MESBOAC

is nothing more than an acronym to help remember
some of the Important things to think about
when sizing and installing a culvert (good footings or compacted base)

It is based on
natural processes with minimum long-term cost
rather than
minimum sizing for minimum short-term costs

The Natural Processes are those related to what a stream transports:

- Sediment
- Water
- Fish
- Debris (one culvert better than two IF you can get just one in)

Before getting into MESBOAC - - -
We need to understand the basics of

SEDIMENT FLOW

BANKFULL WATER FLOW

HOW LAND USE CHANGE - - -
CHANGES BANKFULL FLOW (and much larger)

RISKY BUT REAL BUSINESS
- - - THE RECURRENCE INTERVAL FOR DESIGN

READ THE RIVER

MESBOAC

DESIGN Some CULVERT CROSSINGS WITH HY8

LASER LEVELING

With the possible exception of small culverts (1-ft to 3-ft)

You will need to know laser leveling (or optical levels on a tripod)
(or total stations or gps survey-grade instruments)

Level surveys and setting with levels will ensure an installation that can handle all natural processes

Most culverts set without channel information and without laser-level setting result In installations that will not allow water, sediment and fish to pass in the appropriate amounts.

You don't need to know leveling today for the information materials or for the exercises, but if you're serious about putting in large culverts, you do!


SEDIMENT
FLOW

Inches	PARTICLE	Millimeters	
	Silt / Clay	< .062	S/C
	Very Fine	.062 - .125	SAND
	Fine	.125 - .25	
	Medium	.25 - .50	
	Coarse	.50 - 1.0	
.04 - .08	Very Coarse	1.0 - 2	
.08 - .16	Very Fine	2 - 4	GRAVEL
.16 - .22	Fine	4 - 5.7	
.22 - .31	Fine	5.7 - 8	
.31 - .44	Medium	8 - 11.3	
.44 - .63	Medium	11.3 - 16	
.63 - .89	Coarse	16 - 22.6	
.89 - 1.3	Coarse	22.6 - 32	
1.3 - 1.8	Very Coarse	32 - 45	
1.8 - 2.5	Very Coarse	45 - 64	
2.5 - 3.5	Small	64 - 90	COBBLE
3.5 - 5.0	Small	90 - 128	
5.0 - 7.1	Large	128 - 180	
7.1 - 10.1	Large	180 - 256	
10.1 - 14.3	Small	256 - 362	BOULDER
14.3 - 20	Small	362 - 512	
20 - 40	Medium	512 - 1024	
40 - 80	Large-Vry Large	1024 - 2048	
	Bedrock		BDRK

SEDIMENT

Some is mud and sand,
Some is gravel, cobble and boulders

Wentworth scale of pebble sizes (from silt & clay to boulders)

Each class is twice the size of the previous class

Widely used by geology, engineering, soil, and hydrology disciplines

The unit of choice is universally mm, but inches are shown for comparison

Table 2-6. Pebble count form (Rosgen and Silvey, 2007) with example data.

Site: **Lower Nevada Ck nr Helmville, MT** Date: **8/8/06**

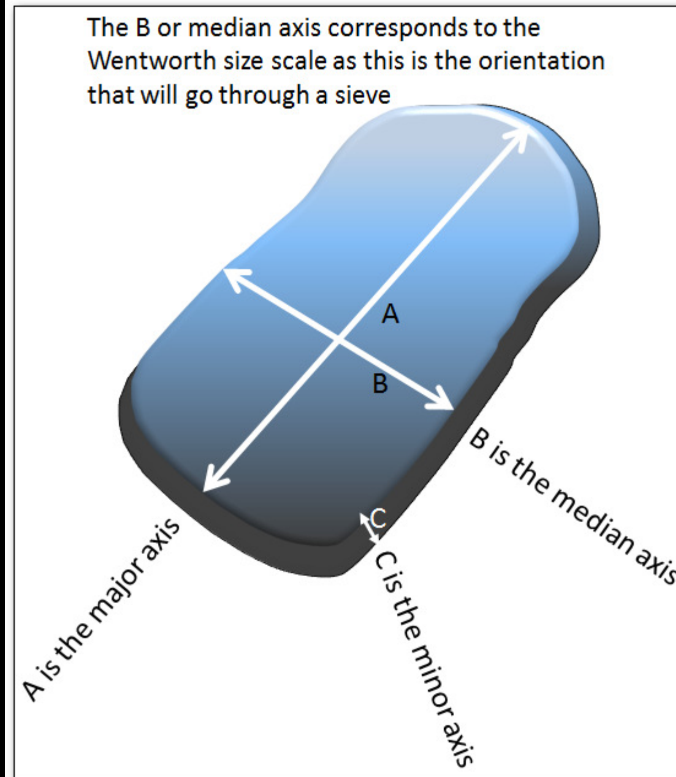
Location: **nr Gauge 12335500** HUC: **10 20 00 02**

Party: **Team 4**

Inches	PARTICLE	Millimeters		Dot Count for RIFFLE 1	POOL 2	COMP. 3
	Silt / Clay	< .062	S/C			
	Very Fine	.062 - .125	SAND			
	Fine	.125 - .25	SAND			
	Medium	.25 - .50	SAND			
	Coarse	.50 - 1.0	SAND			
.04 - .08	Very Coarse	1.0 - 2	SAND			
.08 - .16	Very Fine	2 - 4	GRAVEL			
.16 - .22	Fine	4 - 5.7	GRAVEL			
.22 - .31	Fine	5.7 - 8	GRAVEL			
.31 - .44	Medium	8 - 11.3	GRAVEL			
.44 - .63	Medium	11.3 - 16	GRAVEL			
.63 - .89	Coarse	16 - 22.6	GRAVEL			
.89 - 1.3	Coarse	22.6 - 32	GRAVEL			
1.3 - 1.8	Very Coarse	32 - 45	GRAVEL			
1.8 - 2.5	Very Coarse	45 - 64	GRAVEL			
2.5 - 3.5	Small	64 - 90	COBBLE			
3.5 - 5.0	Small	90 - 128	COBBLE			
5.0 - 7.1	Large	128 - 180	COBBLE			
7.1 - 10.1	Large	180 - 256	COBBLE			
10.1 - 14.3	Small	256 - 362	BOULDER			
14.3 - 20	Small	362 - 512	BOULDER			
20 - 40	Medium	512 - 1024	BOULDER			
40 - 80	Large-Vry Large	1024 - 2048	BOULDER			
	Bedrock		BDRK			

Stream Type: **C4** *Valley Type:* **VIII** TOTAL→

A stylized pebble
Measure the median axis in mm



Need at least 100, use the toe to to method. Developed by Prof. "Redds" Wolman at Rutgers in early '50s

Table 2-6. Pebble count form (Rosgen and Silvey, 2007) with example data.

Site: **Lower Nevada Ck nr Helmville, MT** Date: **8/8/06**

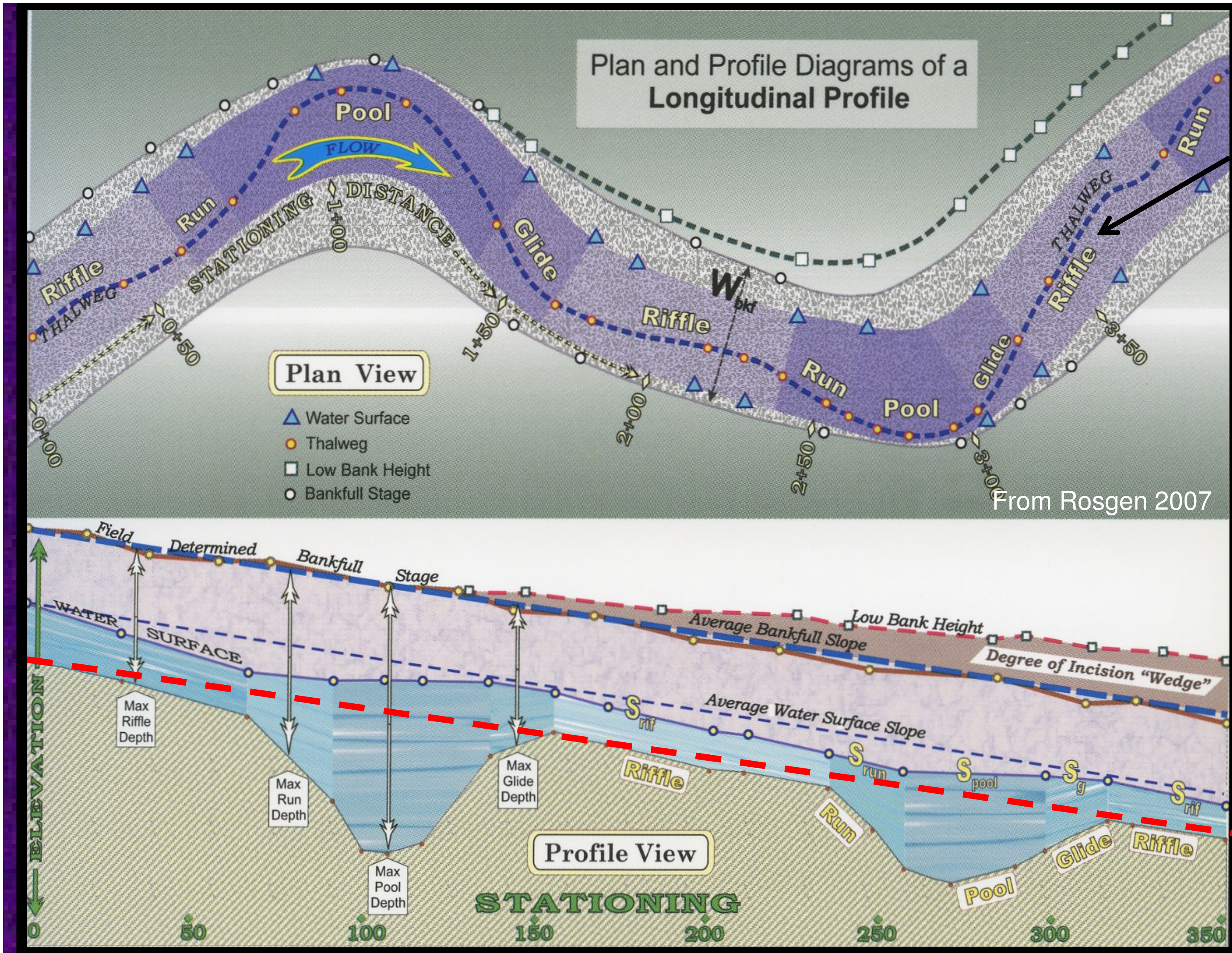
Location: **nr Gauge 12335500** HUC: **10 20 00 02**

Party: **Team 4**

Dot Count for: RIFFLE 1 | POOL 2 | COMP. 3

				RIFFLE (1)			POOL (2)			COMPOSITE (3)		
				Reach: 26+00–32+00			Reach: 26+00–32+00			Reach: 26+00–32+00		
				Date: 8/8/06			Date: 8/8/06			Date: 8/8/06		
Inches	PARTICLE	Millimeters		TOT #	ITEM %	% CUM	TOT #	ITEM %	% CUM	TOT #	ITEM %	% CUM
	Silt / Clay	< .062	S/C	6	6/70= 8.6%	8.6	3	3/30= 10%	10.0	6+3=9	9/100= 9%	9
	Very Fine	.062 - .125	SAND	3	4.3	8.6+4.3 =12.9%	2	6.7	10+6.7 =16.7%	5	5	9+5= 14%
	Fine	.125 - .25	SAND	1	1.4	14.3	1	3.3	20.0	2	2	16
	Medium	.25 - .50	SAND	4	5.7	20.0	1	3.3	23.3	5	5	21
	Coarse	.50 - 1.0	SAND	1	1.4	21.4	0	0.0	23.3	1	1	22
.04 - .08	Very Coarse	1.0 - 2	SAND	1	1.4	22.9	1	3.3	26.7	2	2	24
.08 - .16	Very Fine	2 - 4	GRAVEL	1	1.4	24.3	0	0.0	26.7	1	1	25
.16 - .22	Fine	4 - 5.7	GRAVEL	2	2.9	27.1	3	10.0	36.7	5	5	30
.22 - .31	Fine	5.7 - 8	GRAVEL	2	2.9	30.0	2	6.7	43.3	4	4	34
.31 - .44	Medium	8 - 11.3	GRAVEL	4	5.7	35.7	6	20.0	63.3	10	10	44
.44 - .63	Medium	11.3 - 16	GRAVEL	5	7.1	42.9	4	13.3	76.7	9	9	53
.63 - .89	Coarse	16 - 22.6	GRAVEL	6	8.6	51.4	2	6.7	83.3	8	8	61
.89 - 1.3	Coarse	22.6 - 32	GRAVEL	10	14.3	65.7	2	6.7	90.0	12	12	73
1.3 - 1.8	Very Coarse	32 - 45	GRAVEL	10	14.3	80.0	2	6.7	96.7	12	12	85
1.8 - 2.5	Very Coarse	45 - 64	GRAVEL	9	12.9	92.9	1	3.3	100	10	10	95
2.5 - 3.5	Small	64 - 90	COBBLE	2	2.9	95.7	0	0.0	100	2	2	97
3.5 - 5.0	Small	90 - 128	COBBLE	3	4.3	100	0	0.0	100	3	3	100
5.0 - 7.1	Large	128 - 180	COBBLE									
7.1 - 10.1	Large	180 - 256	COBBLE									
10.1 - 14.3	Small	256 - 362	BOULDER									
14.3 - 20	Small	362 - 512	BOULDER									
20 - 40	Medium	512 - 1024	BOULDER									
40 - 80	Large-Vry Large	1024 - 2048	BOULDER									
	Bedrock		BDRK									
			TOTAL→	70			30			100		

Stream Type: **C4** *Valley Type:* **VIII**



Sediment sizes on the riffle are the primary concern when setting culverts

Additionally, it is said of constructing new channels:

" if you get the riffle slope, width and depth right, the rest of the channel will develop by itself"

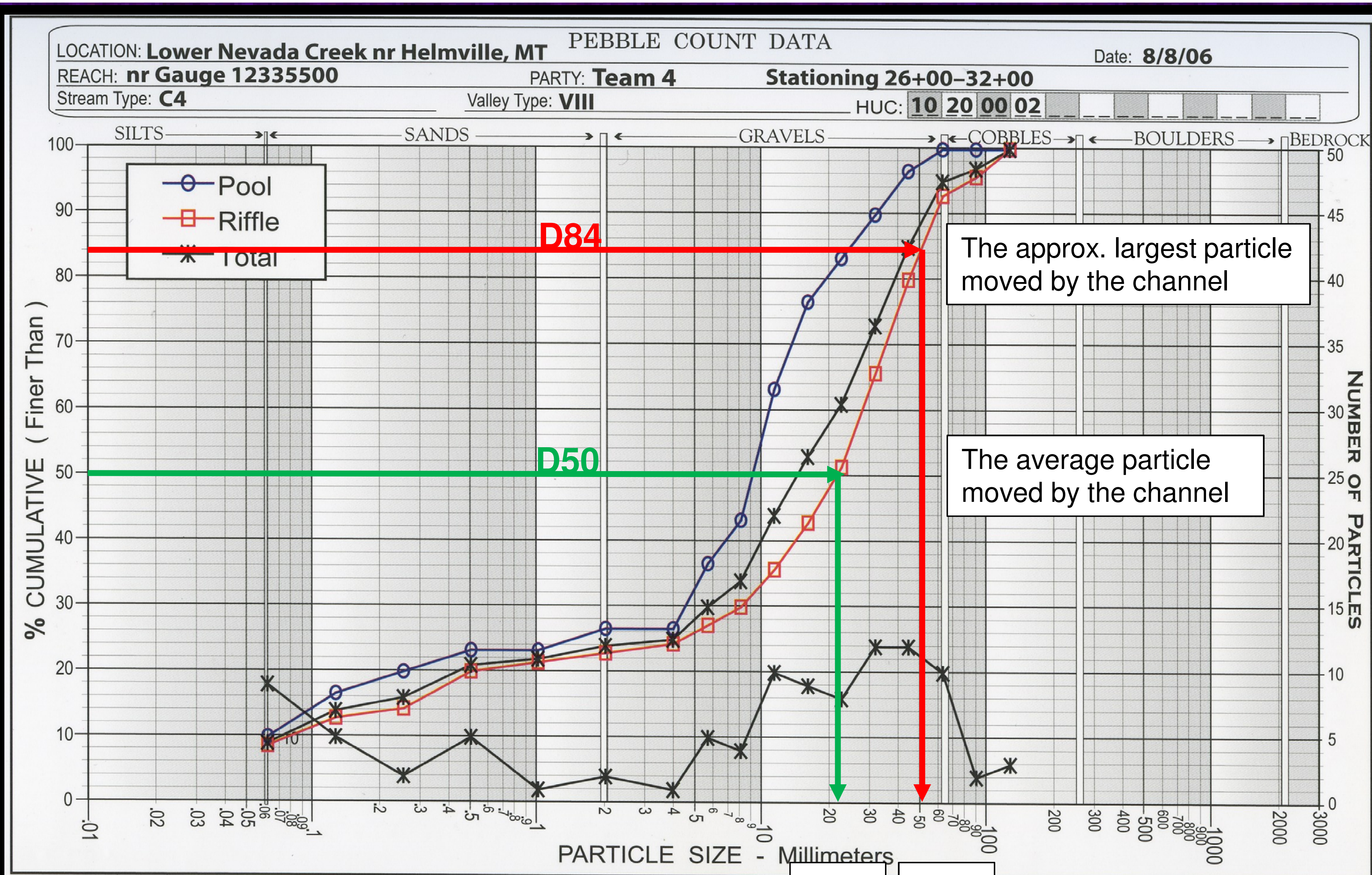


Figure 2-14. Pebble count plot (Rosgen and Silvey, 2007) with example data.

