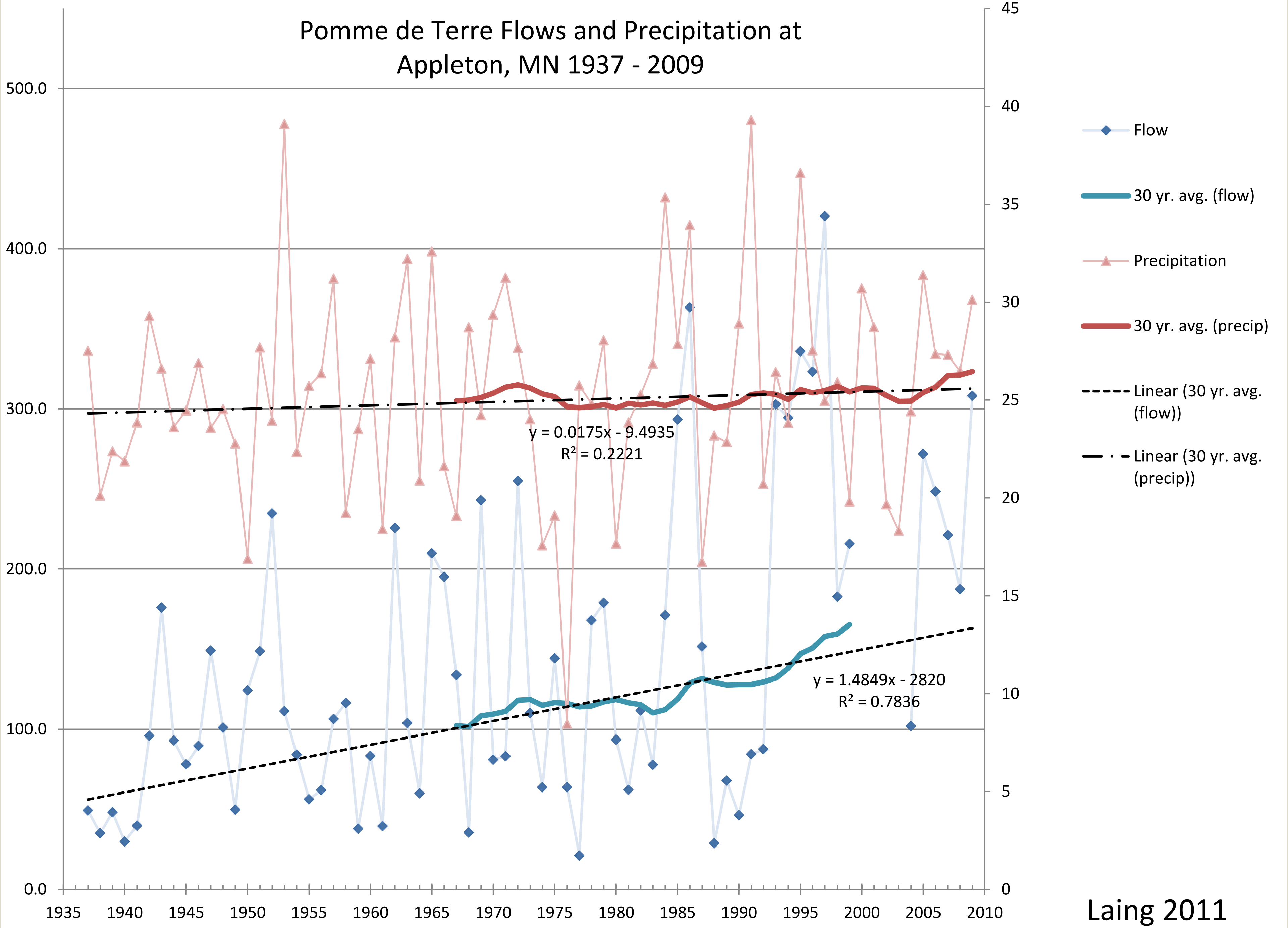
Streamflow Trends

% change to mean annual flow (1940-1979 vs 1980-2009)




Des Moines River at Jackson
30-Year Moving Average
Q25
Q75
2000
1600
1200
800
400
0
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010

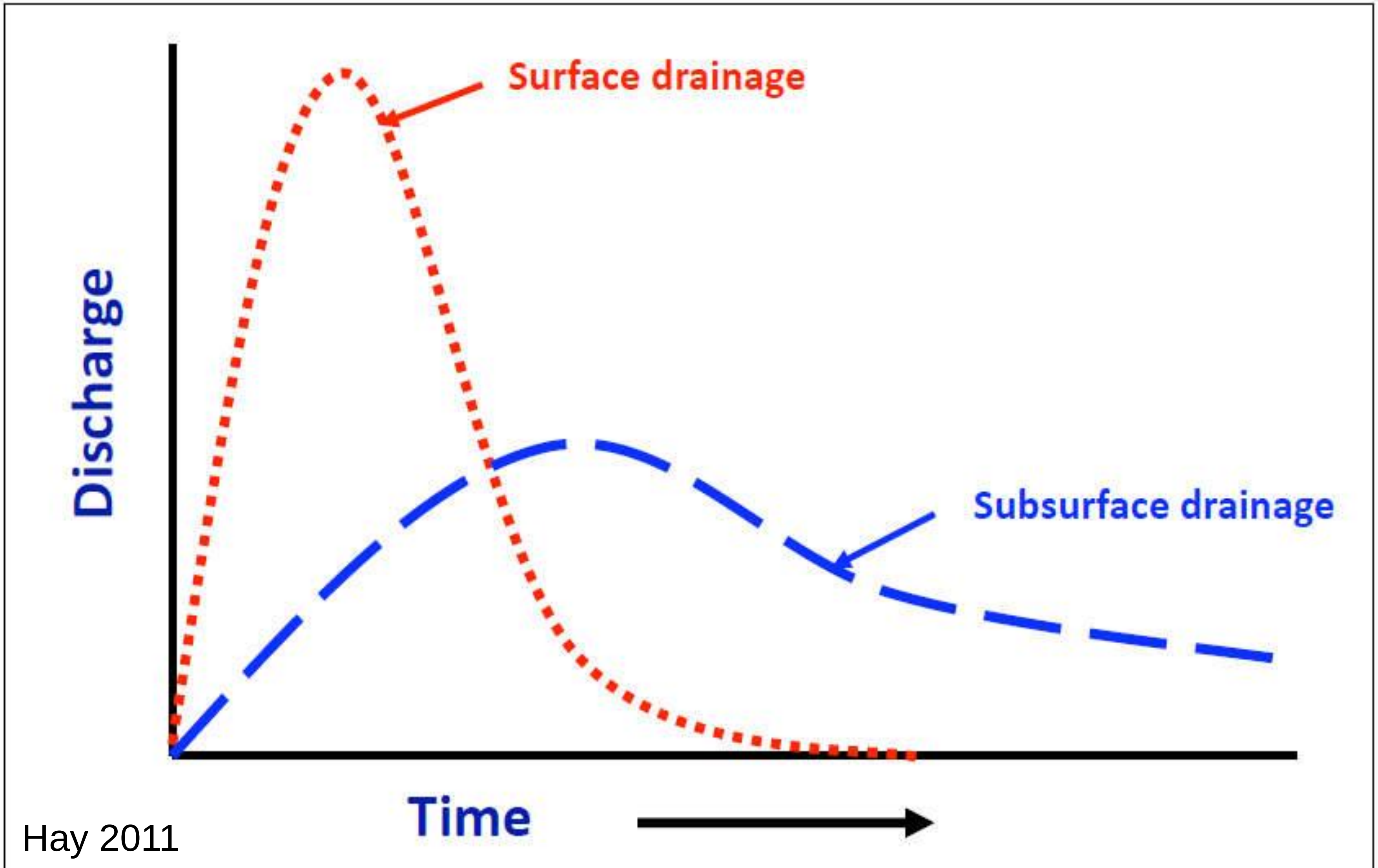

Crow River at Rockford
Mean Annual Discharge
Mean Annual Discharge (cfs)
30-Year Moving Average
Q25
Q75
Mean Annual Discharge (cfs)
2700
2400
2100
1800
1500
1200
900
600
300
0
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
YEAR