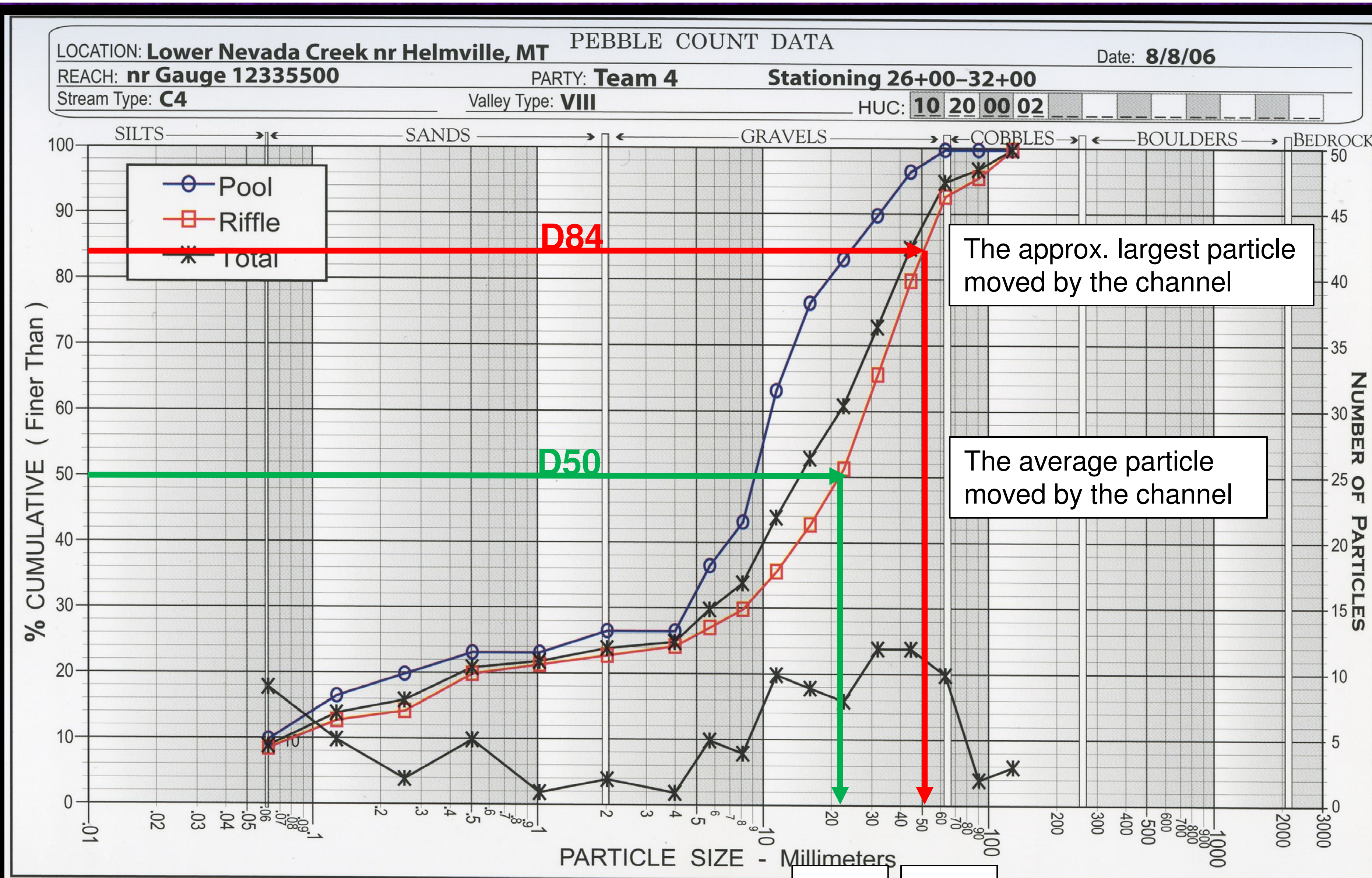
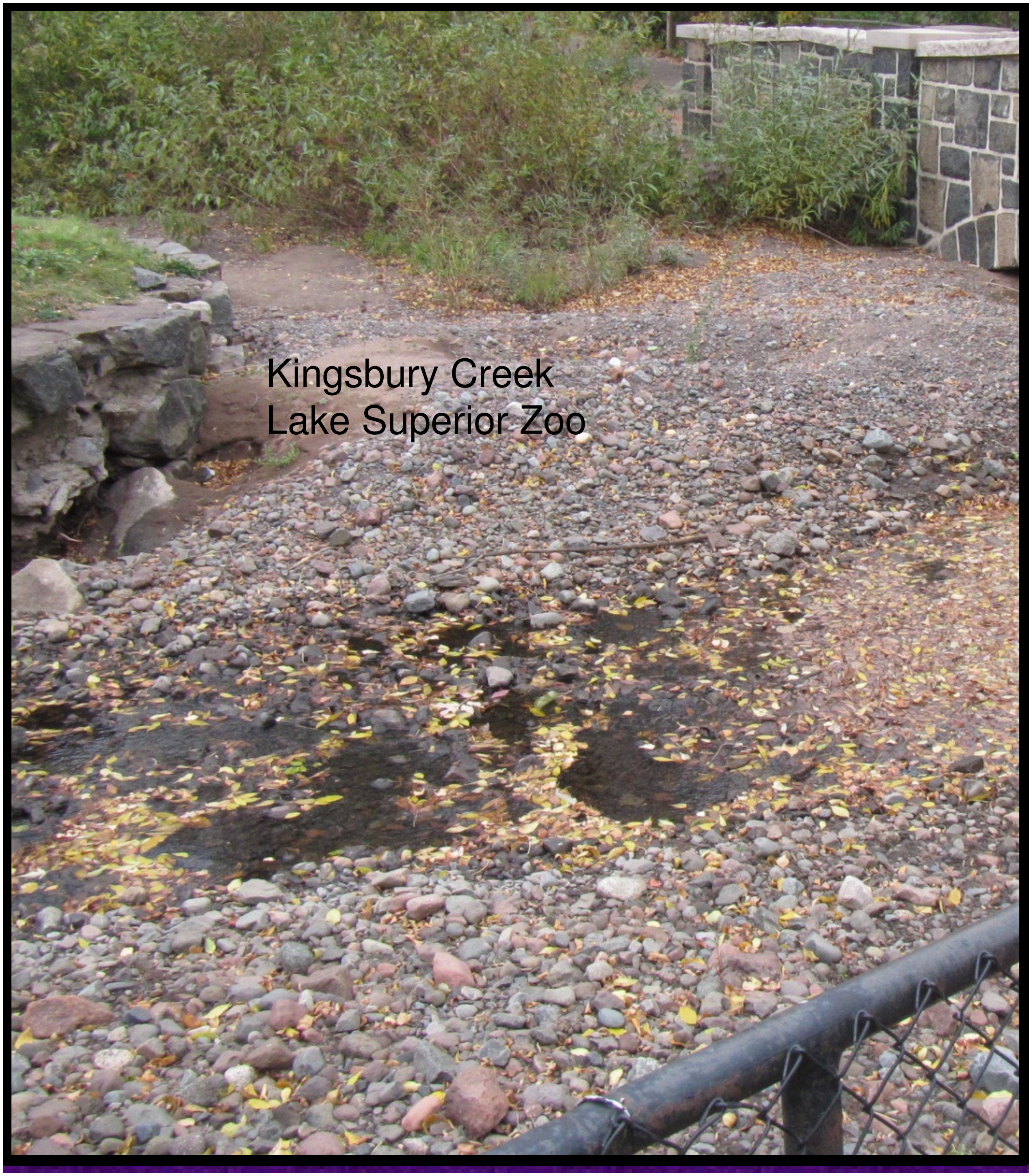


Figure 2-14. Pebble count plot (Rosgen and Silvey, 2007) with example data.

These are the average and largest particles moved by which flow in the channel?


Kingsbury Creek
Lake Superior Zoo

$\tau_c = dS = D$ The equation is derived by a regression of data and seems magic because mm = cm.

$\tau_c = dS = D$ The two MAJOR factors determining

$\tau_c = dS = D$ the size of pebbles moved are

Water Depth (above the riffle)

Water slope

Their product gives shear stress

The force that moves particles

Lane, E.W. 1955. Design of stable channels. Amer. Soc. of Civil Engineers Transactions. Paper 2776:1234-1279.

$$\tau_c = dS = D$$

Shear Stress = depth x Slope = Diameter of particle moved

Kg/m2 = mm x decimal slope = cm

A clever use of regression on water depth, slope and size of particles in canals Channels throughout countries of the British Empire gave an extremely useful equation for predicting the size of particles moved by a channel.

Don’t try to balance units even though all the units are metric, they are derived linear regression.

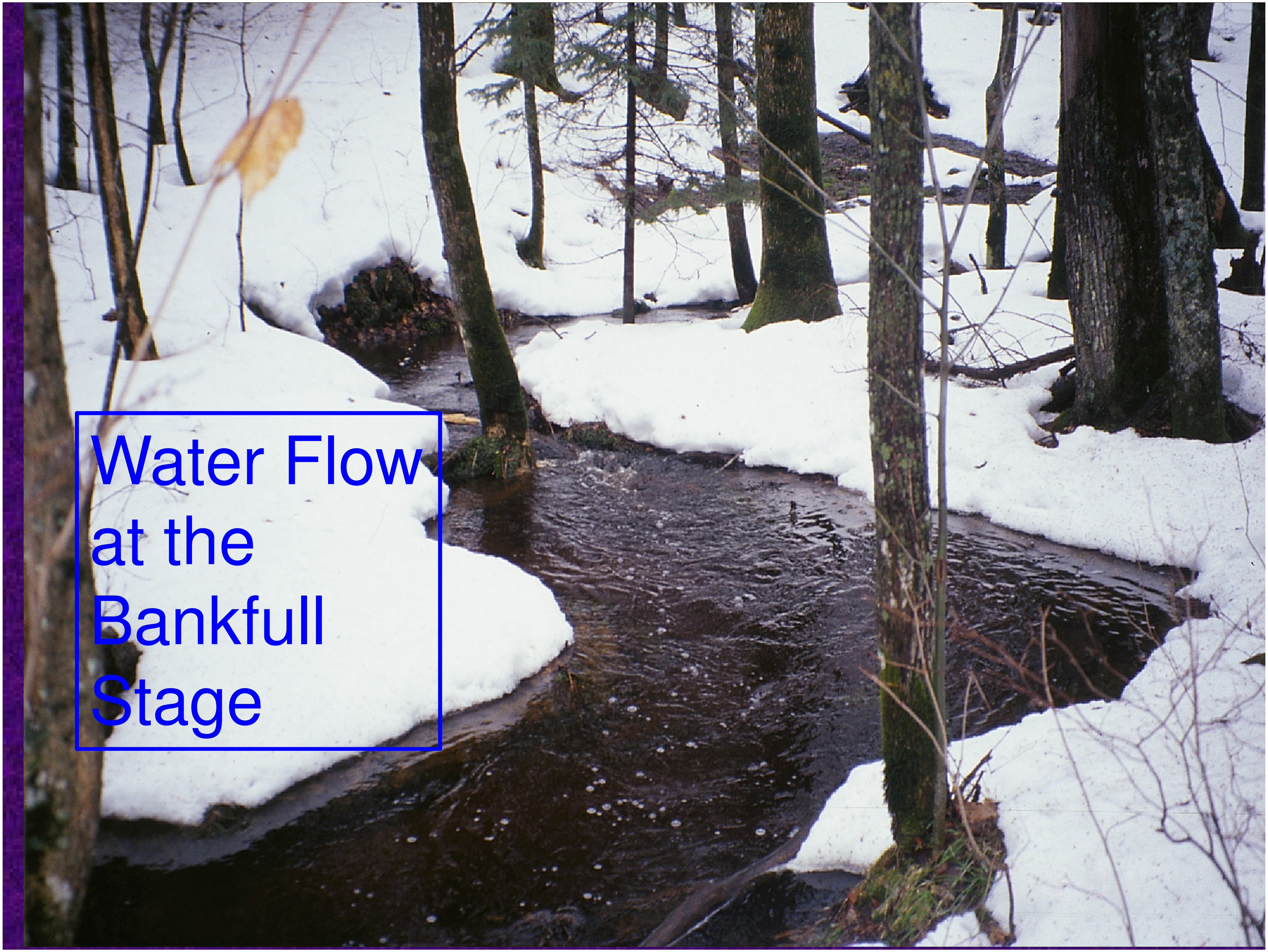
Lane, E.W. 1955. Design of stable channels. Amer. Soc. of Civil Engineers Transactions. Paper 2776:1234-1279.

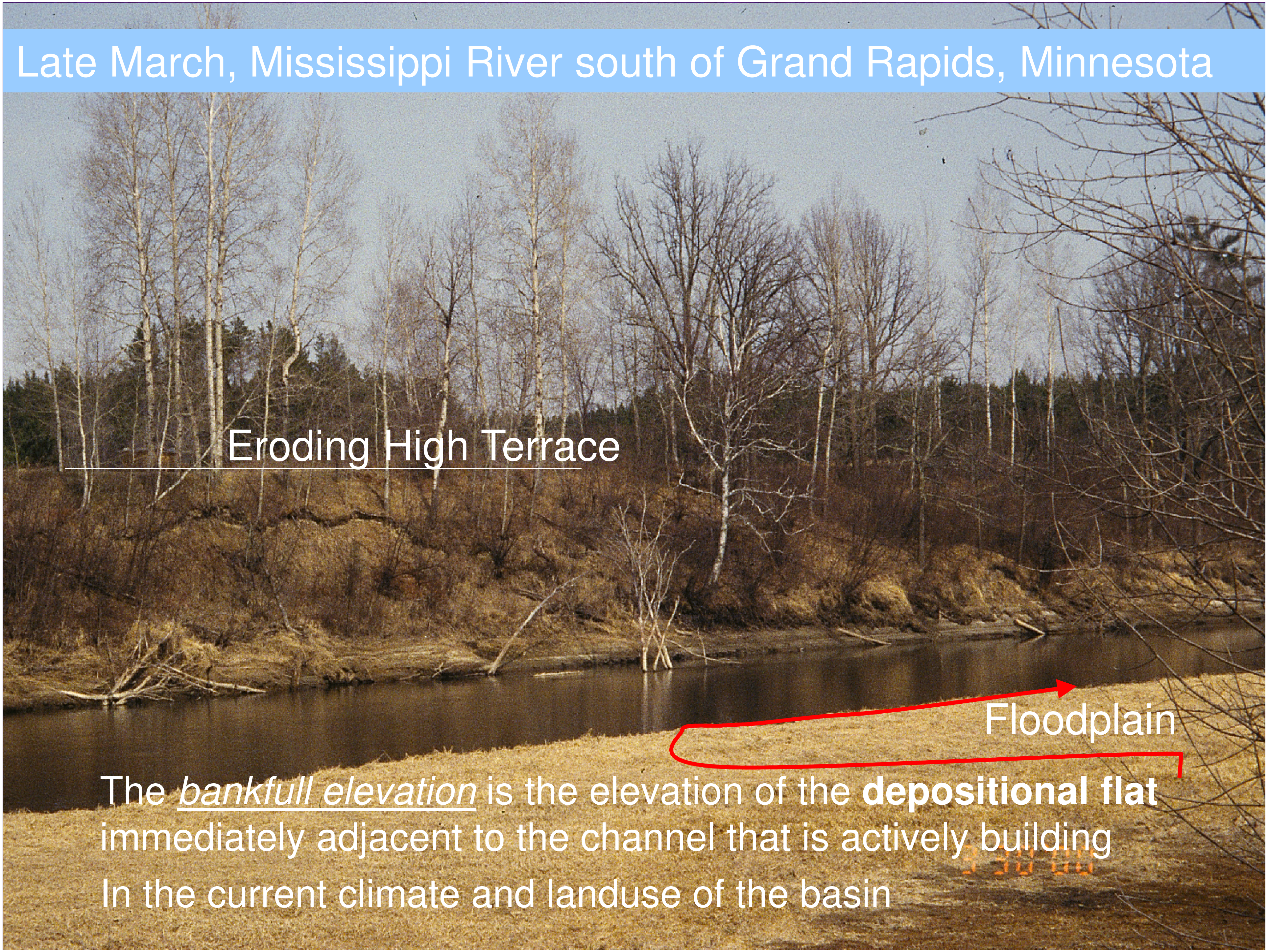
Make Your Own Lane Equation Cheat Sheet

Open up the file:

laneequation.xlxs

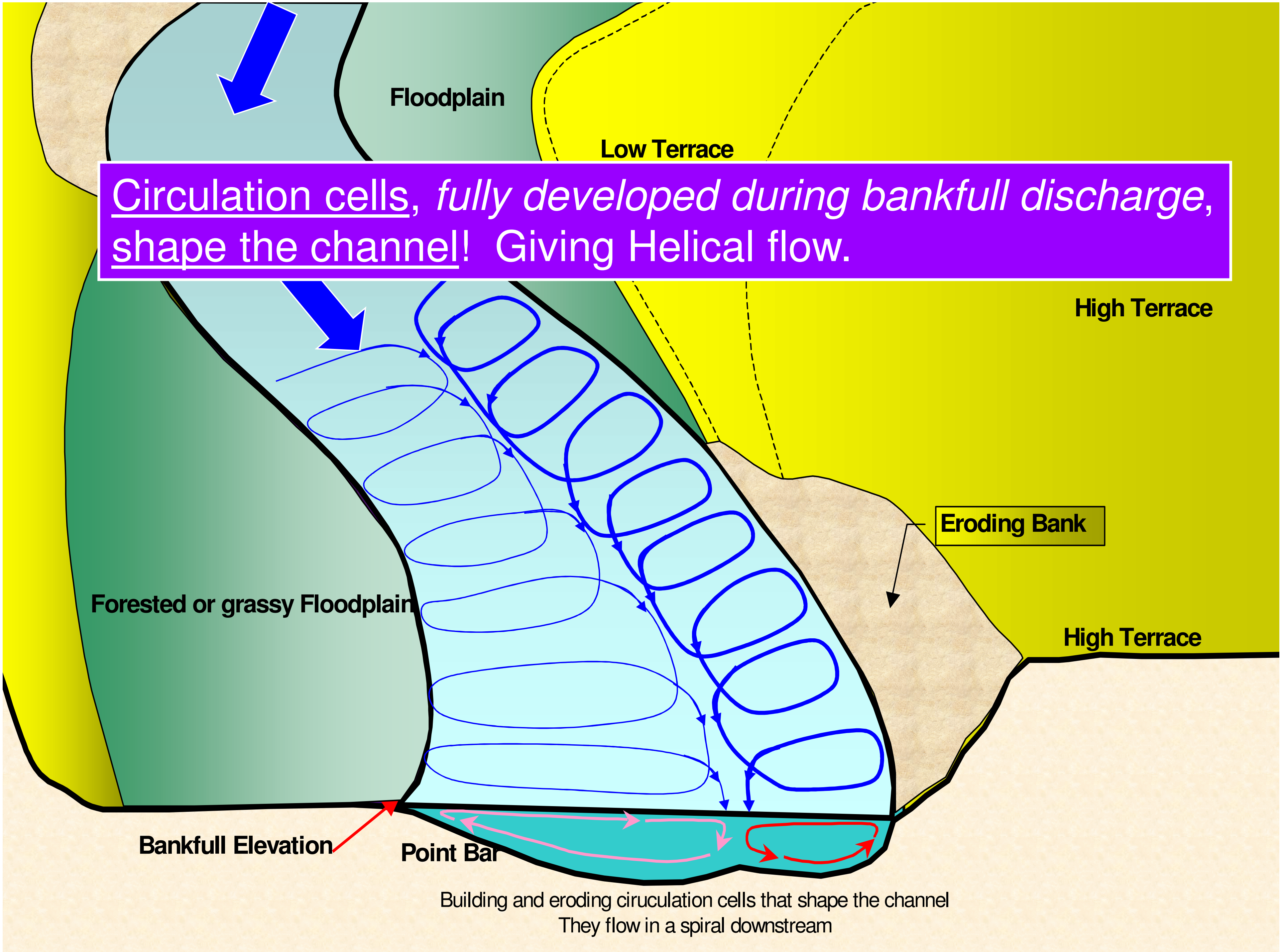
from the memory stick.


Water Flow
at the
Bankfull
Stage



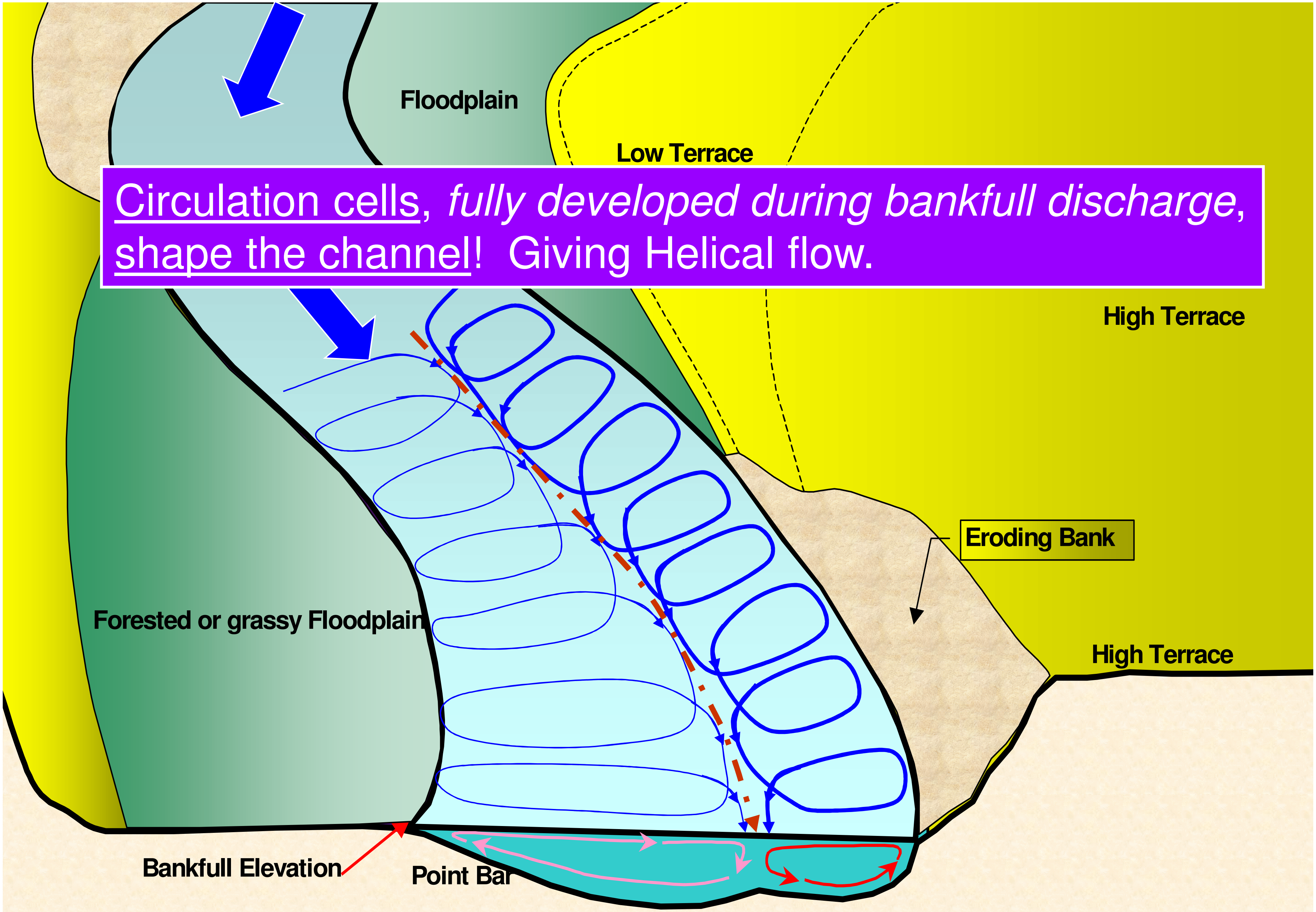
Late March, Mississippi River south of Grand Rapids, Minnesota
Eroding High Terrace
Floodplain
The *bankfull elevation* is the elevation of the **depositional flat**
immediately adjacent to the channel that is actively building
In the current climate and landuse of the basin

Circulation cells, *fully developed during bankfull discharge*, shape the channel! Giving Helical flow.

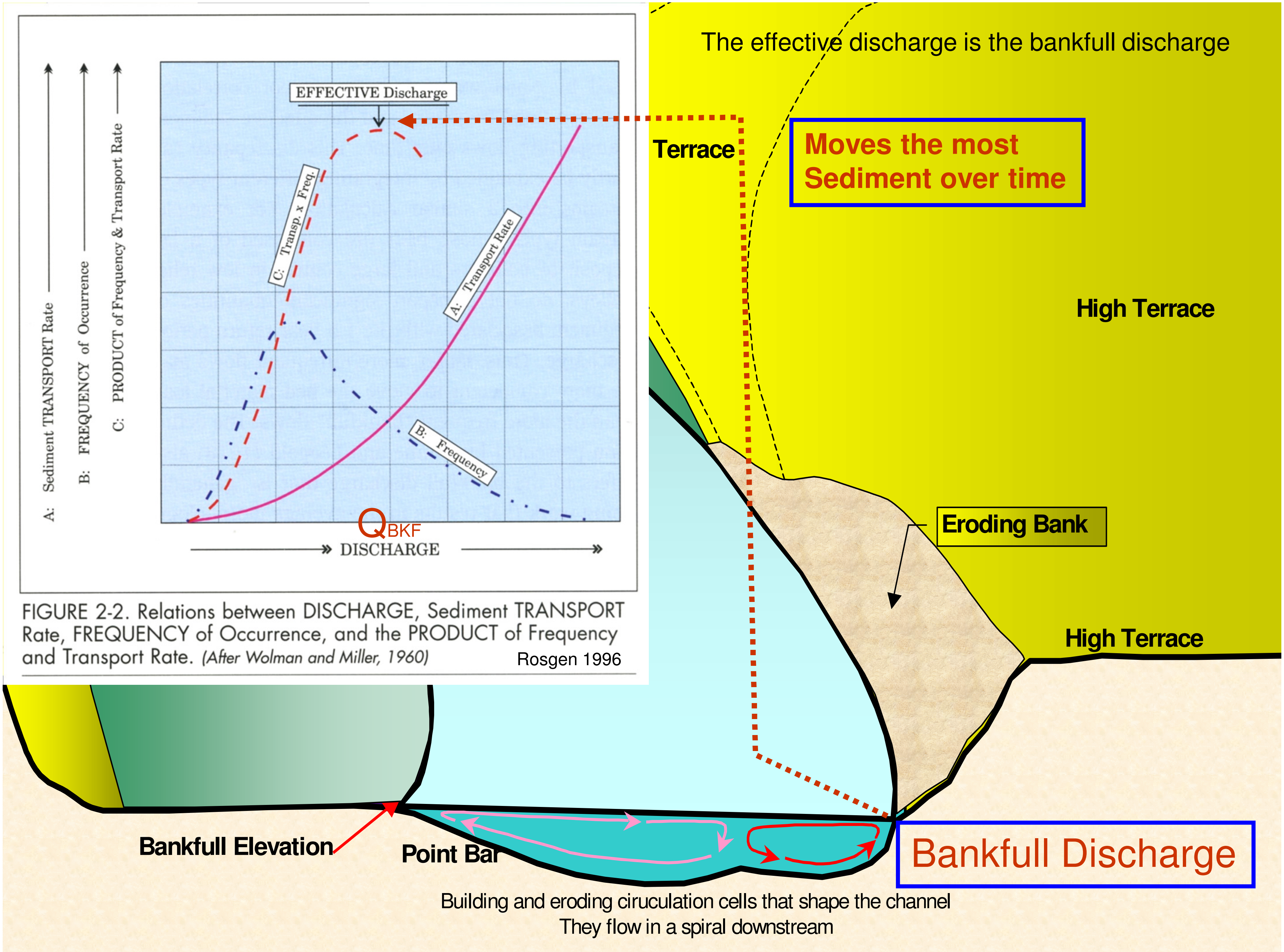


Building and eroding ciruculation cells that shape the channel
They flow in a spiral downstream