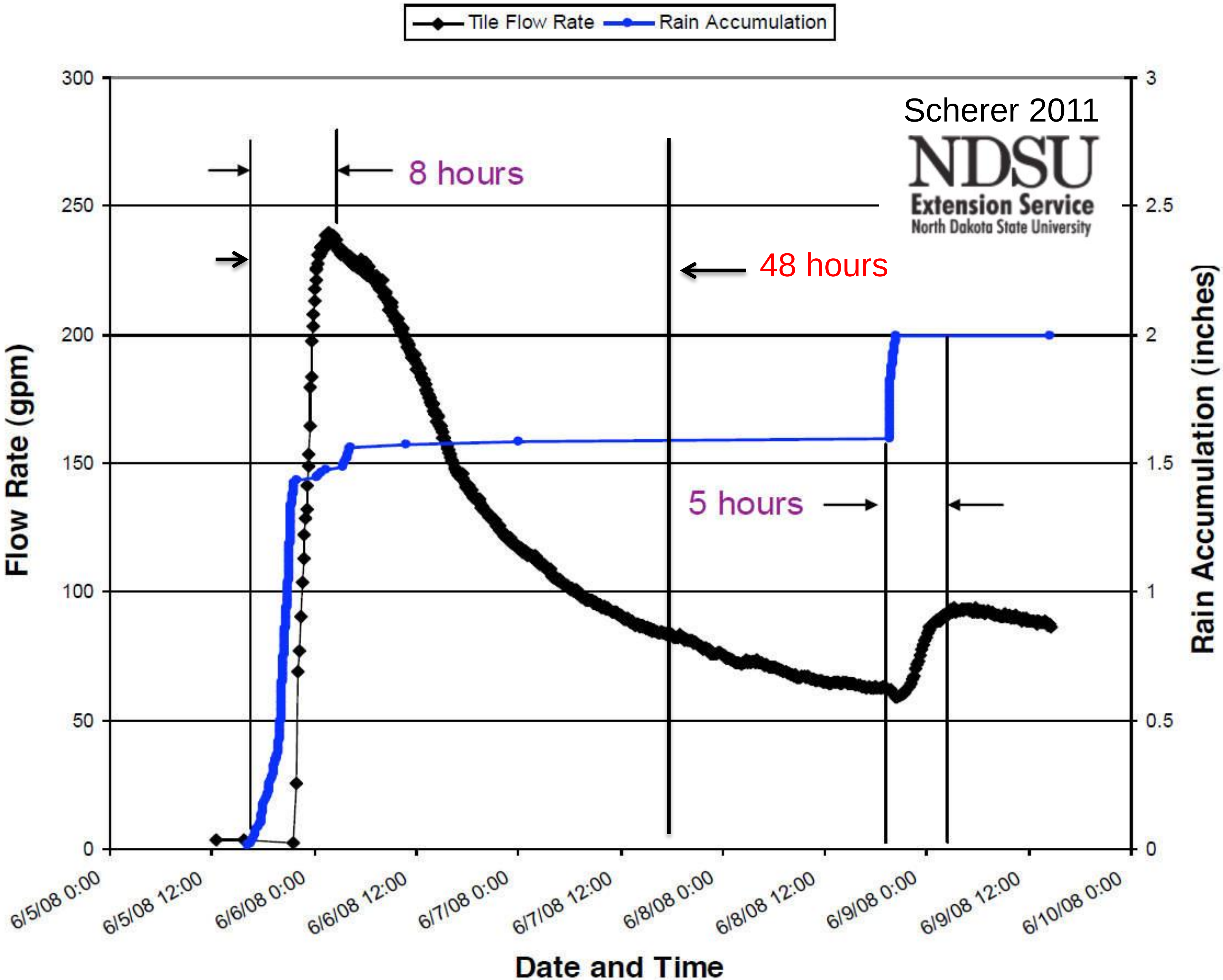


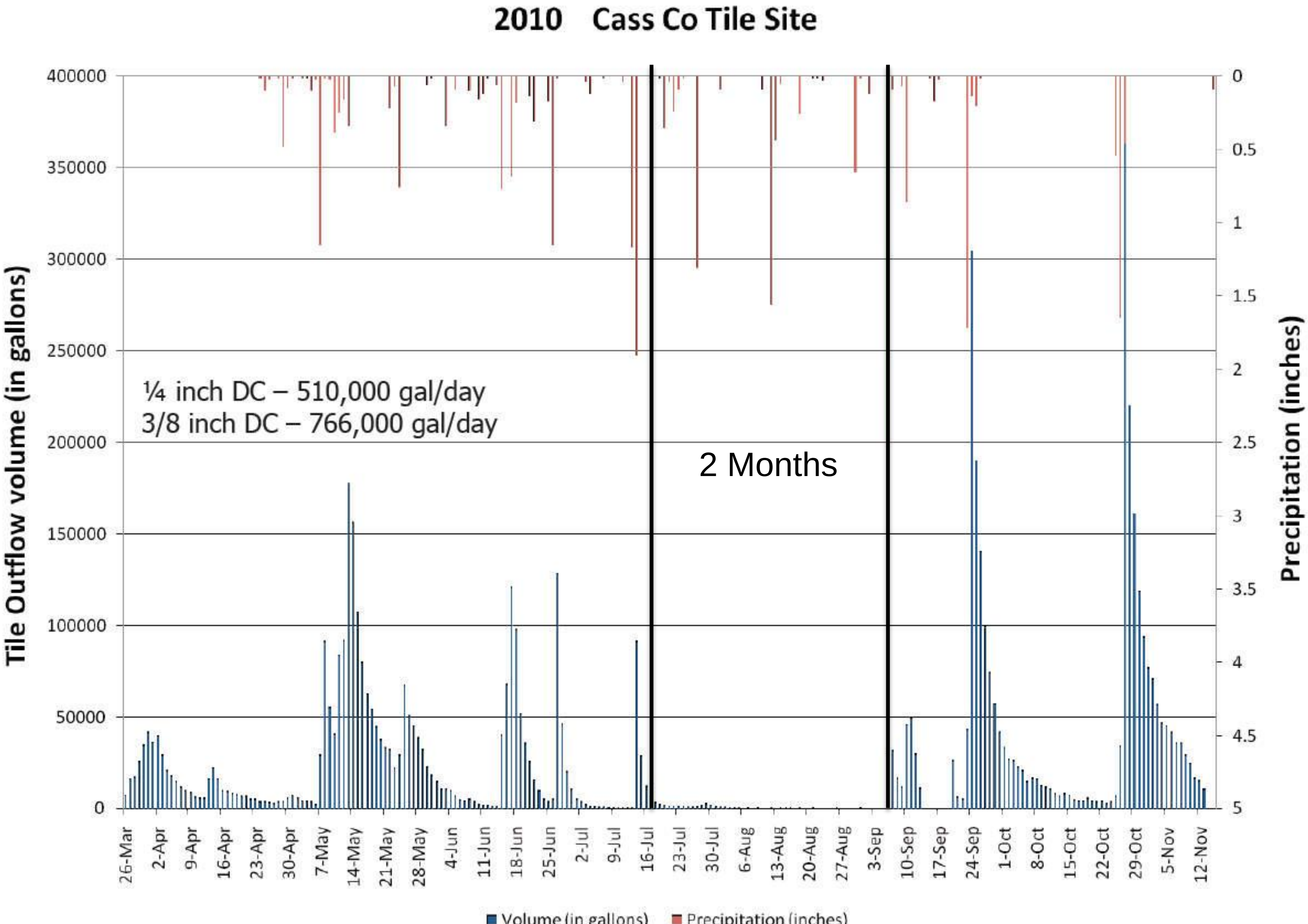
Pomme de Terre Flows and Precipitation at Appleton, MN 1937 - 2009
500.0
400.0
300.0
200.0
100.0
0.0
45
40
35
30
25
20
15
10
5
0
1935
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
y = 0.0175x - 9.4935
R² = 0.2221
y = 1.4849x - 2820
R² = 0.7836
Flow
30 yr. avg. (flow)
Precipitation
30 yr. avg. (precip)
Linear (30 yr. avg. (flow))
Linear (30 yr. avg. (precip))

Laing 2011

Subsurface drainage alters the timing of flows

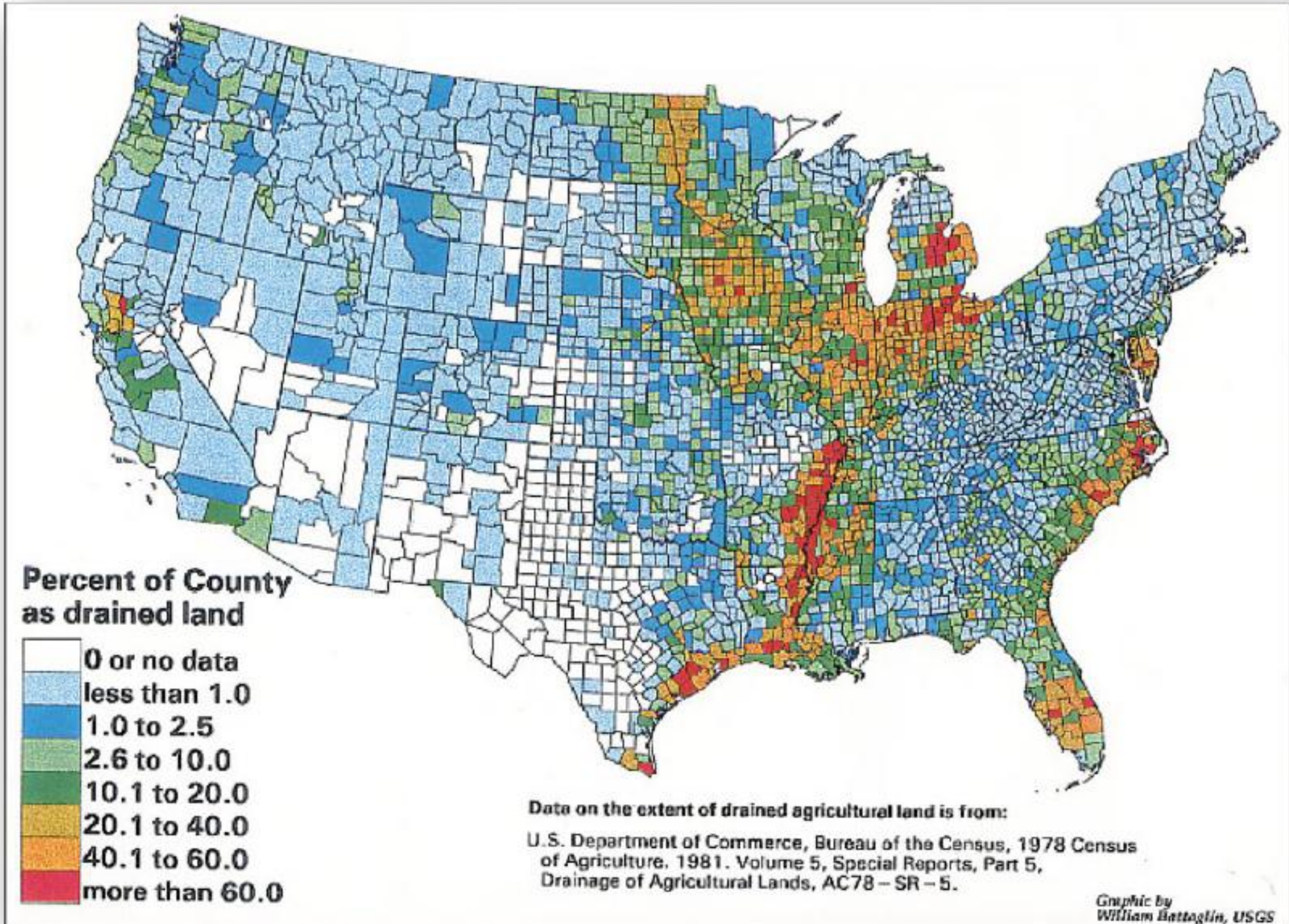



Tile Flow Rate
Rain Accumulation
Scherer 2011
NDSU
Extension Service
North Dakota State University
8 hours
48 hours
5 hours
Flow Rate (gpm)
Rain Accumulation (inches)
Date and Time
300
250
200
150
100
50
0
3
2.5
2
1.5
1
0.5
0
6/5/08 0:00
6/5/08 12:00
6/6/08 0:00
6/6/08 12:00
6/7/08 0:00
6/7/08 12:00
6/8/08 0:00
6/8/08 12:00
6/9/08 0:00
6/9/08 12:00
6/10/08 0:00



Scherer 2011

Approximately 25% of U.S. cropland is drained



StarTribune

Farm drainage choking Lake Pepin, Gulf of Mexico

Article by: JOSEPHINE MARCOTTY , Star Tribune

Updated: October 19, 2011 - 11:04 PM

A study has identified the primary source of runoff in Mississippi River.

Evaluation of Factors contributing to changes in runoff ratio in 21 tributaries to Lake Pepin

- Climate Change – negligible effect
- Increased row-cropping (ET changes) – 5 - 10%
- Increased drainage (new ditching, tiling, wetland drainage) - 60 – 95%

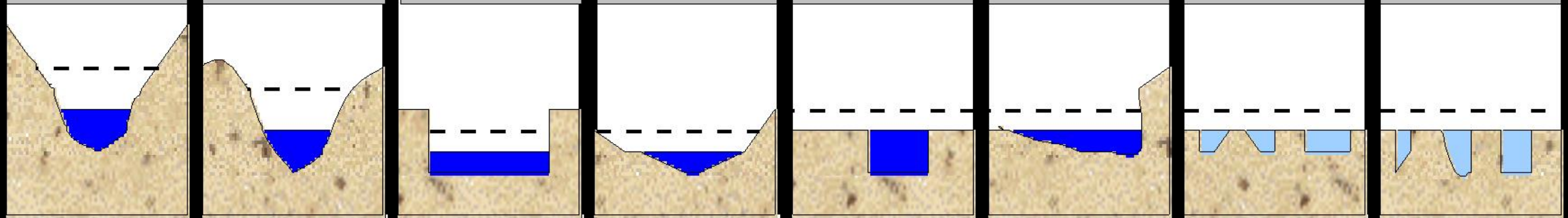
Ulrich 2011


Where's the high ground?
What's happening to our public streams?

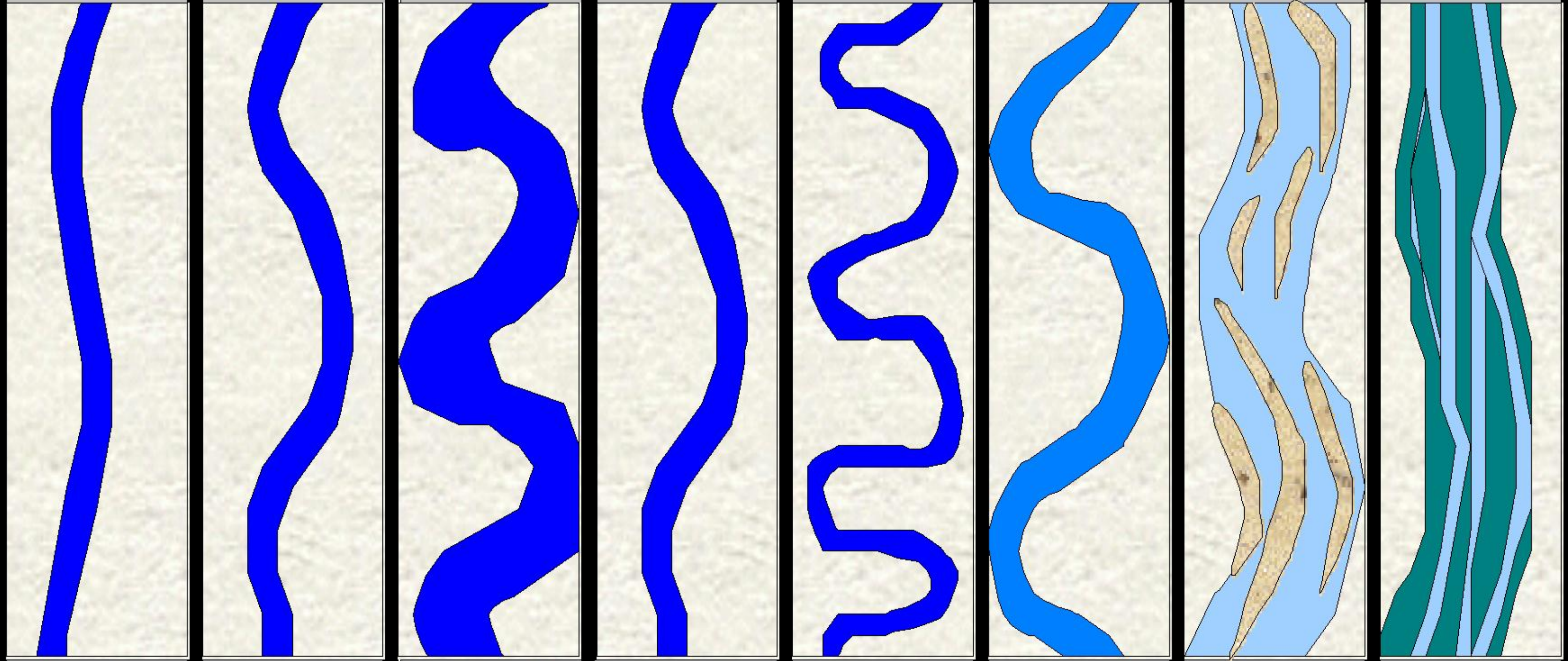
Stream type classes are defined by class boundaries of ratios

	A	G	F	B	E	C	D	DA
Entrench.	1.0 - 1.4	1.0 - 1.4	1.0 - 1.4	1.41 - 2.2	> 2.2	> 2.2	Mult.Chnls	Mult.Chnls
w/d Ratio	< 12	< 12	> 12	> 12	< 12	> 12	> 40	< 40
Sinuosity	< 1.2	> 1.2	> 1.2	> 1.2	> 1.5	> 1.2	< 1.2	1.2 - 1.5
Slope (%)	10 - 4	4 - 2	4 - < 2	4 - < 2	2 - < 2	2 - < .1	2 - < .1	< .5
Str'mType	A	G	F	B	E	C	D	DA