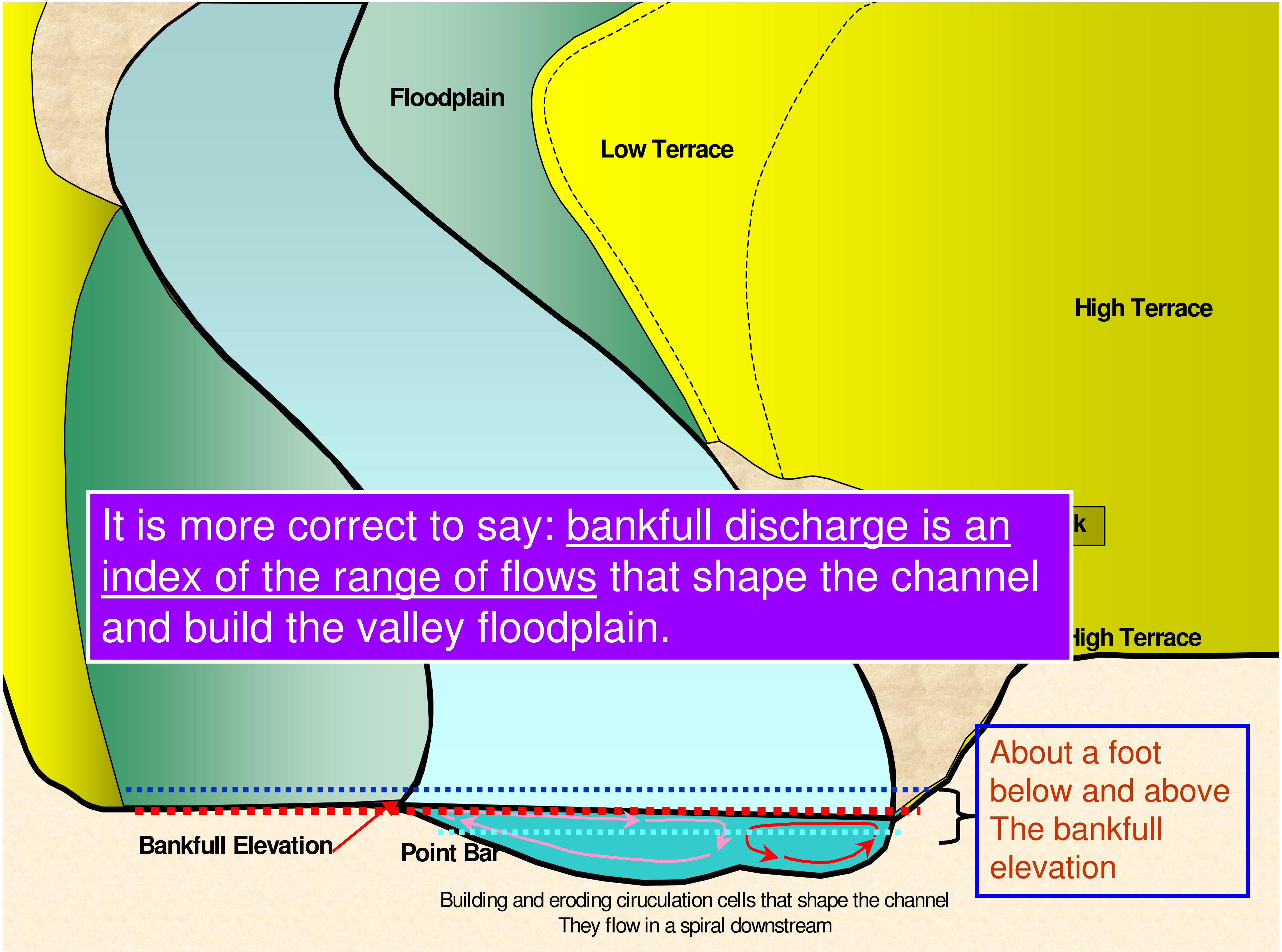
Circulation cells, *fully developed during bankfull discharge*, shape the channel! Giving Helical flow.



Building and eroding ciruculation cells that shape the channel
They flow in a spiral downstream



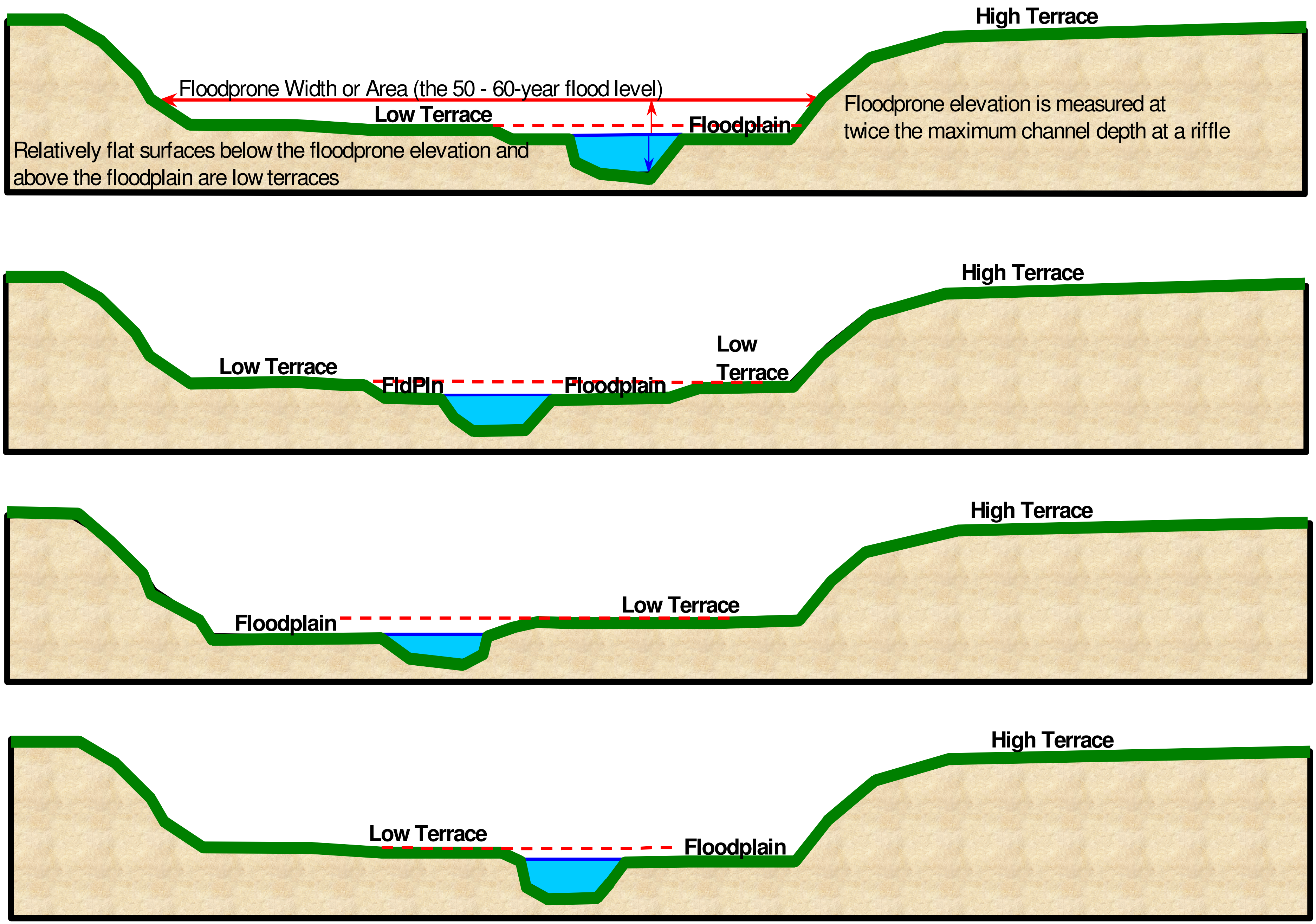
The effective discharge is the bankfull discharge
EFFECTIVE Discharge
C: Transp. x Freq.
A: Transport Rate
B: Frequency
A: Sediment TRANSPORT Rate
B: FREQUENCY of Occurrence
C: PRODUCT of Frequency & Transport Rate
QBKF
DISCHARGE
FIGURE 2-2. Relations between DISCHARGE, Sediment TRANSPORT Rate, FREQUENCY of Occurrence, and the PRODUCT of Frequency and Transport Rate. (After Wolman and Miller, 1960)
Rosgen 1996
Terrace
Moves the most Sediment over time
High Terrace
Eroding Bank
High Terrace
Bankfull Elevation
Point Bar
Bankfull Discharge
Building and eroding ciruculation cells that shape the channel
They flow in a spiral downstream



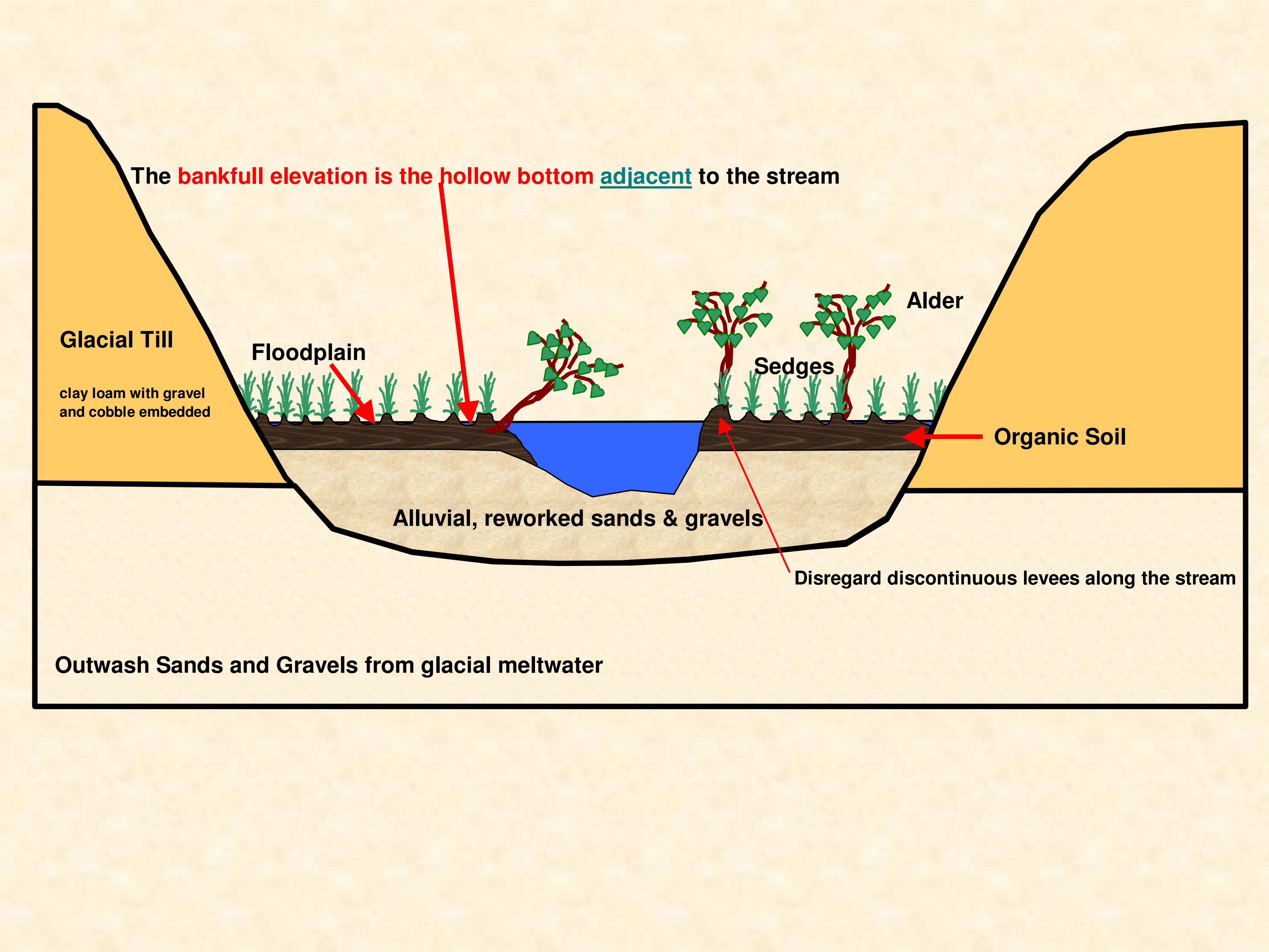
It is more correct to say: <u>bankfull discharge is an index of the range of flows</u> that shape the channel and build the valley floodplain.

About a foot below and above The bankfull elevation


4 12 '01


High Terrace
Floodprone Width or Area (the 50 - 60-year flood level)
Low Terrace
Floodplain
Floodprone elevation is measured at
twice the maximum channel depth at a riffle
Relatively flat surfaces below the floodprone elevation and
above the floodplain are low terraces
High Terrace
Low Terrace
FldPln
Floodplain
Low
Terrace
High Terrace
Floodplain
Low Terrace
High Terrace
Low Terrace
Floodplain


INGA CREEK


The bankfull elevation is the hollow bottom adjacent to the stream
Glacial Till
clay loam with gravel
and cobble embedded
Floodplain
Alder
Sedges
Organic Soil
Alluvial, reworked sands & gravels
Disregard discontinuous levees along the stream
Outwash Sands and Gravels from glacial meltwater

Bankfull Flow from Two Perspectives:

First
The math perspective
Using USGS peak flow
At a gaging station

- Based on a frequency analysis of the annual peak flows .
- Allows only one peak value for each year of record.
- A frequency analysis must have a minimum of 10 years
- The depositional flat found upstream from the gauging site will correspond to the 1.2- to 1.8-year frequency.
- On average it is about the 1.5-year event.
- Taken as a full fraction: 3 / 2 it occurs 2 out of 3 years.
- Over the long span of years, the bankfull flow is the most prevalent flow that is fast enough to entrain the channel bottom and transport bed & suspended sediment.
- Bankfull flow shapes the channels.
- Doing this procedure at a USGS gauging site is a good way to calibrate your eye.

Bankfull Flow from two perspectives: First, the Math Perspective at a USGS Gage

- Based on a frequency analysis of annual peak flows
- Make a list of the largest flow in each year of record
- You need at least 10-years of record to do the minimum analysis
- Order the list with the highest flow first and the lowest flow last
- Calculate plotting positions with a simple formula and get frequency of occurrence

- The depositional flat near a USGS gage station will correspond with a water stage
  - and flow at that elevation having a frequency between 1- and 2-years.

- On average, it is the 1.5-year flow
- Taken as a full fraction, 3/2, it occurs 2 out of 3 years

- Over the long span of years, the bankfull flow is the most prevalent flow that is fast enough
  - to entrain the channel bottom and transport large sediment sizes as well as
  - suspended sediment (silts, clays, fine sand)

- Bankfull flow shapes the channel!

- Doing a frequency analysis at a USGS gage and finding the depositional flat is a good
- way to calibrate you eye to see bankfull flats

Bankfull Flow Second Perspective, The Every Year Reality from Observations

- In 2 out of 3 years the bankfull flow will just fill the channel and hover there for a few hours, a few days, a few weeks, (I seen it last 10-weeks with the right melt, freeze, rain cycles)
- In the third year there is either a flood or a drought
- If we allow some variation in flow rate (say + or – 10% the bankfull flow occurs more than once a year
- During the melt of large snowpacks it may occur during one, two, or three weeks
- Usually a large July or a large Fall storm will bring the channel to bankfull stage too
- Both spring, fall, and early winter spawning fish will key on the spate associated with flow near the bankfull stage
- Bankfull flows course through a watershed like an “almost flood wave” rather than filling all of the channels in a watershed at the same time.

Bankfull Flow from Two Perspectives:

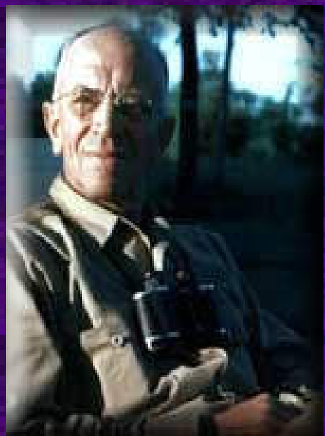
Second
The every year Reality from Observations

- In 2 out of 3 years the water in the stream will rise to just fill the channel at bankfull and hover there for a few hours or a few days.
- In the 3rd year there is either a flood or a drought.
- If we allow some variation in flow rate, say +/- 10%, the bankfull flow actually occurs more than once a year.
- During the melt of large snowpacks, it may occur during one, two, or three weeks; depending on the melt/freeze cycles.
- Usually, a large July or a large Fall rain will also bring the channel to near the bankfull stage.
- Both Spring and Fall spawning fish are responding to the near bankfull flow rate.
- Bankfull flows course through basins in a pulse, rather than filling all of the channels to bankfull at the same time.

Read the River

- There is only ONE Bankfull elevation
- It is the depositional flat immediately adjacent to the channel   continuous or discontinuous enormous or only as large as your foot.
- In B, G, C, E, D, DA, and F channels the DEPOSITIONAL FLAT is the bankfull elevation
- In A channels calculate bankfull flow in a nearby reach of the same channel with a different channel type, then transfer the flow back to the A channel and use appropriate slope and roughness terms to calculate bankfull stage

Top: Aldo, Estella, Luna, Starker; bottom Nina, Estella, Jr. and Gus. Carl took the picture.

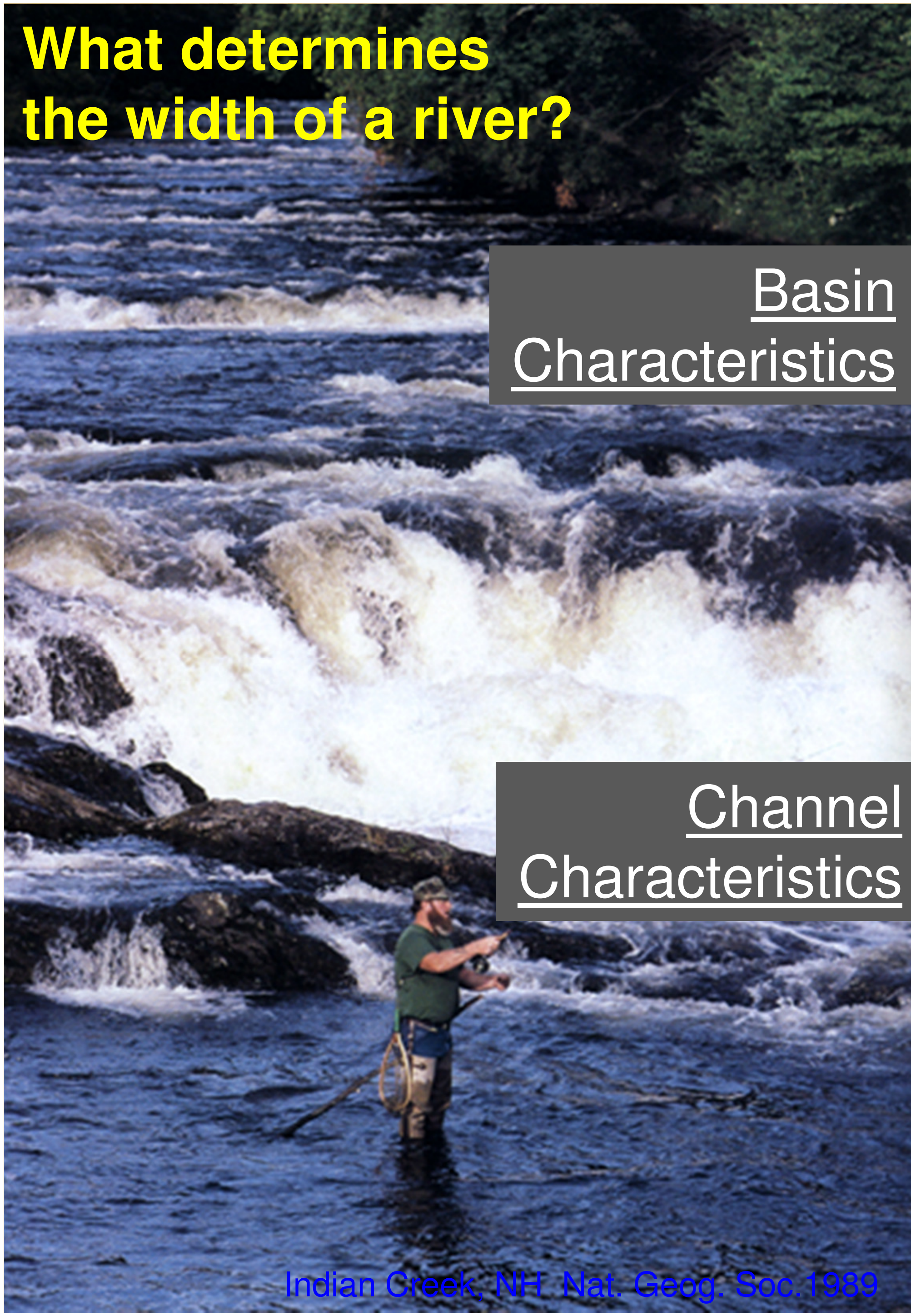


“Learn to read the land (river), and when you do
I have no fear of what you will do with it;
indeed, I am excited about what you will do for it.”

Aldo Leopold, 1966 A Sand County Almanac


HOW LAND USE CHANGE
CHANGES BANKFULL
Luther Aadland

What determines the width of a river?


Indian Creek, NH. Nat. Geog. Soc.1989

Basin Characteristics 1 — 70%

- **Climate**
  - Rainfall and Snowmelt Occurrence reflected in the ANNUAL Water Cycle
- **Watershed Area**
- **Watershed Slope**
- **Sediment Supply**

Channel Characteristics 2 — 30%

- **Valley Width & Shape**
- **Channel Slope**
- **Sediment Type**
  - Clay, Silt
  - Sand, Gravel
  - Cobble, Boulder
  - Bedrock
- **Bank Vegetation**

3 — 50%

- **Land Use**
- **Channel Obstacles**
  - Trees, Dams
  - Culverts, Roads

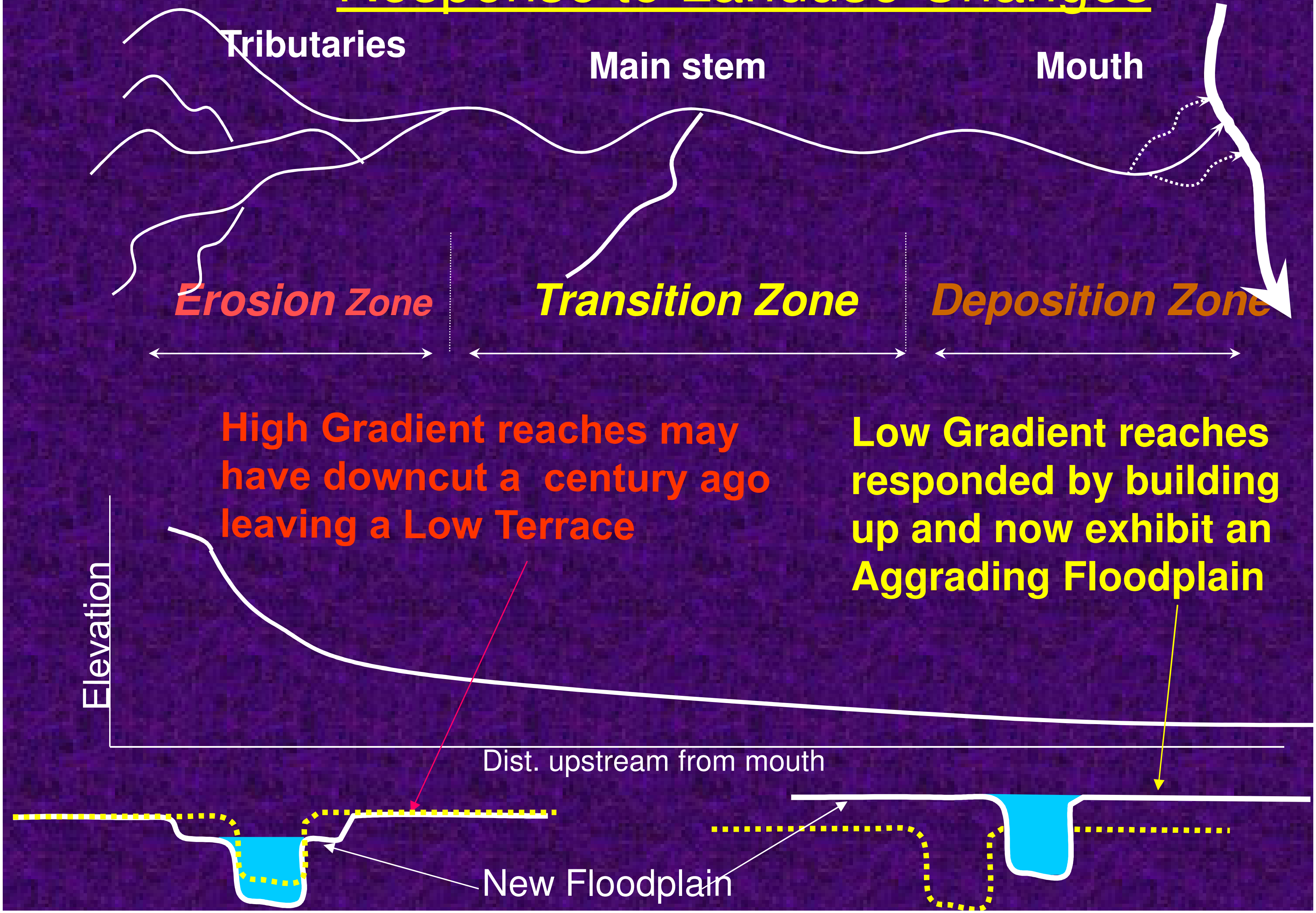
How to Read the River & the Land

- Water that just fills the channel and begins to overflow on its floodplain is the Bankfull Flow

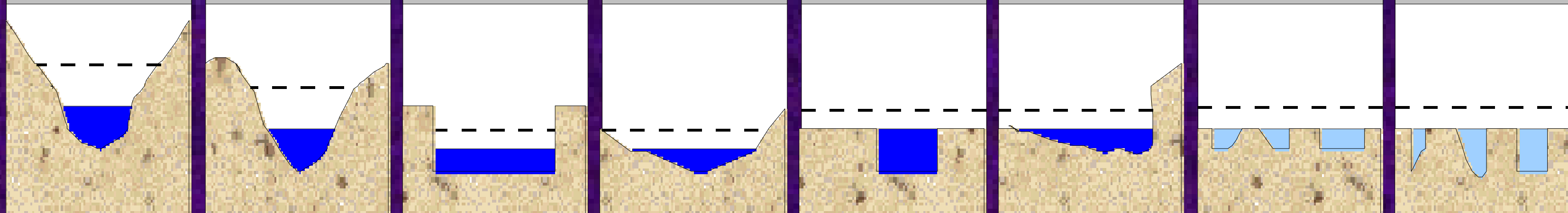
- At Bankfull flow, water velocity is high enough to move sediment in the channel bottom, yet low enough to allow fish migration during spawning.

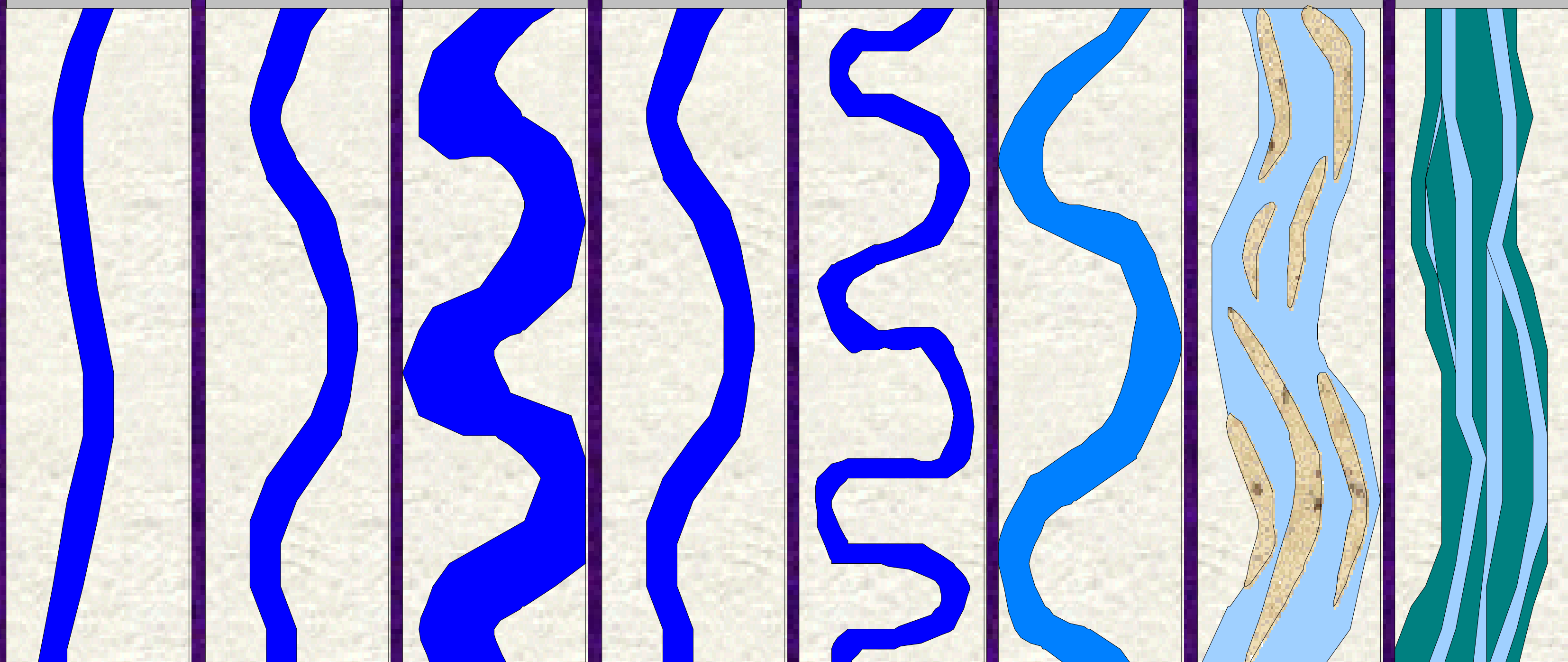
- Land Use Change changes the magnitude of bankfull flow
- Mechanisms that allow LU Change to Impact Streams
- How Much LU Change on What Size Basin

Response to Landuse Changes



	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
Dimension								
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
Pattern								
Slope (%)	10 - 4	4 - 2	4 - 2	4 - <2	2 - <2	2 - <.1	2 - <.1	<.5
[illegible]	A						D	





Stream Stability

- The ability of a stream to maintain, over time, its Dimension, Pattern, and Profile
- So it neither aggrades nor degrades
- And is able to transport, without adverse effect, the flows and detritus of its watershed

Physical Cause May Include:

- Lowering of a larger order channel
- Cutting off meander bends to align culverts
- Straightening channels to pass floods quicker
- Blocking or using too much of the floodplain
  – Deep road fills with too small culverts
  – Broad road bases paralleling the stream
- Excessive removal of large woody debris
- Changes in land use

Unstable Streams Don’t Like Their Type

Unstable streams deviate from the mode of their class
They are in the process of changing from one type to another

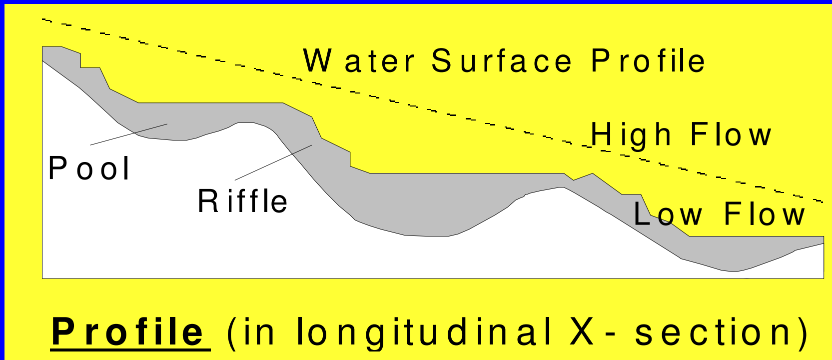
Modal Stream Dimension Values for Stable Streams in the Eastern US