Dimension



Pattern



Dimension, Pattern, Profile, & Floodprone Width

Yield 4 ratios used for stream reach **classification**

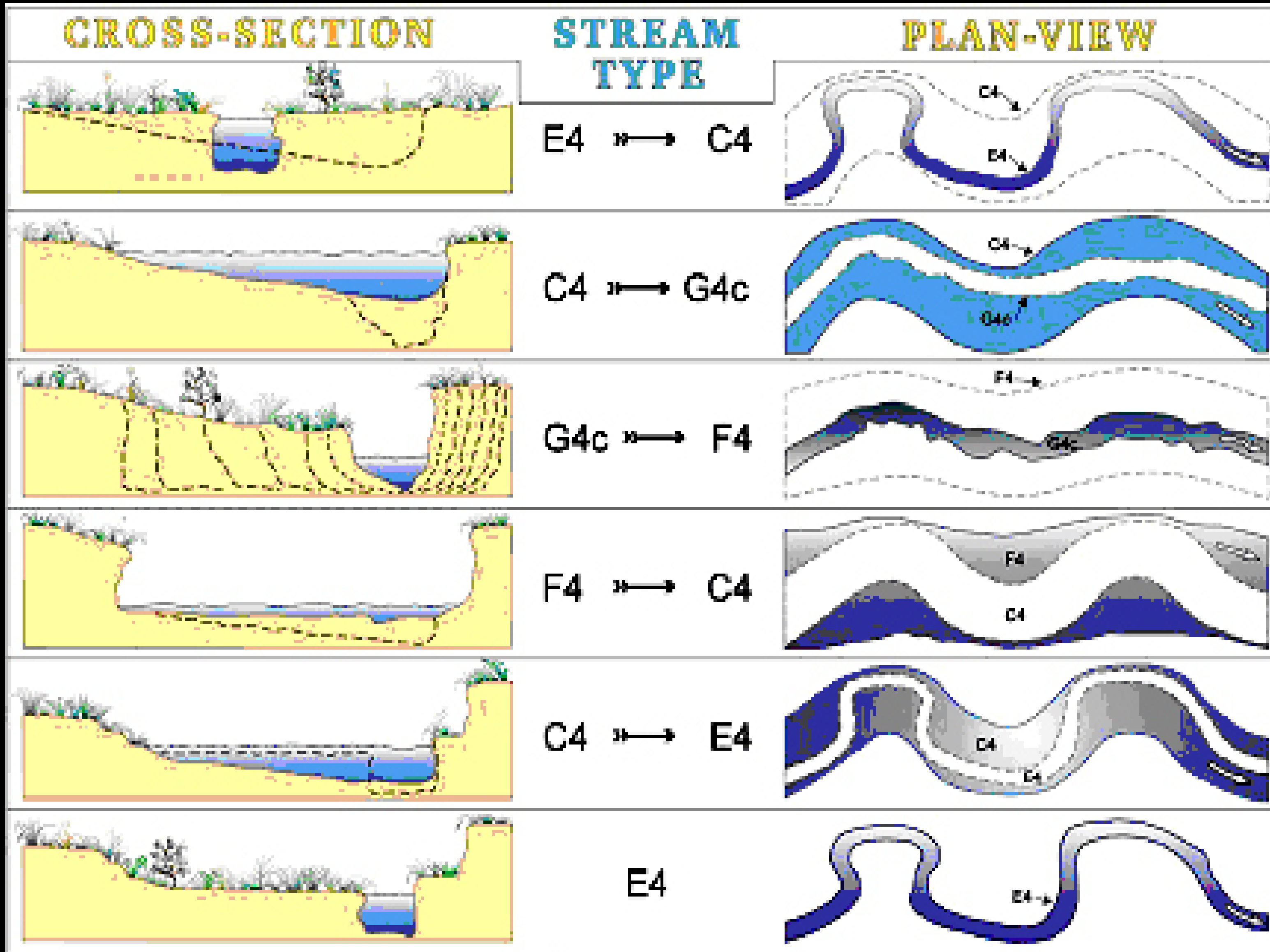
1. **Entrenchment Ratio = $\frac{\text{Flood-Prone Width}}{\text{Bankfull Width}}$**

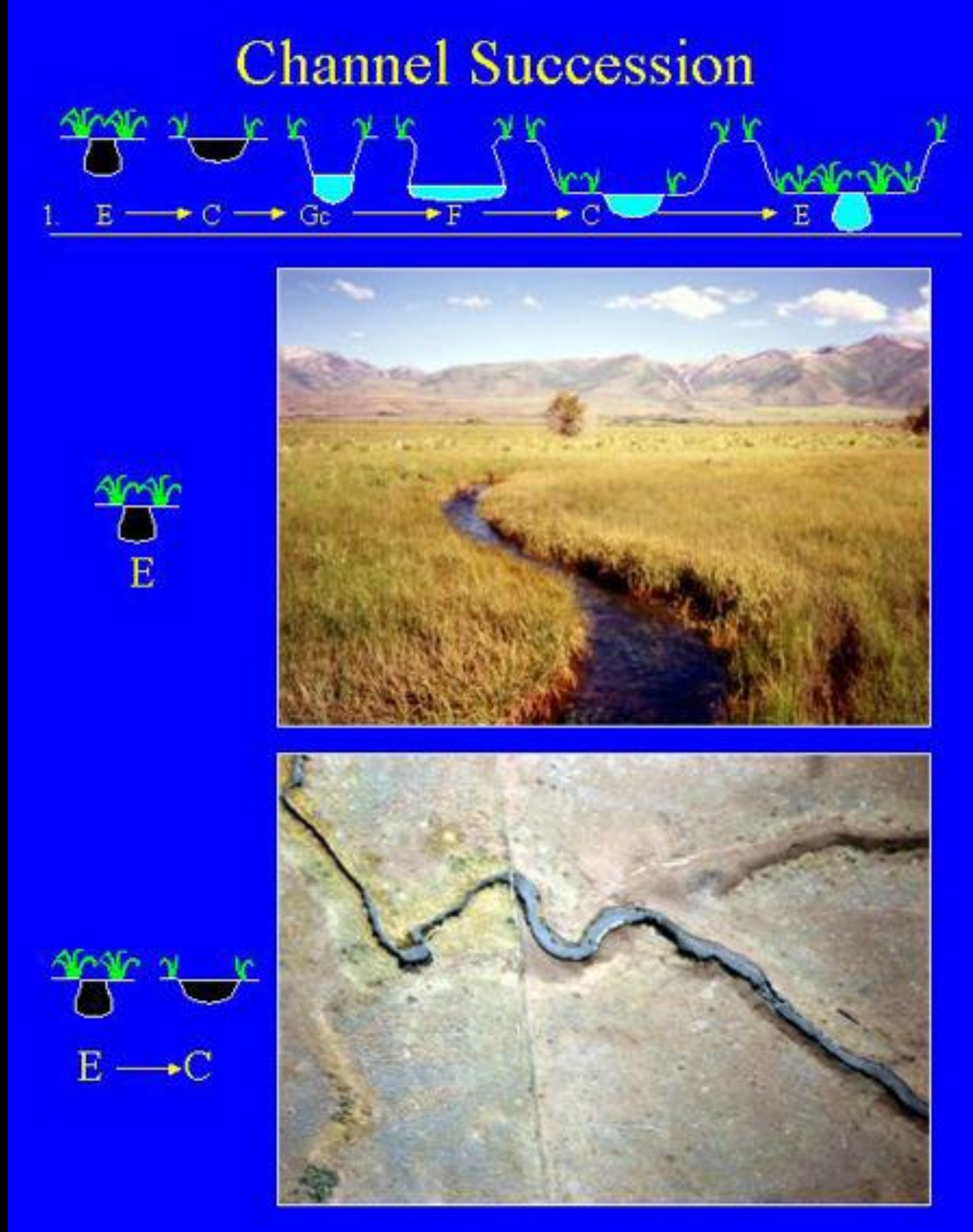
2. **W/D ratio = $\frac{Width_{bkf}}{Depth_{mean}}$**

3. **Sinuosity = $\frac{\text{Channel Length}}{\text{Valley Length}}$**

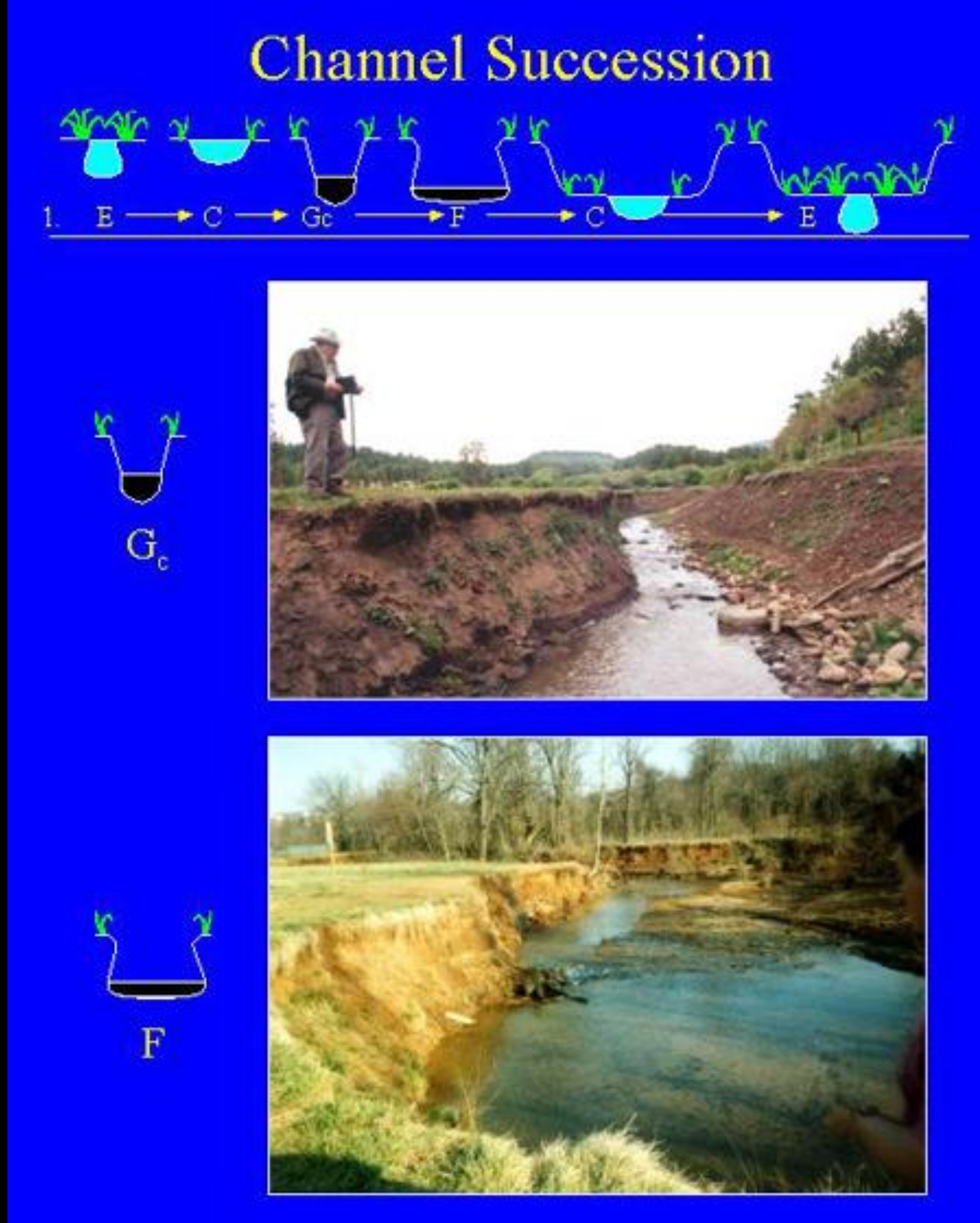
4. **Slope = $\frac{\text{Elevation difference}}{\text{Channel length}}$**

All of these ratios define how a stream and its valley handle the energy of flowing water, sediment, and debris