Stream Type	A	G	F	B	E	C	D	DA
W/D	7	7	20	20	8	24	50	40
Sinuosity	1.1	~1.5	1.5	~1.2	2.0	1.3	1.1	~1.2

Based on Annable 1995, Rosgen 1996, Stevens-Savory et al., 1998

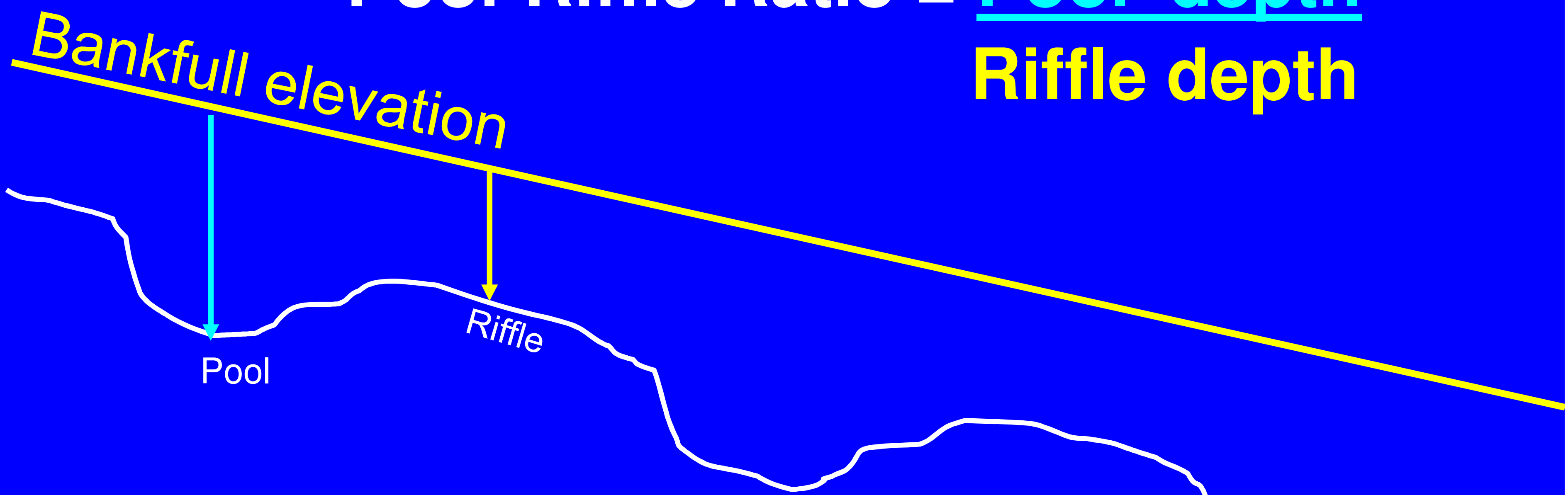
Look for unstable streams when W/D > +25% (C&E) or Sinuosity < -33% (F&E)

	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
Dimension								
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
Pattern								
Slope (%)	10 - 4	4 - 2	4 - 2	4 - <2	2 - <2	2 - <.1	2 - <.1	<.5
[illegible]	A						D	

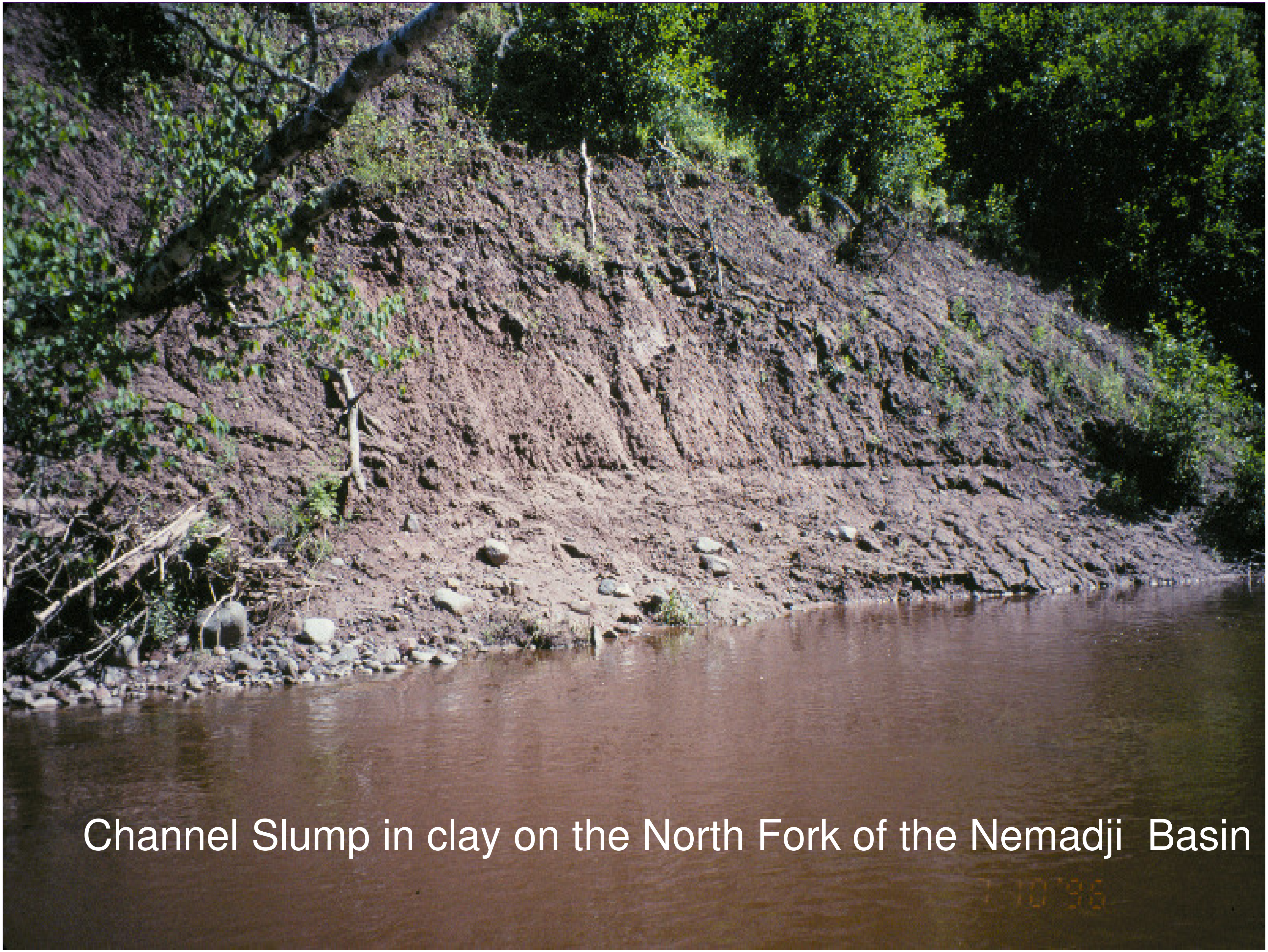


Better habitat has a Pool-Riffle Ratio Based on Maximum Depths of more than 1.4, 2.0 is better

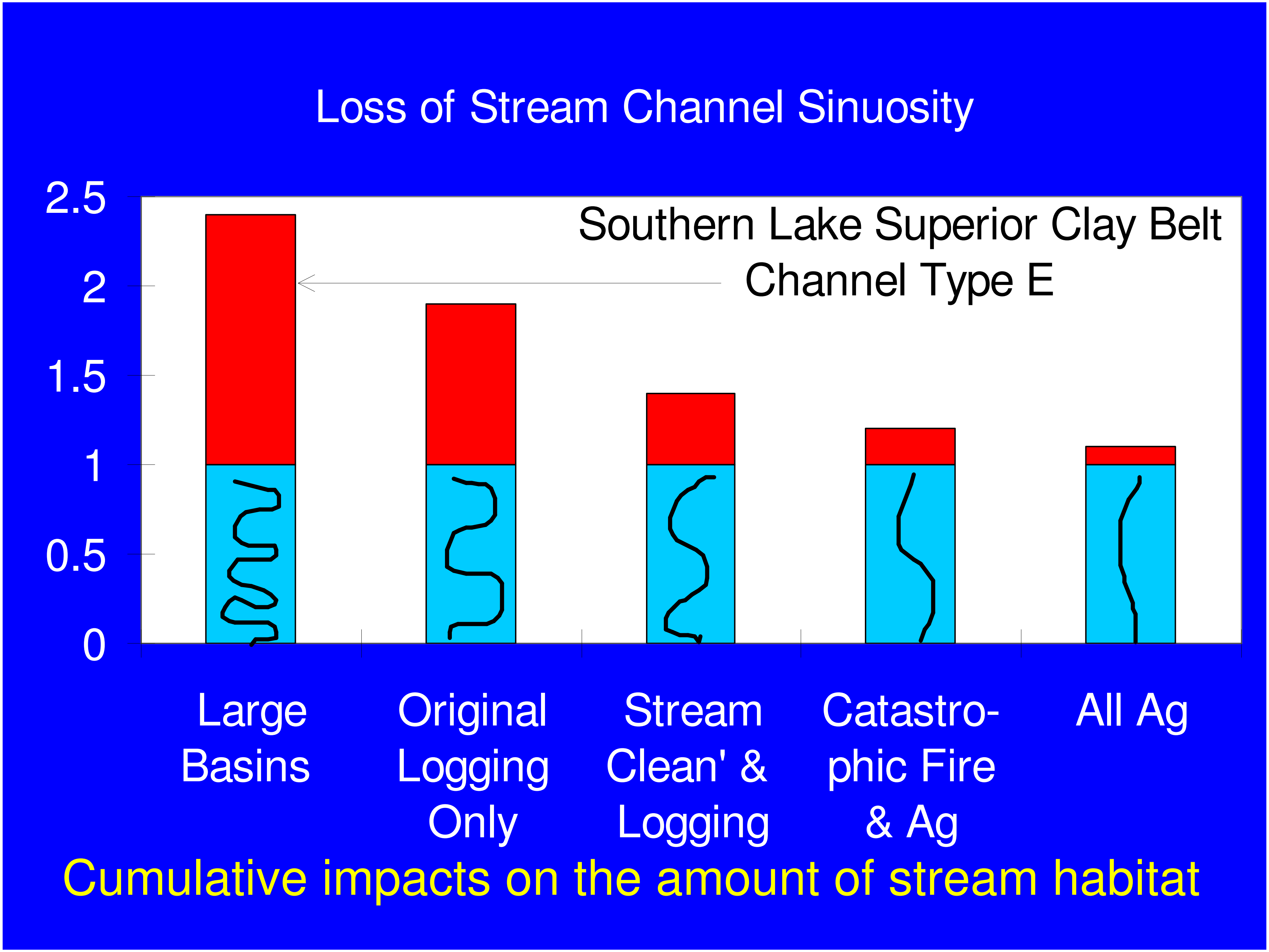
Pool-Riffle Ratio = Pool depth / Riffle depth



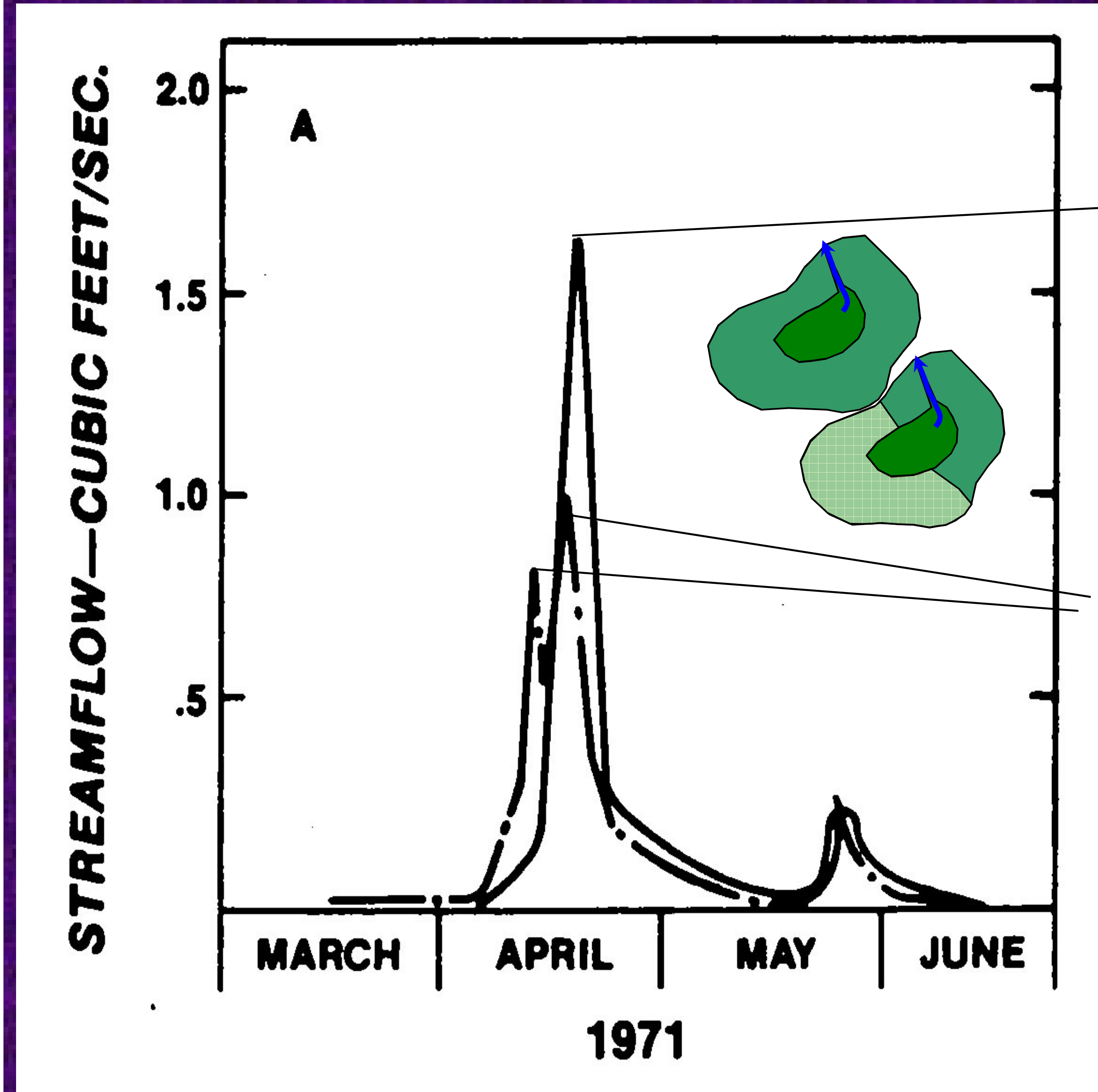
If you are using Mean Cross Sectional Depths
Look for a Pool-Riffle Ratio of 2 to 3 as desirable



Channel Slump in clay on the North Fork of the Nemadji Basin



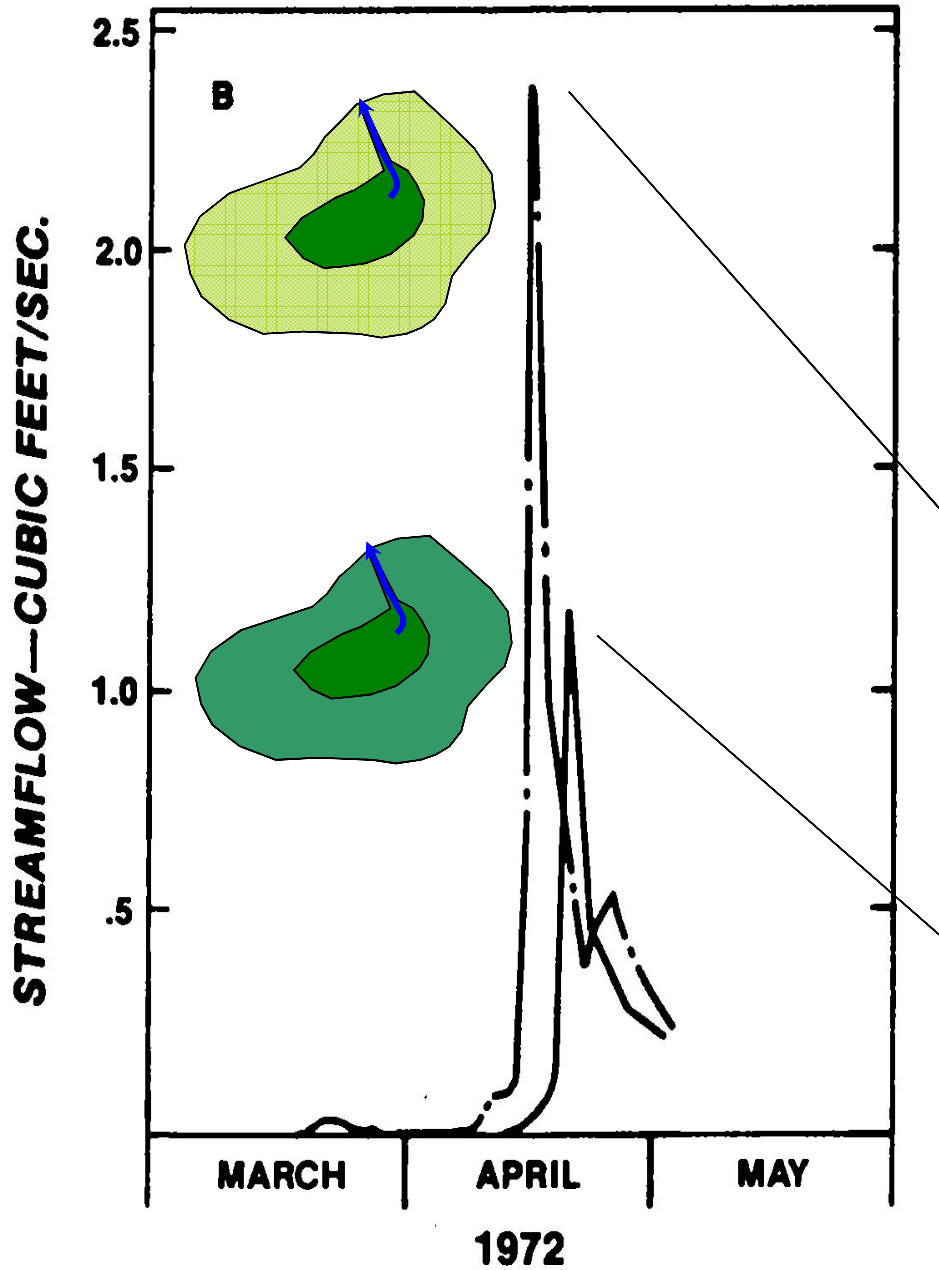
Loss of Stream Channel Sinuosity
2.5
2
1.5
1
0.5
0
Southern Lake Superior Clay Belt
Channel Type E
Large Basins
Original Logging Only
Stream Clean' & Logging
Catastro-phic Fire & Ag
All Ag
Cumulative impacts on the amount of stream habitat



Mature forest hydrograph

With 50% of the upland aspen forest clearcut, snowmelt peaks become de-synchronized yielding two smaller peak flows

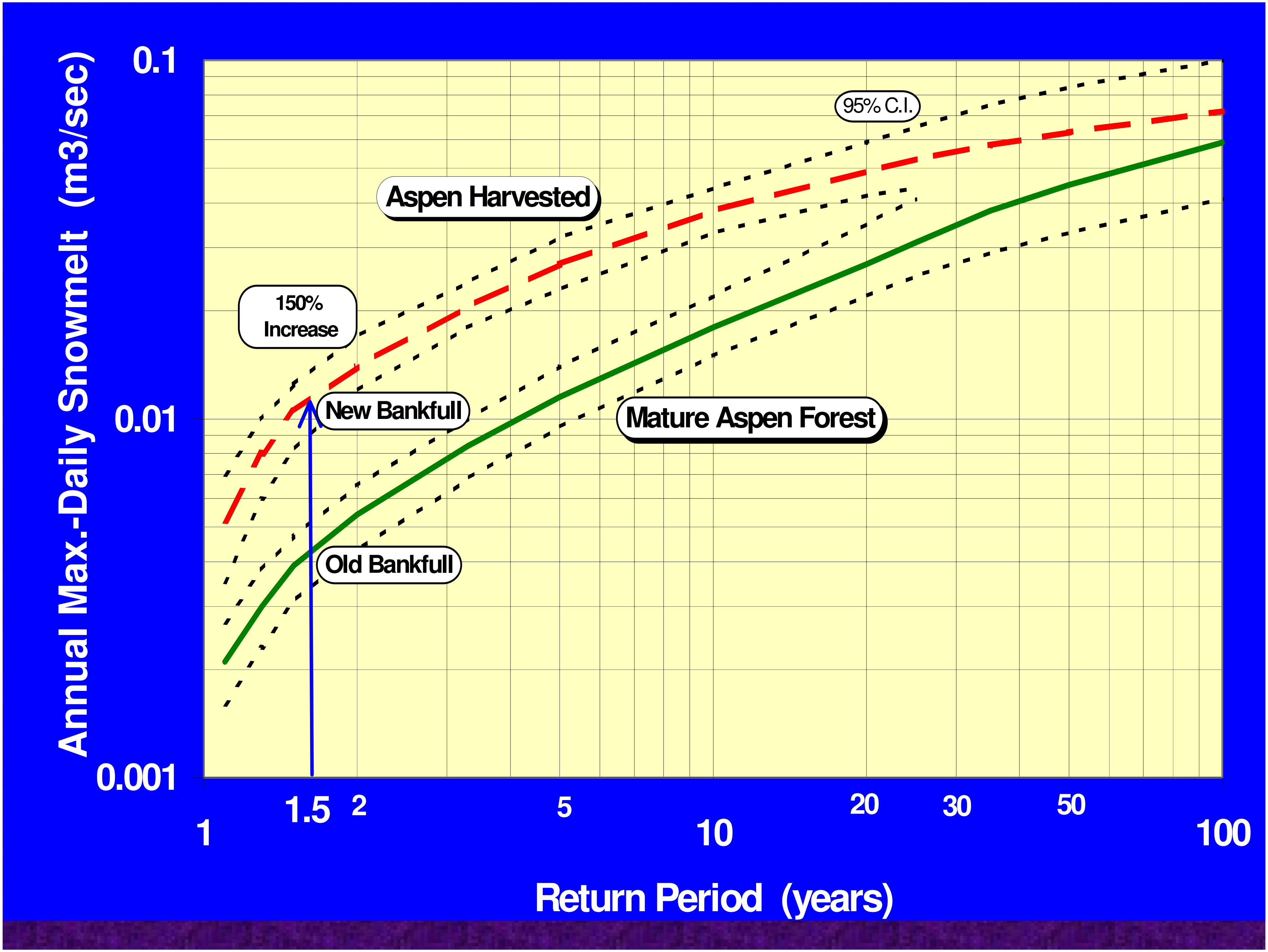
Marcell Experimental Forest, northern Minnesota, watershed no. 4

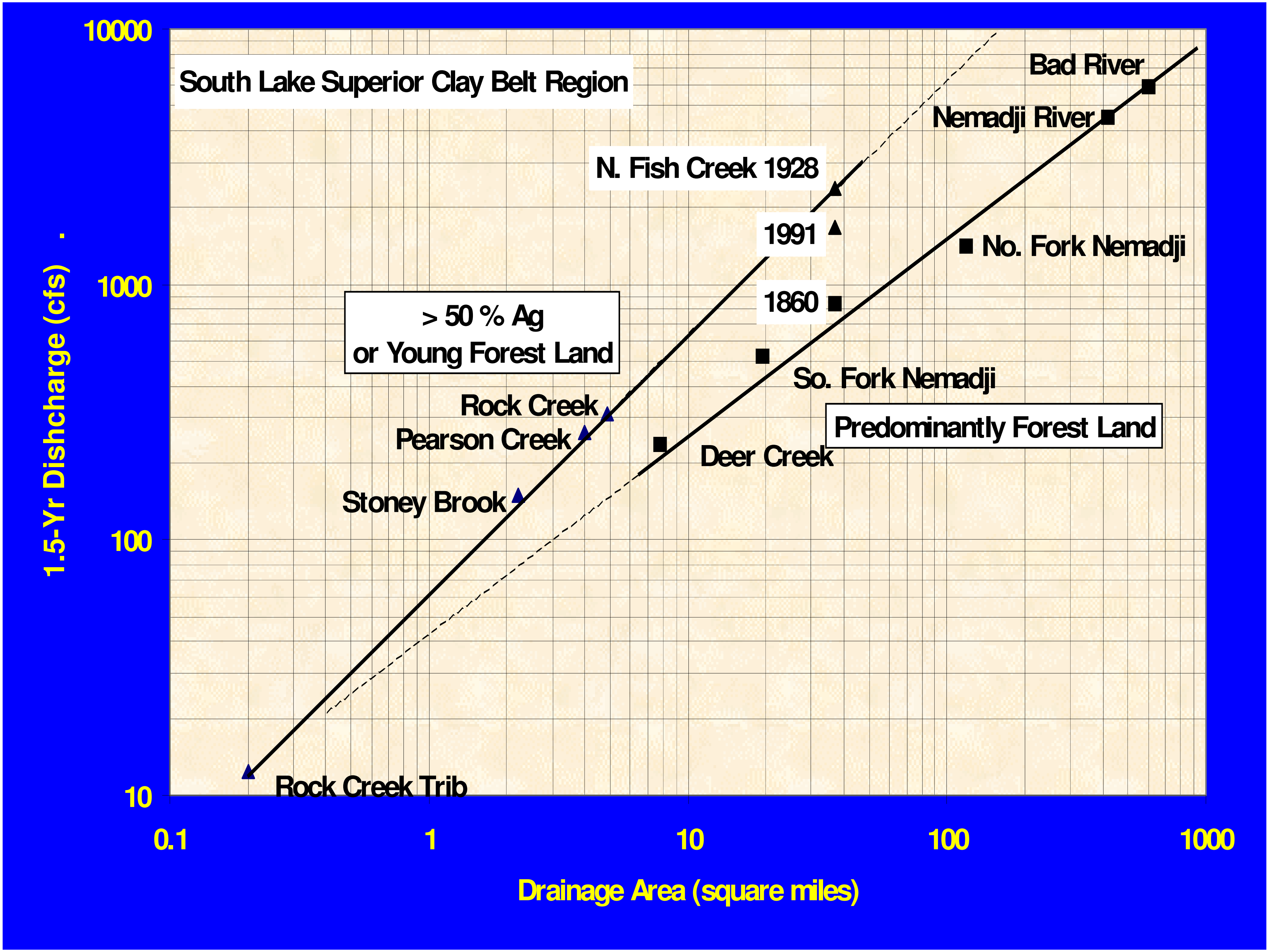


With all of the aspen upland clearcut, snowmelt peakflow is synchronized, occurring 4 days earlier than mature forest conditions, and at twice the peakflow rate.

Mature forest hydrograph

Marcell Experimental Forest, northern Minnesota, watershed no. 4


Annual Max.-Daily Snowmelt (m3/sec)
0.1
0.01
0.001
95% C.I.
Aspen Harvested
150% Increase
New Bankfull
Mature Aspen Forest
Old Bankfull
1
1.5
2
5
10
20
30
50
100
Return Period (years)



South Lake Superior Clay Belt Region
1.5-Yr Dishcharge (cfs)
10000
1000
100
10
0.1
1
10
100
1000
Drainage Area (square miles)
Bad River
Nemadji River
N. Fish Creek 1928
1991
1860
No. Fork Nemadji
> 50 % Ag
or Young Forest Land
So. Fork Nemadji
Rock Creek
Pearson Creek
Predominantly Forest Land
Deer Creek
Stoney Brook
Rock Creek Trib

Channel adjustments may occur in one storm, or they may take ½ to several centuries

In the North Fish Creek Basin near Ashland, Wisconsin

A headcut on the Nemaji River tributary

"The amount of channel sedimentation caused by land-cover changes over 125 years since European settlement is about equal to that caused mainly by an increase in base level change over 4,000 years before European settlement."
Fitzpatrick, Knox and Whitman, 1999

How much landuse change does it take to cause these changes ?

- Using a basin with all 15-year to 150-year aged forests as the normal condition

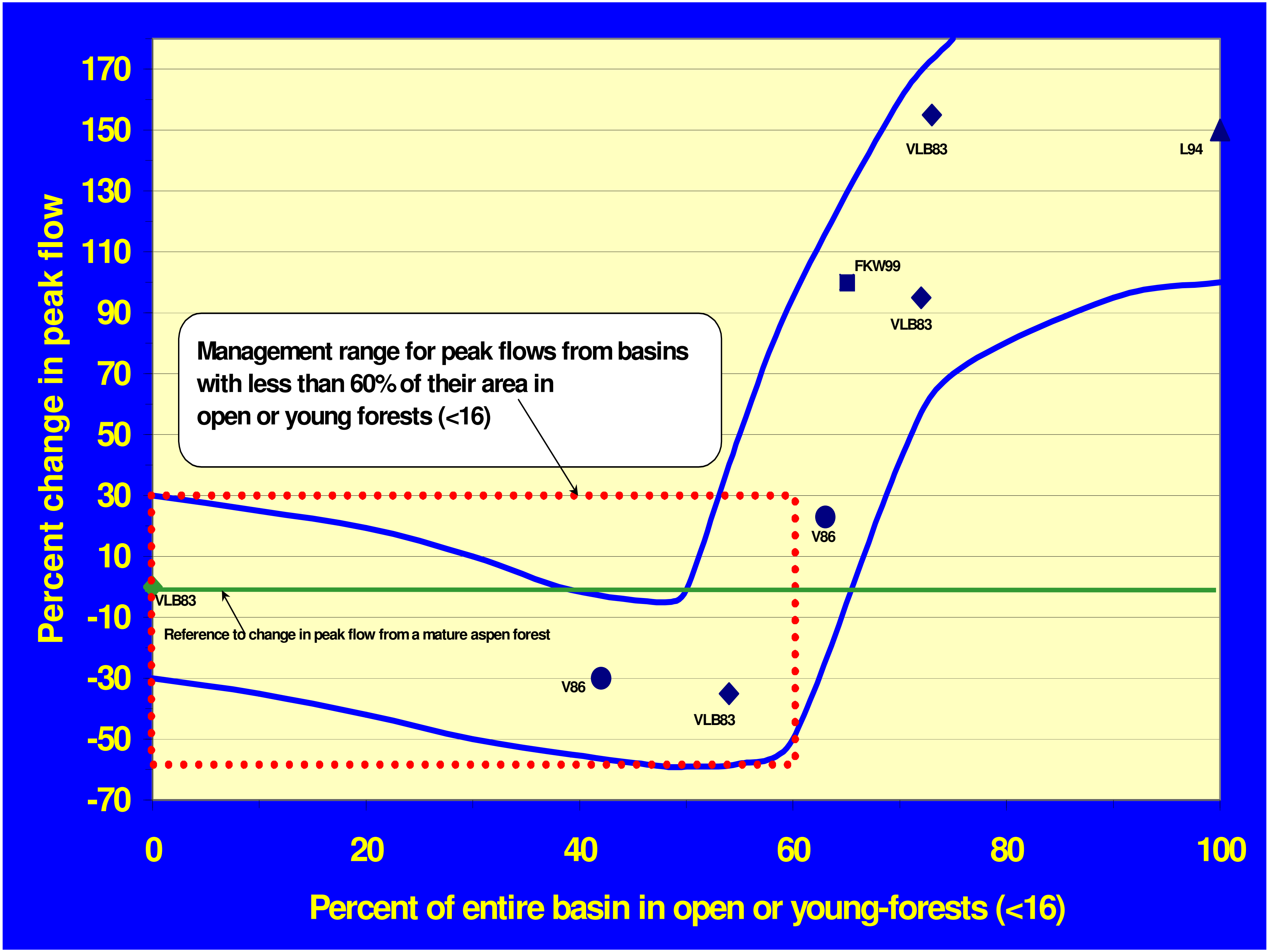
- Converting ½ the basin to agriculture would actually reduce bankfull flows about 20%

- Converting 2/3 of the basin to agriculture would double or triple bankfull flows

- Combinations of open land and young forest land (< 15 years old) does the same thing

How does this land use change work?