CROSS-SECTION
STREAM TYPE
PLAN-VIEW
E4 → C4
C4
E4
C4 → G4c
C4
G4c
G4c → F4
F4
G4c
F4 → C4
F4
C4
C4 → E4
C4
C4
E4
E4

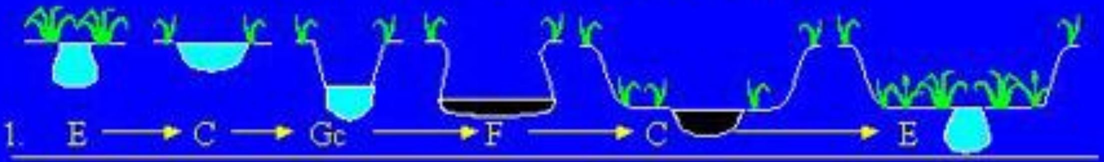


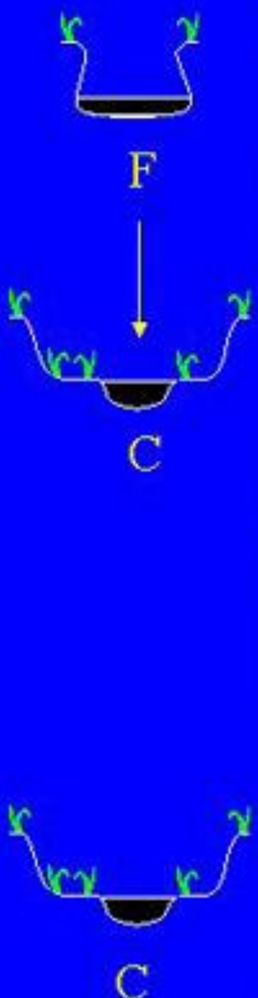
www.epa.gov - Rosge



www.epa.gov - Rosgen

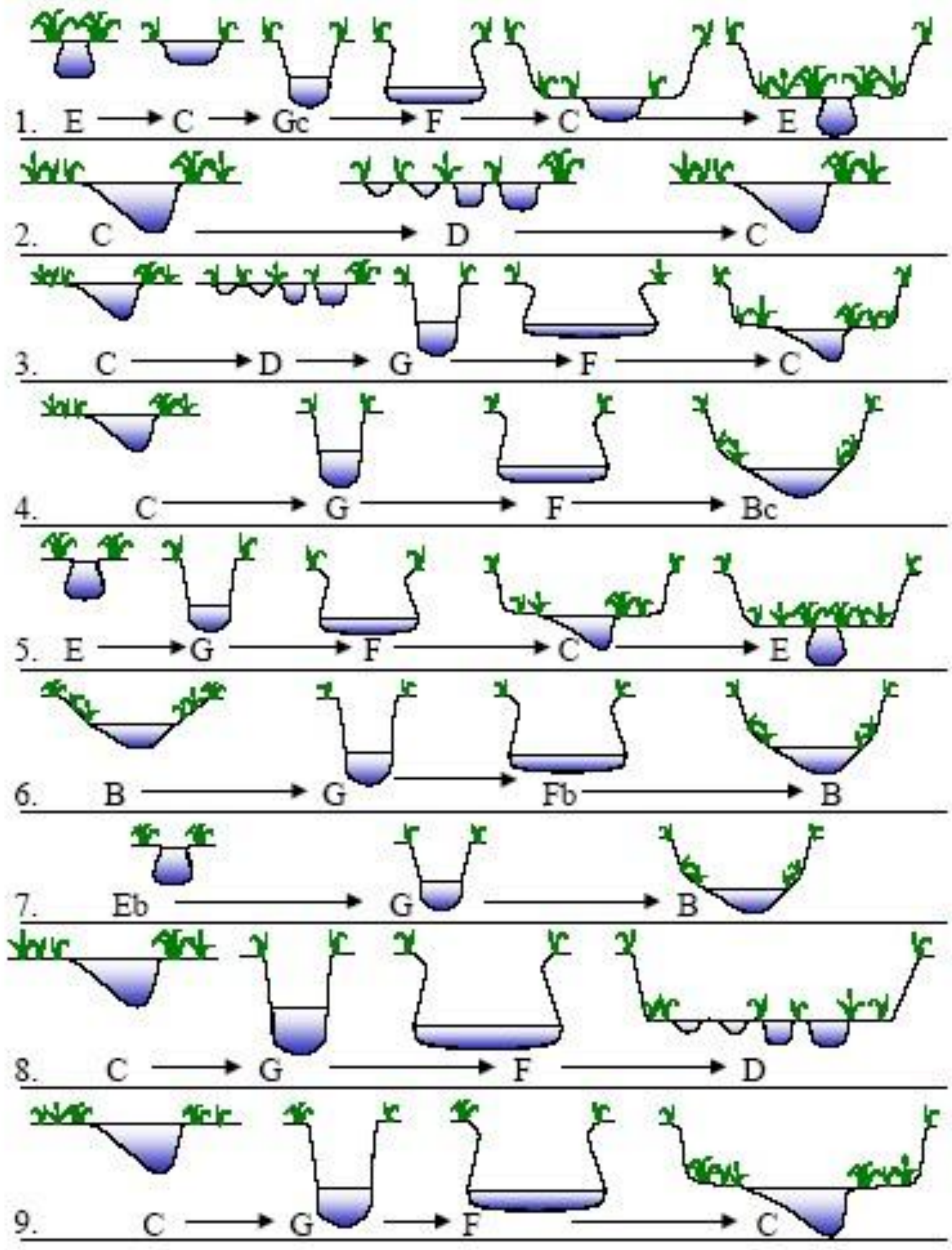
Channel Succession





www.epa.gov - Rosgen

Various stream type evolution scenarios (from Rosgen 2000)



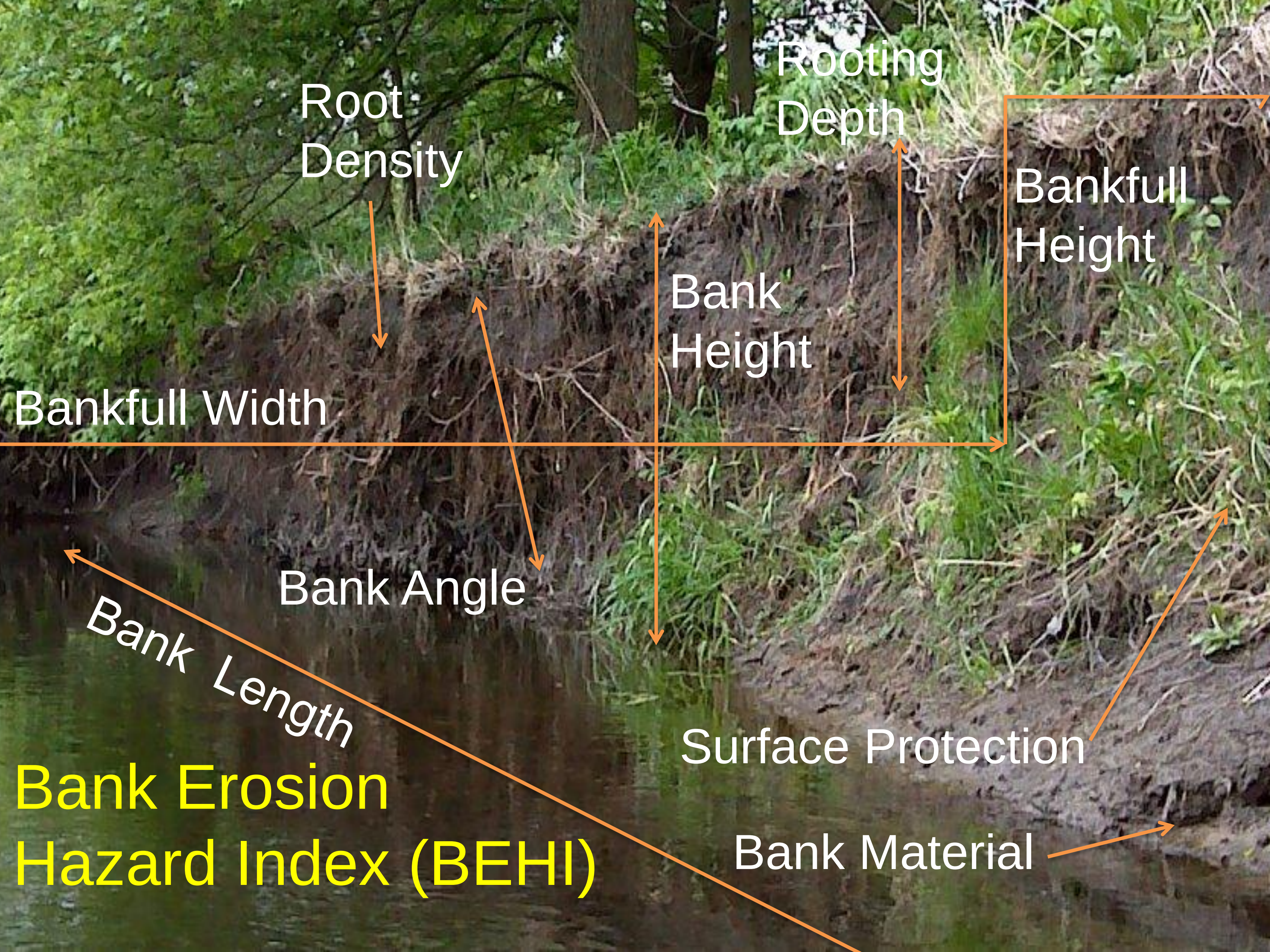
Aquatic Habitat Response

Stream Type Succession

Variable	C → G	G → F	F → C
Instream Cover	↓	↓	↑
Overhead Cover	↓	↓	↑
Substrate Composition	↓	↓	↑
Pool Quality	↓	↓	↑
Holding Cover Velocity	↓	↓	↑
Temperature	→	↑	↓
Dissolved Oxygen	→	↓	↑
Macro Invertebrates	↓	↓	↑
Spawning Habitat	↓	↓	↑
Diversity	↓	↓	↑
Rearing Habitat	↓	↑	↑
IBI Score	↓	↓	↑
Sediment Supply	↑	↑	↓
Bank Erosion	↑	↑	↓

Streambank Inventory

Bank Assessment for Non-Pojnt source Consequences of Sediment (BANCS)

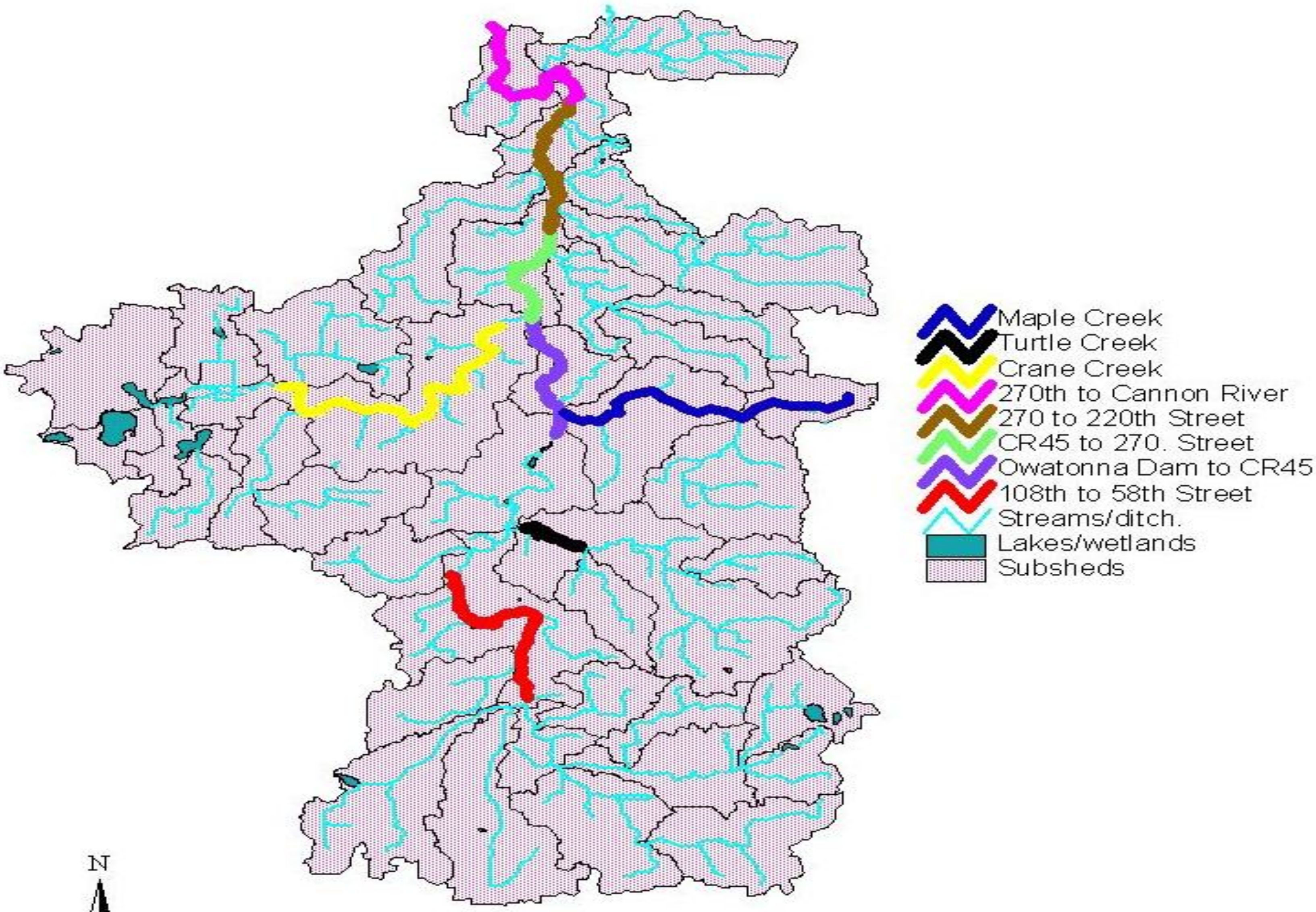

Root Density
Rooting Depth
Bankfull Height
Bank Height
Bankfull Width
Bank Angle
Bank Length
Surface Protection
Bank Material
Bank Erosion Hazard Index (BEHI)

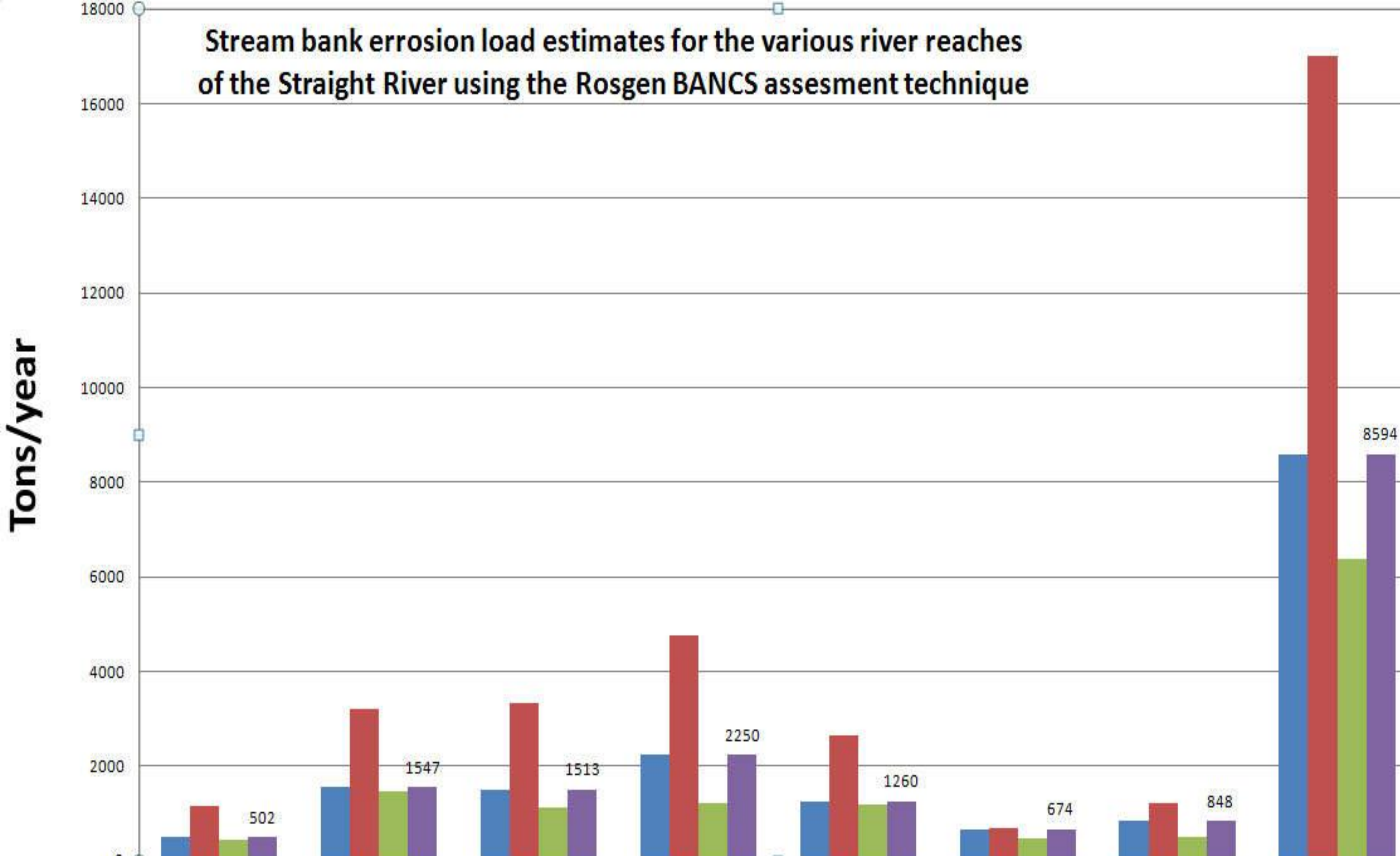
Near Bank Sheer Stress Determinations

Pomme de Terre River-10th Street to HW 12-BANCS Empirical Model Stream Bank Erosion Predictions

Study Bank	BEHI Rating	NBS Rating	Bank Length (ft)	Loss (cu yd/yr)	Loss (tons/yr)	Loss (cu yd/yr)	Loss (tons/yr)	Loss (cu yd/yr)	Loss (tons/yr)
1	Moderate	High	1200	116	150	68	88	18	23
2	Moderate	Moderate	600	63	82	63	82	17	22
3	High	Moderate	1100	114	148	49	64	24	32
4	Moderate	Moderate	200	8	10	4	5	1	1
5	High	High	1200	213	277	213	277	36	46
6	Moderate	High	130	19	24	11	14	4	6
7	Low	Low	350	2	3	2	3	0	0
8	Moderate	Moderate	280	14	18	8	10	2	3
9	Moderate	High	450	76	99	44	58	12	15
10	Moderate	Moderate	470	18	23	10	13	3	3
11	Moderate	High	600	116	150	68	88	21	28
12	Moderate	High	1150	138	180	81	105	26	33
13	High	Moderate	560	73	94	31	40	16	20
14	High	Moderate	150	19	25	8	11	4	5
15	High	Moderate	400	52	67	22	29	11	14
16	High	High	1200	213	277	89	116	36	46
17	High	High	1100	147	191	61	79	24	32
18	Very High	High	450	120	156	50	65	100	130
19	Very High	High	250	67	87	28	36	56	72
20	Very High	High	300	80	104	33	43	67	87
		Total	12140	1,667	2,167	943	1,227	465	619
Total Reach Length (20,275 ft) Total Loss (tons/yr) per ft of Reach:				0.1069 using Yellowstone Data		0.0605 using Colorado Data		0.0305 using NC Data	

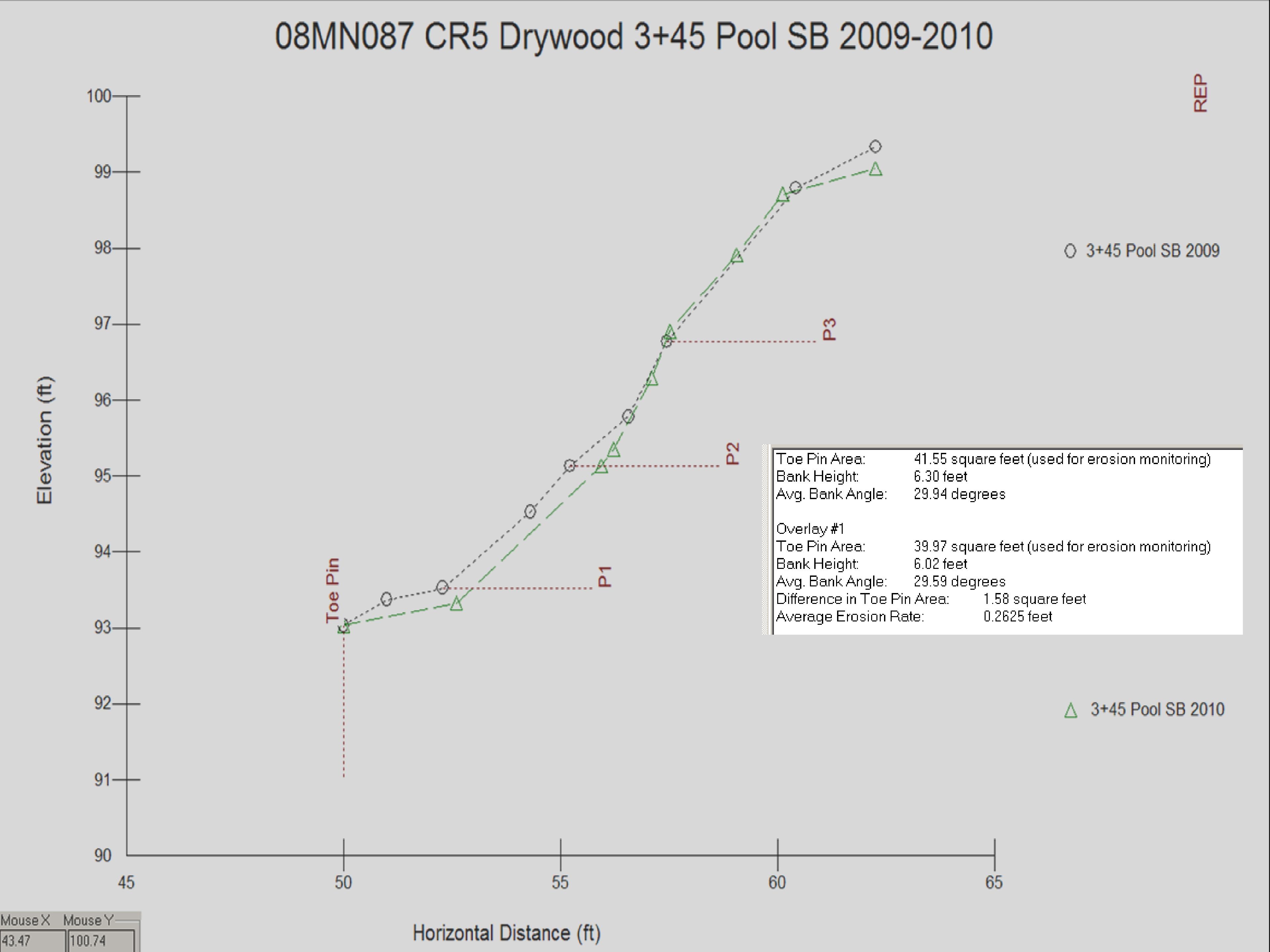
Straight River Watershed
BANCS Assessment Reaches





	Above Owatonna Dam	Below Owatonna Dam	Medford Reach	Midway Reach	Faribault Reach	Crane Creek	Maple Creek	Total Load Estimates
Colorado	502	1547	1513	2250	1260	674	848	8594
Yellowstone	1143	3221	3321	4761	2664	686	1218	17014
North Corolina	428	1468	1115	1209	1174	472	510	6376
Median	502	1547	1513	2250	1260	674	848	8594

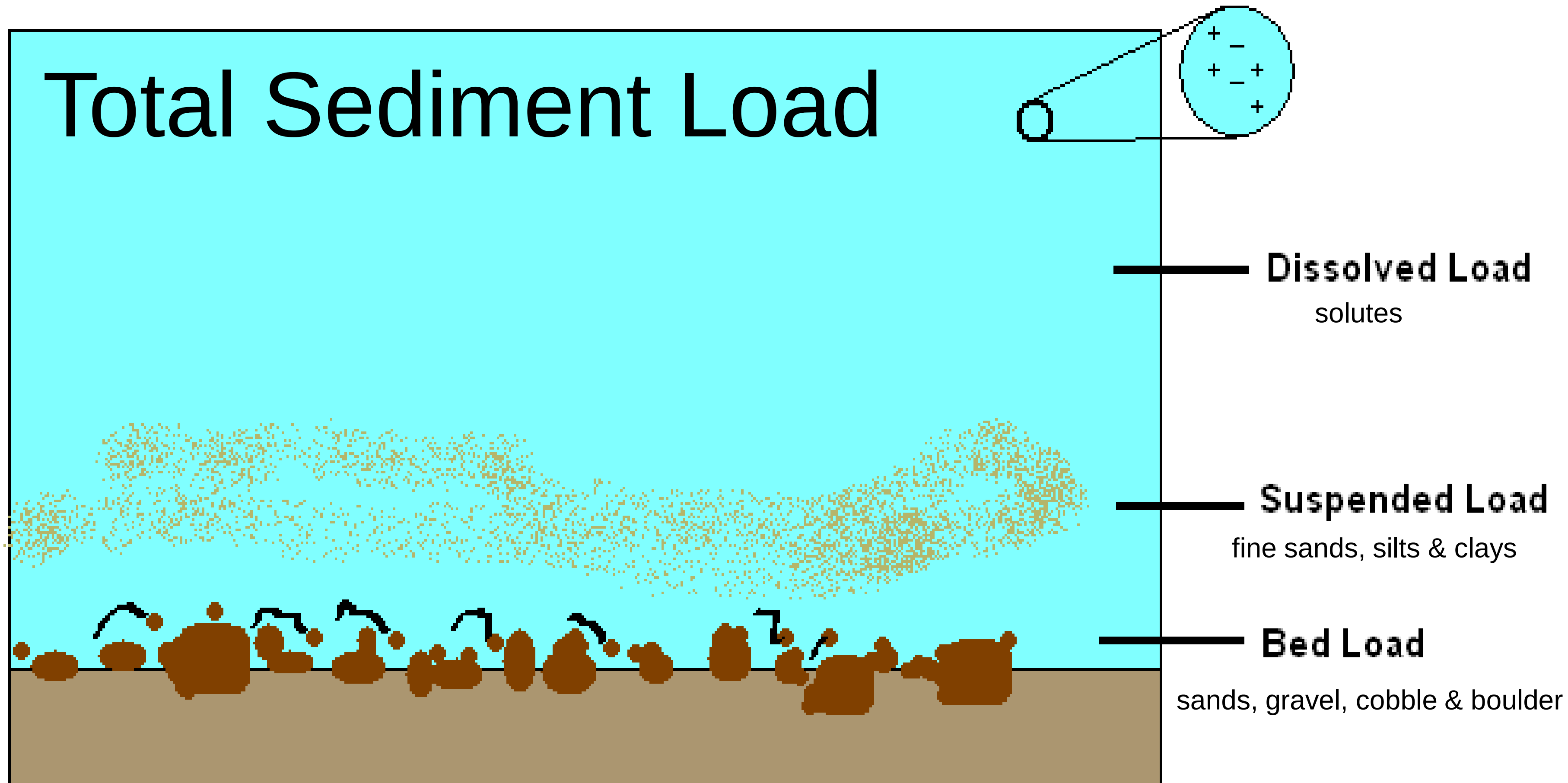

BED-ROCK
WE CAME
WE SAW
WE FIXED IT
CONSTRUCTION
(704) 279-4201


08MN087 CR5 Drywood 3+45 Pool SB 2009-2010
REP
Elevation (ft)
Horizontal Distance (ft)
100
99
98
97
96
95
94
93
92
91
90
45
50
55
60
65
Toe Pin
P1
P2
P3
3+45 Pool SB 2009
3+45 Pool SB 2010
Toe Pin Area: 41.55 square feet (used for erosion monitoring)
Bank Height: 6.30 feet
Avg. Bank Angle: 29.94 degrees
Overlay #1
Toe Pin Area: 39.97 square feet (used for erosion monitoring)
Bank Height: 6.02 feet
Avg. Bank Angle: 29.59 degrees
Difference in Toe Pin Area: 1.58 square feet
Average Erosion Rate: 0.2625 feet
Mouse X
Mouse Y
43.47
100.74

Study Bank Predicted and Measured Erosion Rates

				Predicted	Measured	Measured
Study Reach	BEHI Rating	NBS Rating	Bank Length (ft)	Erosion Rate	Erosion loss	Erosion Rate
Drywood 87	High	Extreme	100	0.35-1.69 ft/yr	1.58sq ft	0.263ft/yr
Drywood 88	Moderate	Moderate	74	0.06-.726 ft/yr	4.43sq ft	0.726ft/yr
Drywood 89	High	Moderate	38	0.15-.691 ft/yr	4.80sq ft	0.533ft/yr
Cedar River	Moderate	Extreme	65	0.27-.924 ft/yr	3.45sq ft	0.503ft/yr

Total Sediment Load



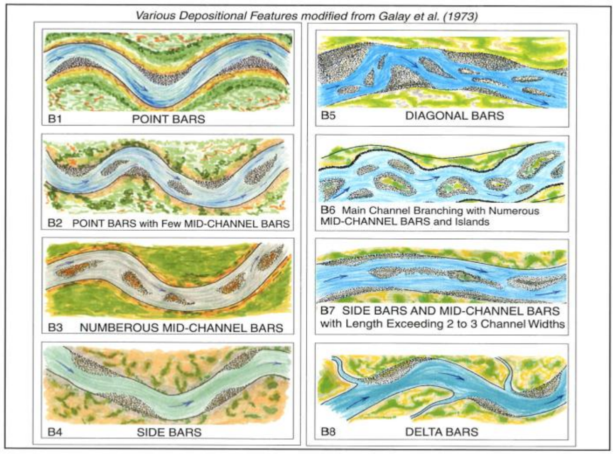


Figure 4-28. Depositional features related to potential excess sediment/aggradation potential (Rosgen, 1996).

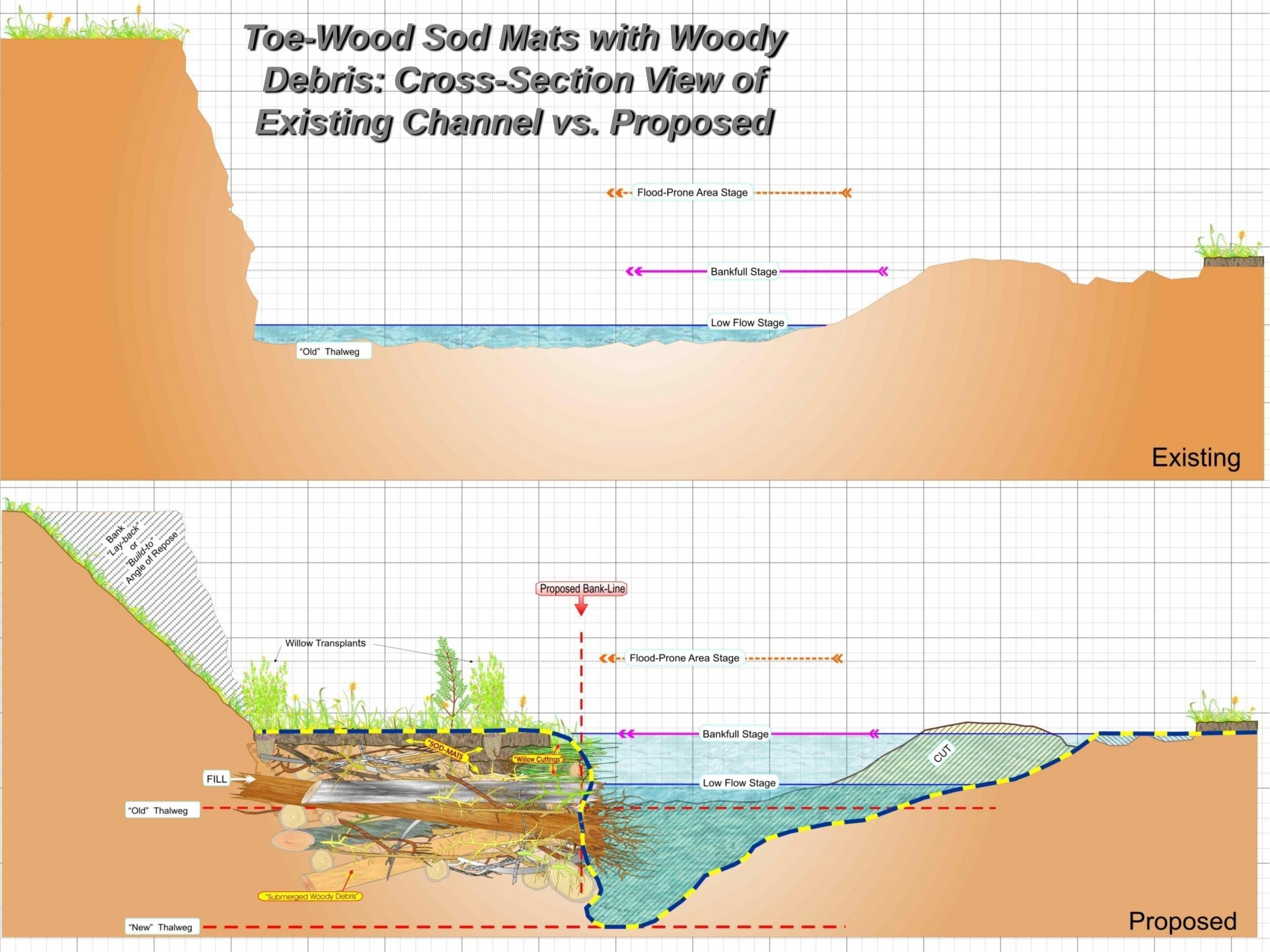
Streambank Protection using Toe Wood

Enhance fish habitat

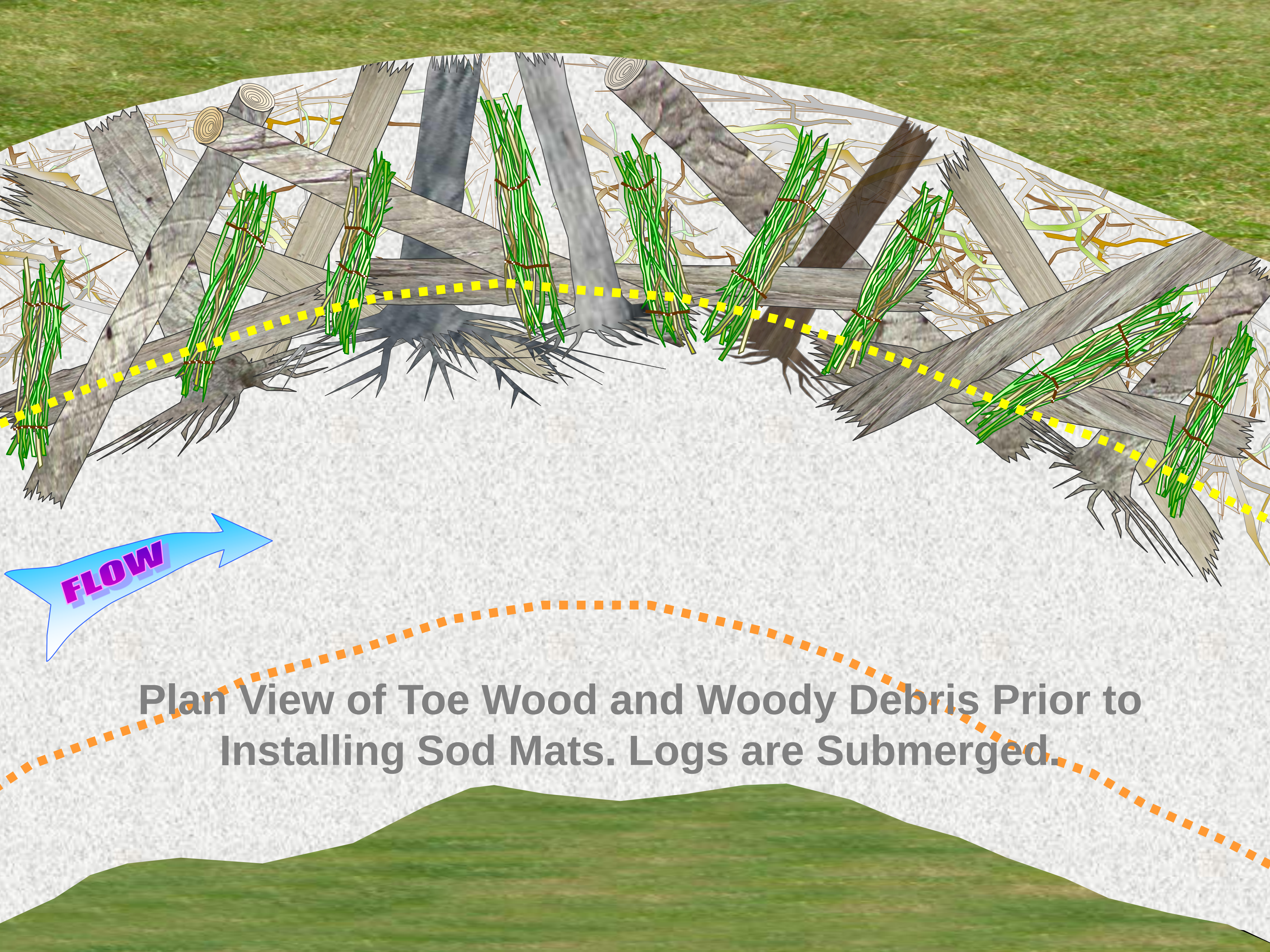
Stabilize stream banks

Maintain a low width/depth ratio

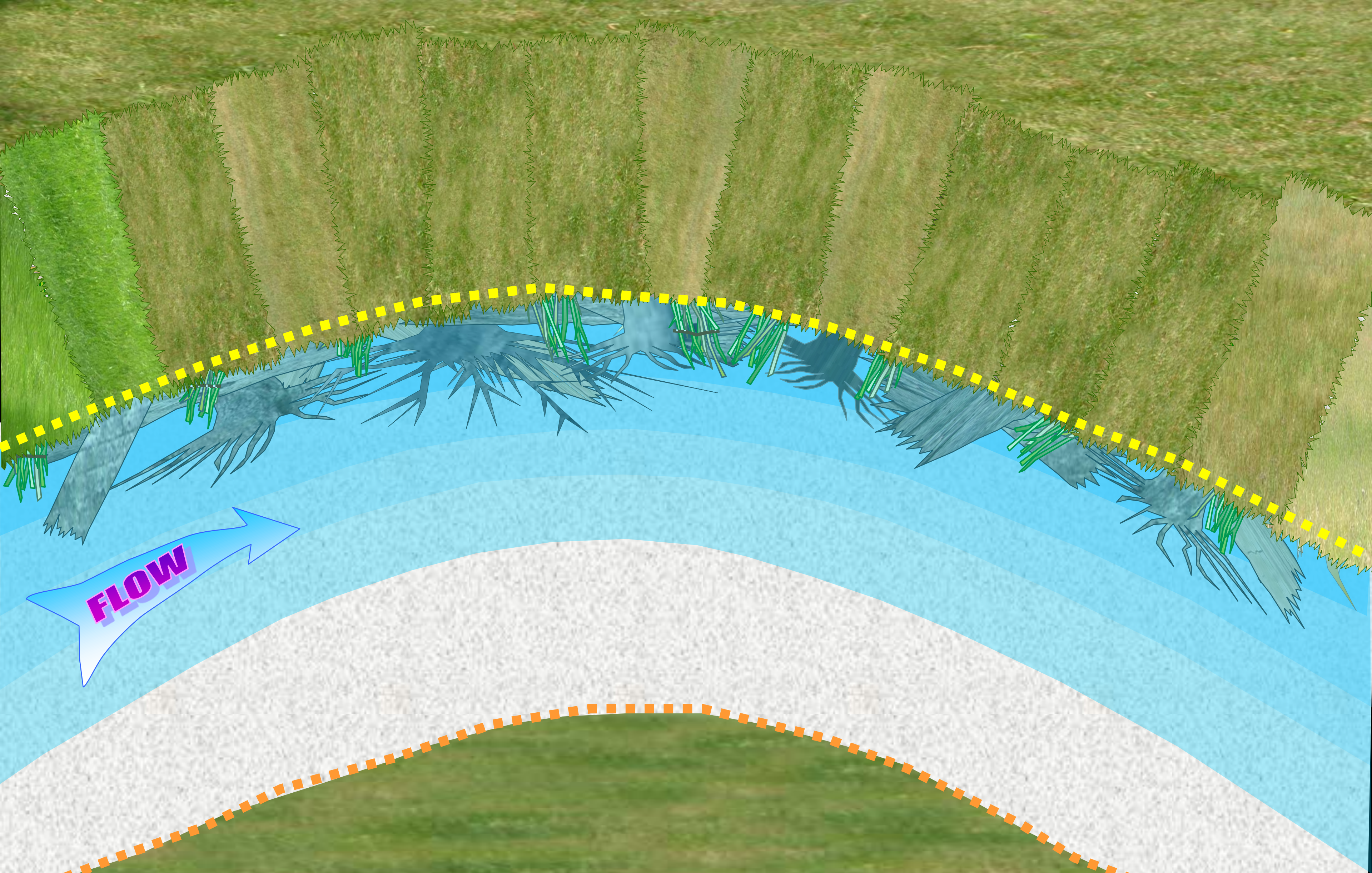
Toe-Wood Sod Mats with Woody Debris: Cross-Section View of Existing Channel vs. Proposed




FLOW
Plan View Prior to Installing Toe
Wood-Sod Mats with Woody Debris



Plan View of Toe Wood and Woody Debris Prior to Installing Sod Mats. Logs are Submerged.

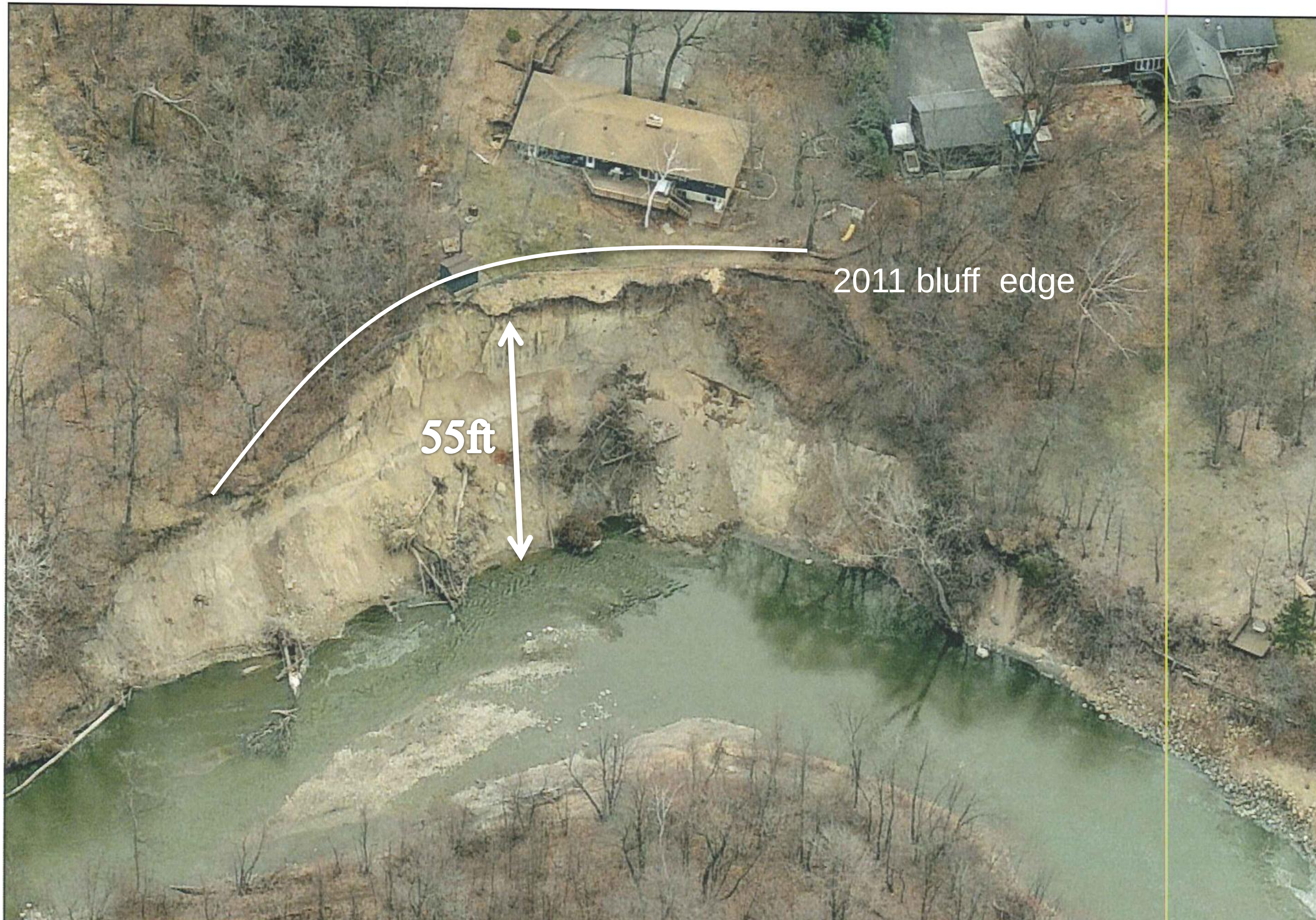


Plan View of Toe Wood-Sod Mats w/ Woody Debris & Vegetation Cover. Wood is submerged and counter-weighted so that 80% of wood is covered & integrated with bank.


Toe Wood Sites on the
Le Sueur River

Source: ©Pictometry International Corp. April 2009

View from North to South



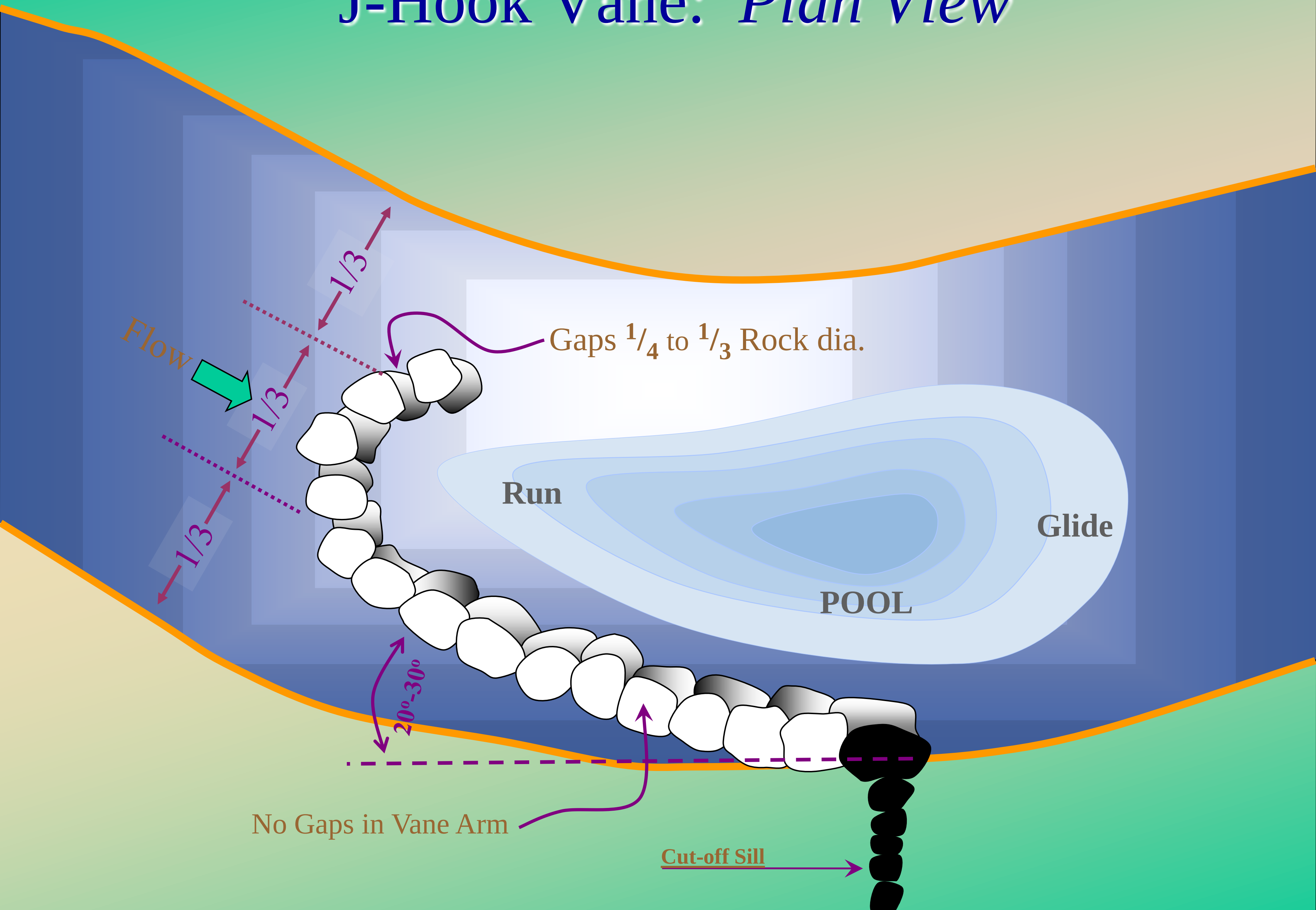
Source: ©Pictometry International Corp. April 2009

View from West to East


10/07/2011 13:58


10/13/2011 15:31

J-Hook Vane: *Plan View*

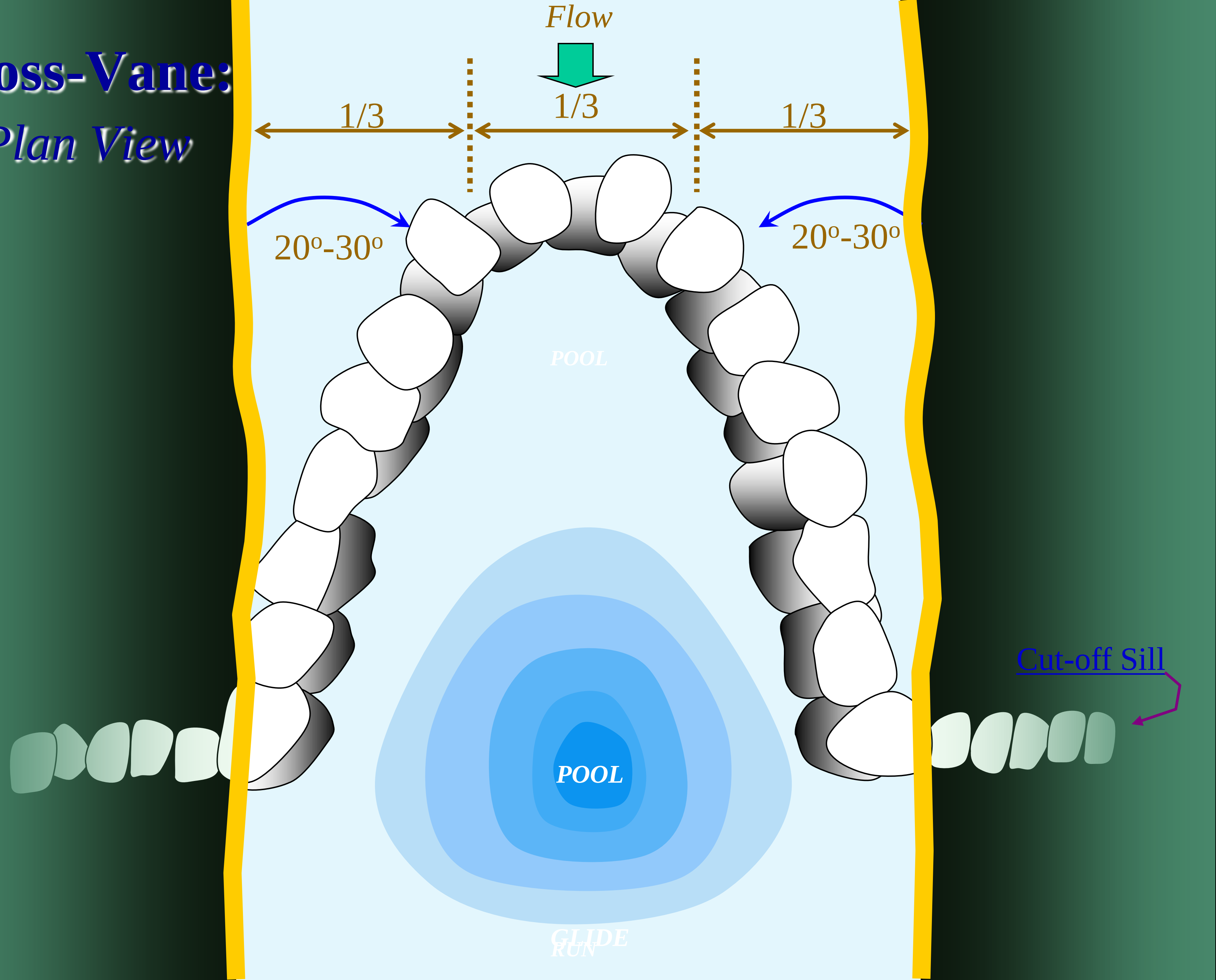


CopyRight 2005 Wildland Hydrology, Inc.

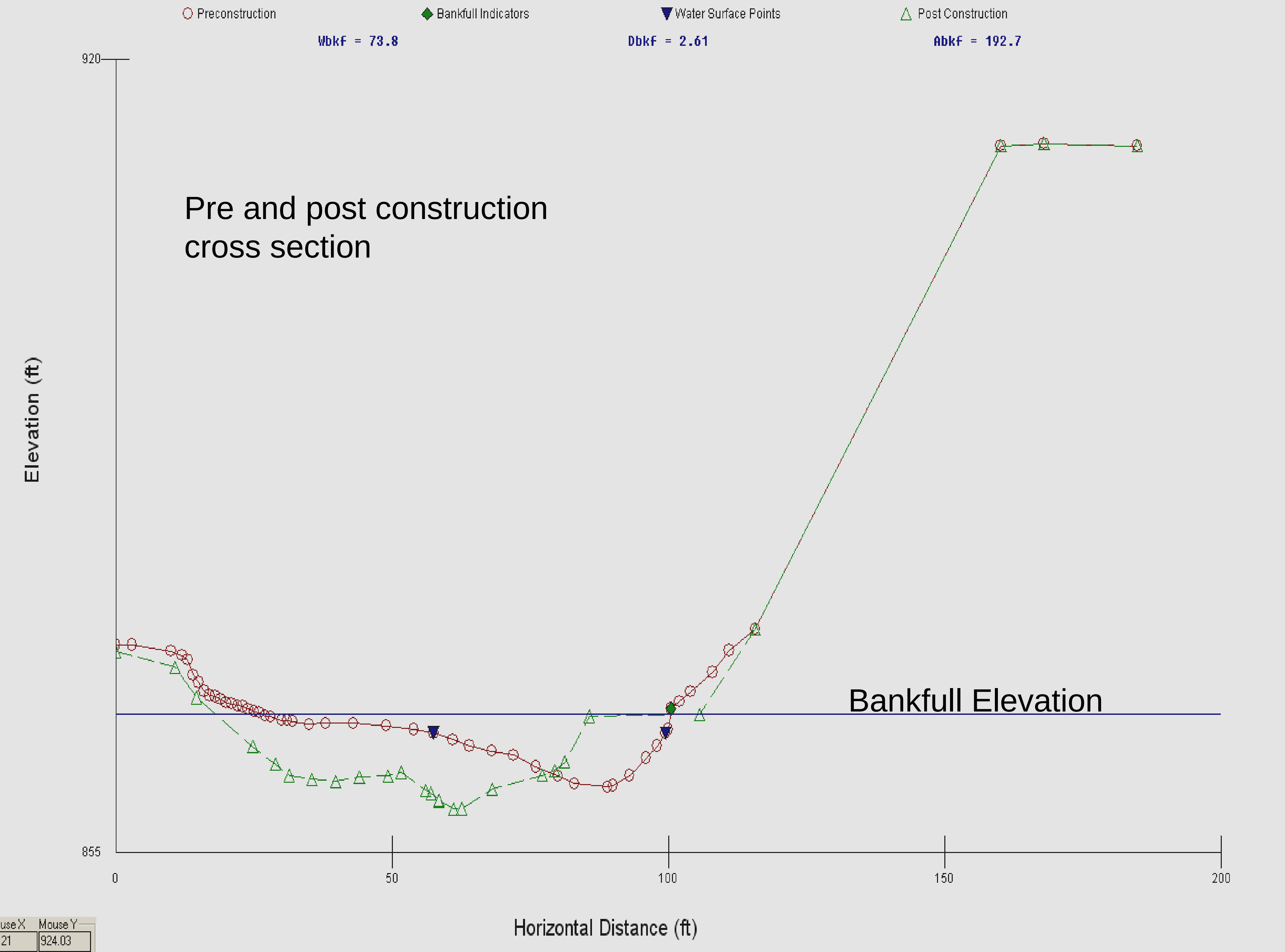

Toe-Wood Bench
J-Hook
10/28/2011 15:14

Cross-Vane:

Plan View



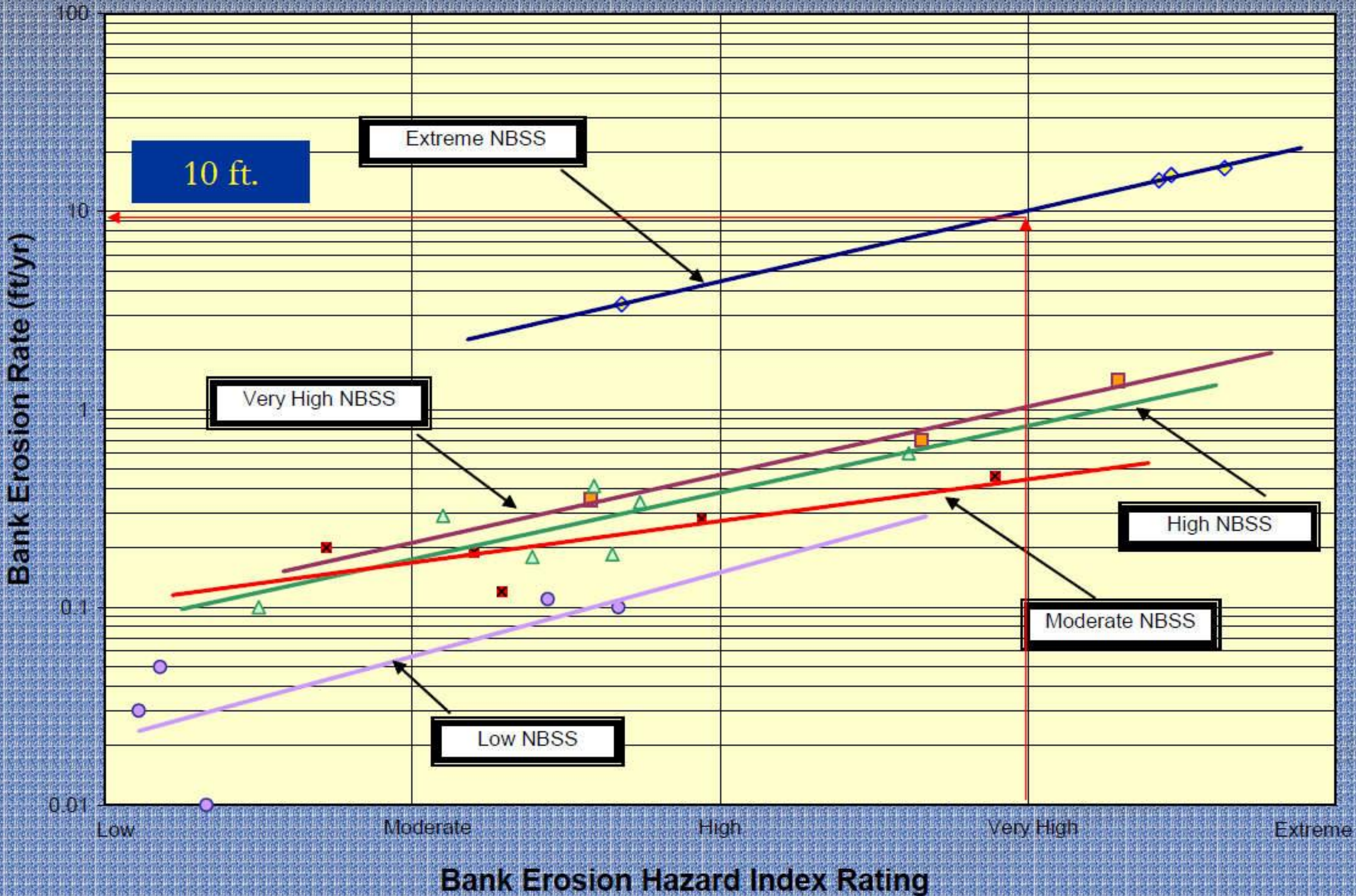

Gabion Basket Wall
Future Angle of Repose?


Preconstruction
Bankfull Indicators
Water Surface Points
Post Construction
Wbkf = 73.8
Dbkf = 2.61
Abkf = 192.7
Pre and post construction cross section
Elevation (ft)
920
855
Bankfull Elevation
0
50
100
150
200
Horizontal Distance (ft)
use X
Mouse Y
21
924.03


Questions?

Streambank Erosion Prediction Model

West Fork White River Watershed, Northwest Arkansas



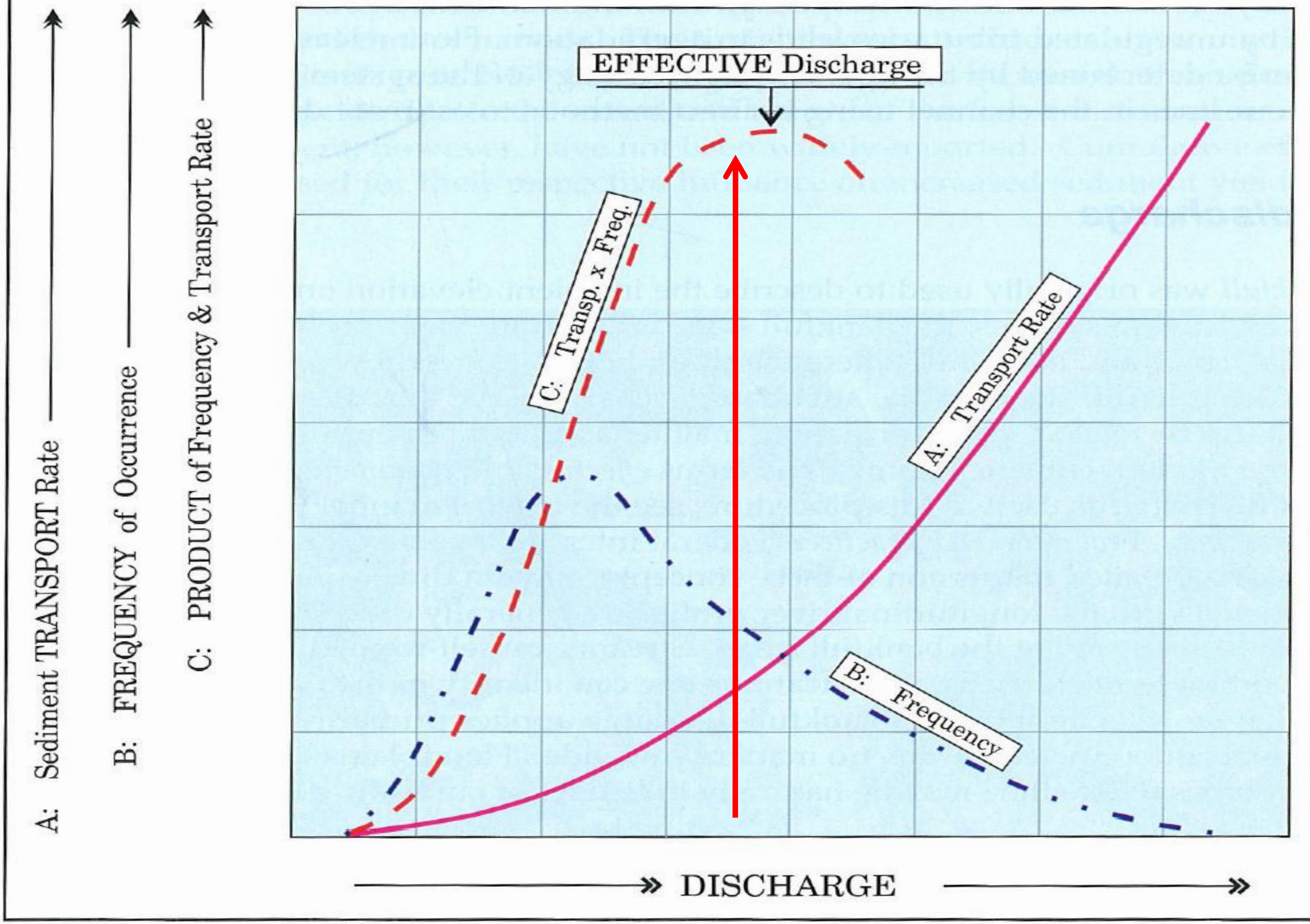
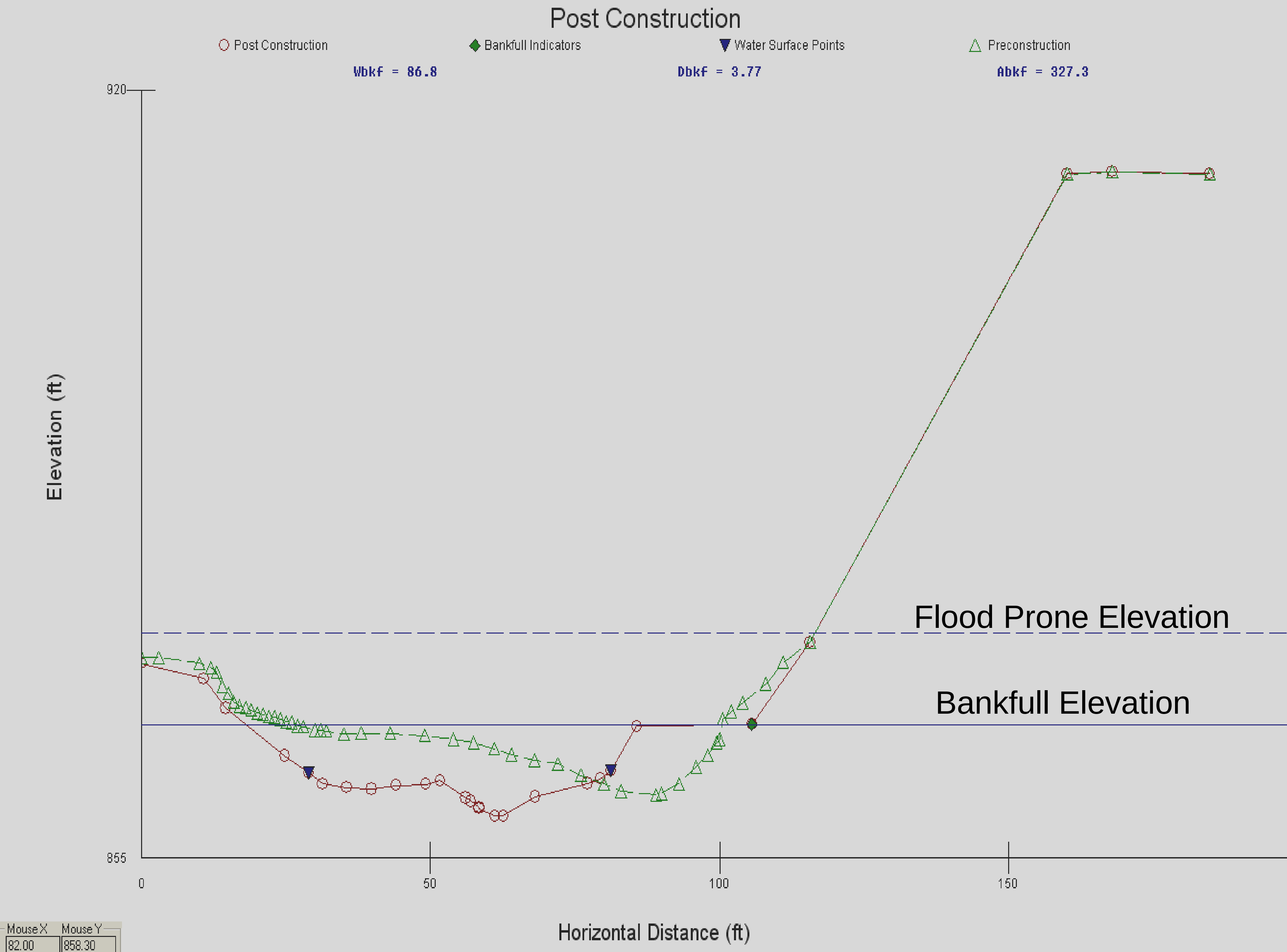


Figure 2-48. Relations among discharge, sediment transport rate, frequency of occurrence, and the product of frequency and transport rate (after Wolman and Miller, 1960).

Stream type	Sensitivity to disturbance	Recovery potential	Sediment supply	Streambank erosion potential	Vegetation controlling influence
A1	very low	excellent	very low	very low	negligible
A2	very low	excellent	very low	very low	negligible
A3	very high	very poor	very high	very high	negligible
A4	extreme	very poor	very high	very high	negligible
A5	extreme	very poor	very high	very high	negligible
A6	high	poor	high	high	negligible
B1	very low	excellent	very low	very low	negligible
B2	very low	excellent	very low	very low	negligible
B3	low	excellent	low	low	moderate
B4	moderate	excellent	moderate	low	moderate
B5	moderate	excellent	moderate	moderate	moderate
B6	moderate	excellent	moderate	low	moderate
C1	low	very good	very low	low	moderate
C2	low	very good	low	low	moderate
C3	moderate	good	moderate	moderate	very high
C4	very high	good	high	very high	very high
C5	very high	fair	very high	very high	very high
C6	very high	good	high	high	very high
D3	very high	poor	very high	very high	moderate
D4	very high	poor	very high	very high	moderate
D5	very high	poor	very high	very high	moderate


Study Bank Pins



Post Construction
Post Construction
Bankfull Indicators
Water Surface Points
Preconstruction
Wbkf = 86.8
Dbkf = 3.77
Abkf = 327.3
920
855
Elevation (ft)
Flood Prone Elevation
Bankfull Elevation
0
50
100
150
Horizontal Distance (ft)
Mouse X
Mouse Y
82.00
858.30

Landscape evolution in south-central Minnesota and the role of geomorphic history on modern erosional processes

- This is a natural process, but studies have shown erosion rates in the Le Sueur River to be 4 to 5 times higher than holocene-average loading rates.

Gran et al. 2011

Fingerprinting Sources of Sediment in Large Agricultural River Systems

- Lake Pepin post-settlement loading rates have increased 10 fold.
- The majority of this sediment is not from field erosion, but stream banks, bluffs and ravines.

Schottler et al 2010