- The change is caused by more rapid snowmelt or by more rapid delivery of rain
- Either permanent conversion to open areas (agriculture, towns, roads, power lines, etc.) or high rates of forest harvest (more than 1 ½% per year)
- Will cause the bankfull flows that shape channels to double (or triple)

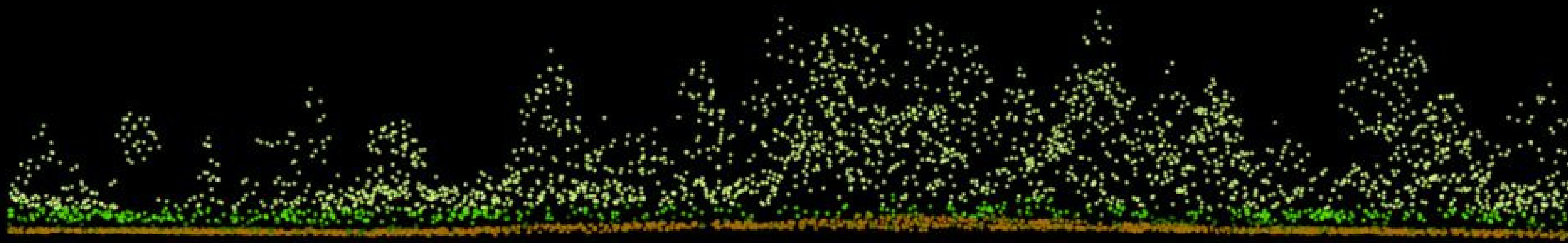


Percent change in peak flow
170
150
130
110
90
70
50
30
10
-10
-30
-50
-70
0
20
40
60
80
100
Percent of entire basin in open or young-forests (<16)
Management range for peak flows from basins with less than 60% of their area in open or young forests (<16)
Reference to change in peak flow from a mature aspen forest
VLB83
L94
FKW99
VLB83
V86
VLB83
V86
VLB83

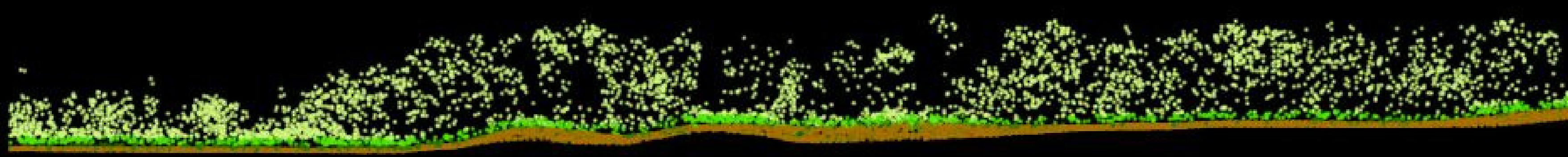
LIDAR hits

John Jereczek

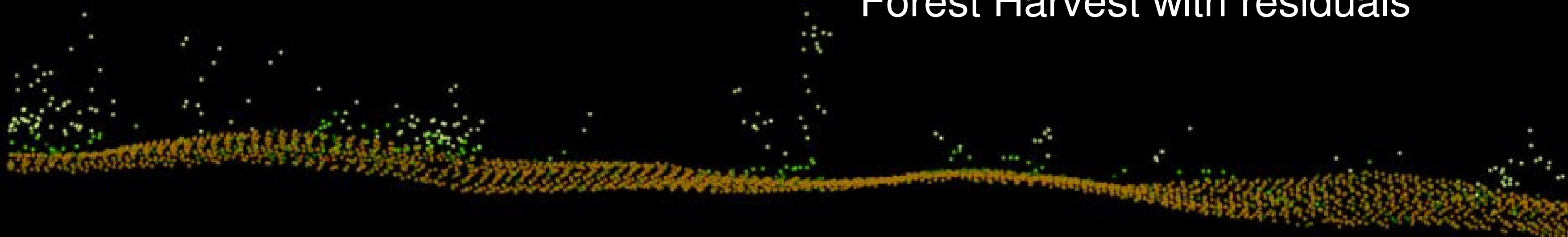
Conifer Forest



Deciduous Forest

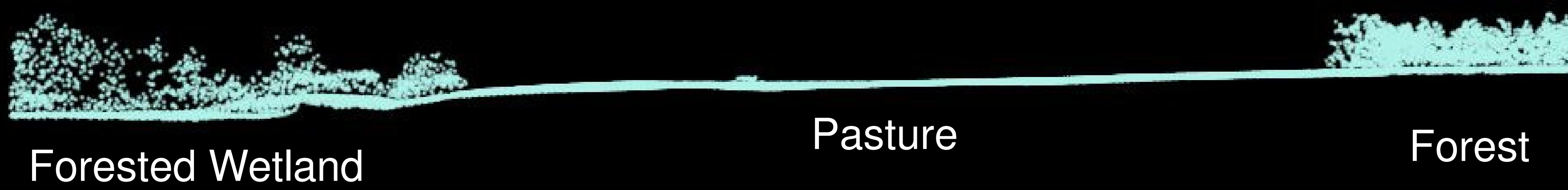


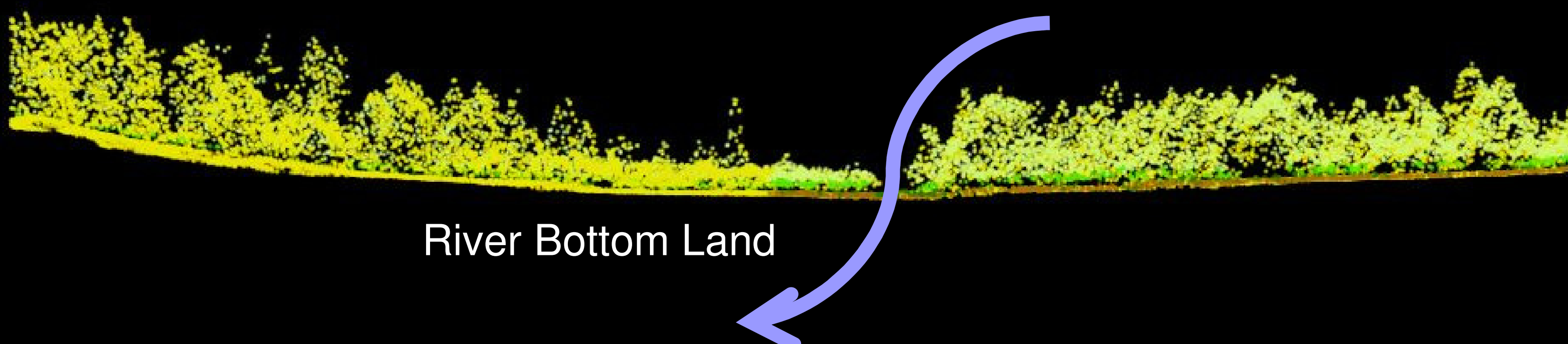
Forest Harvest with residuals

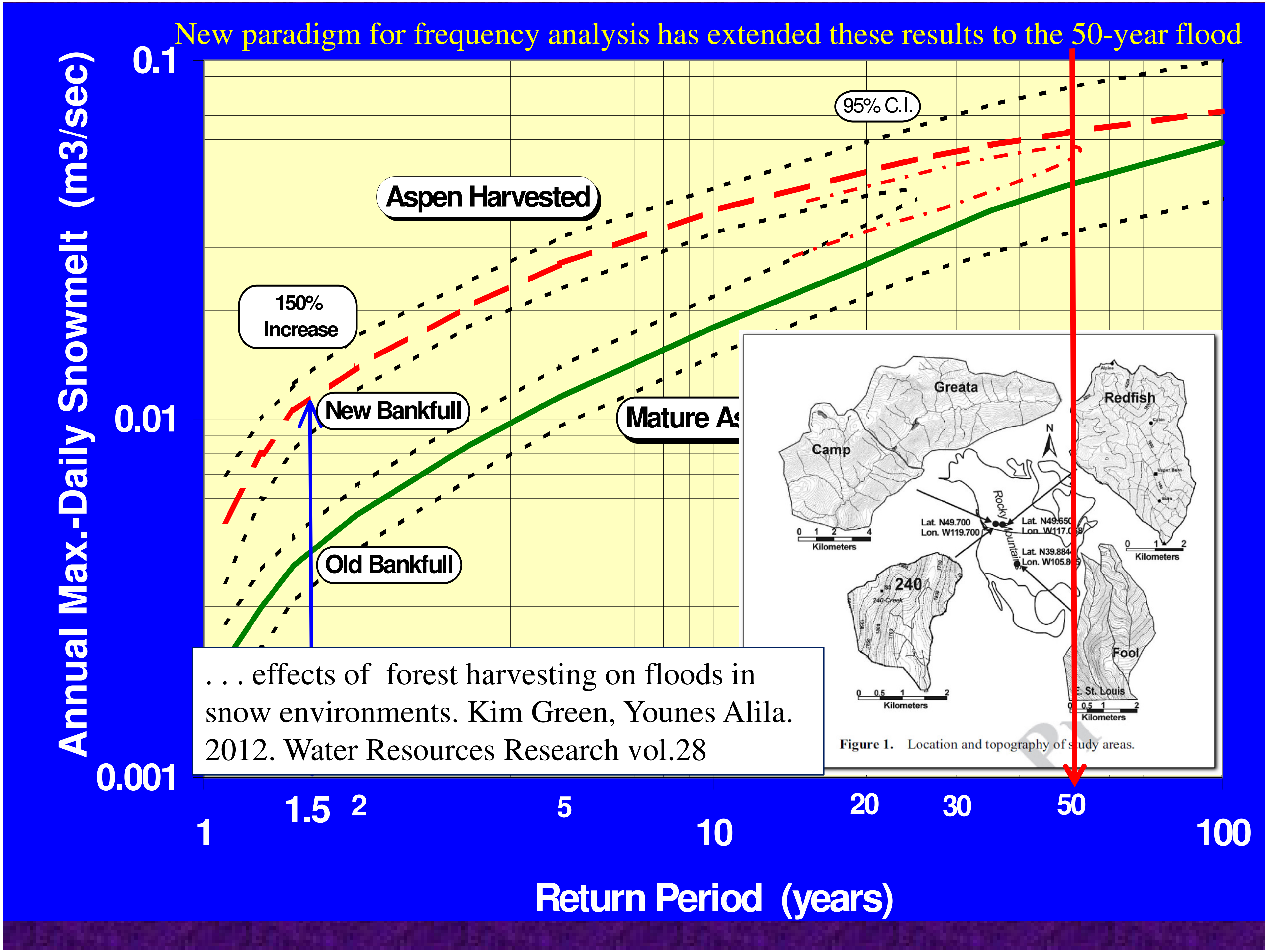


LIDAR hits

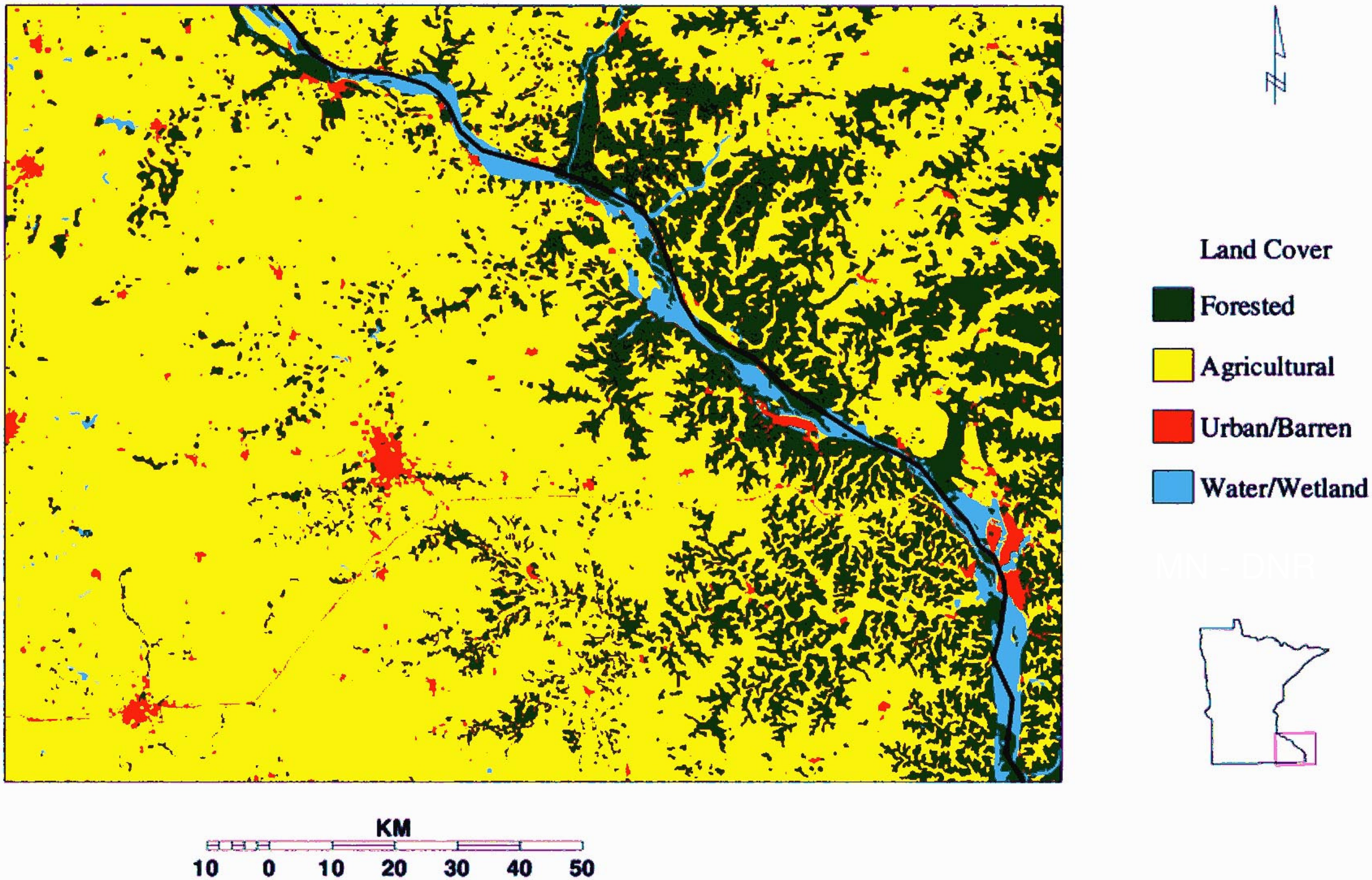
John Jereczek

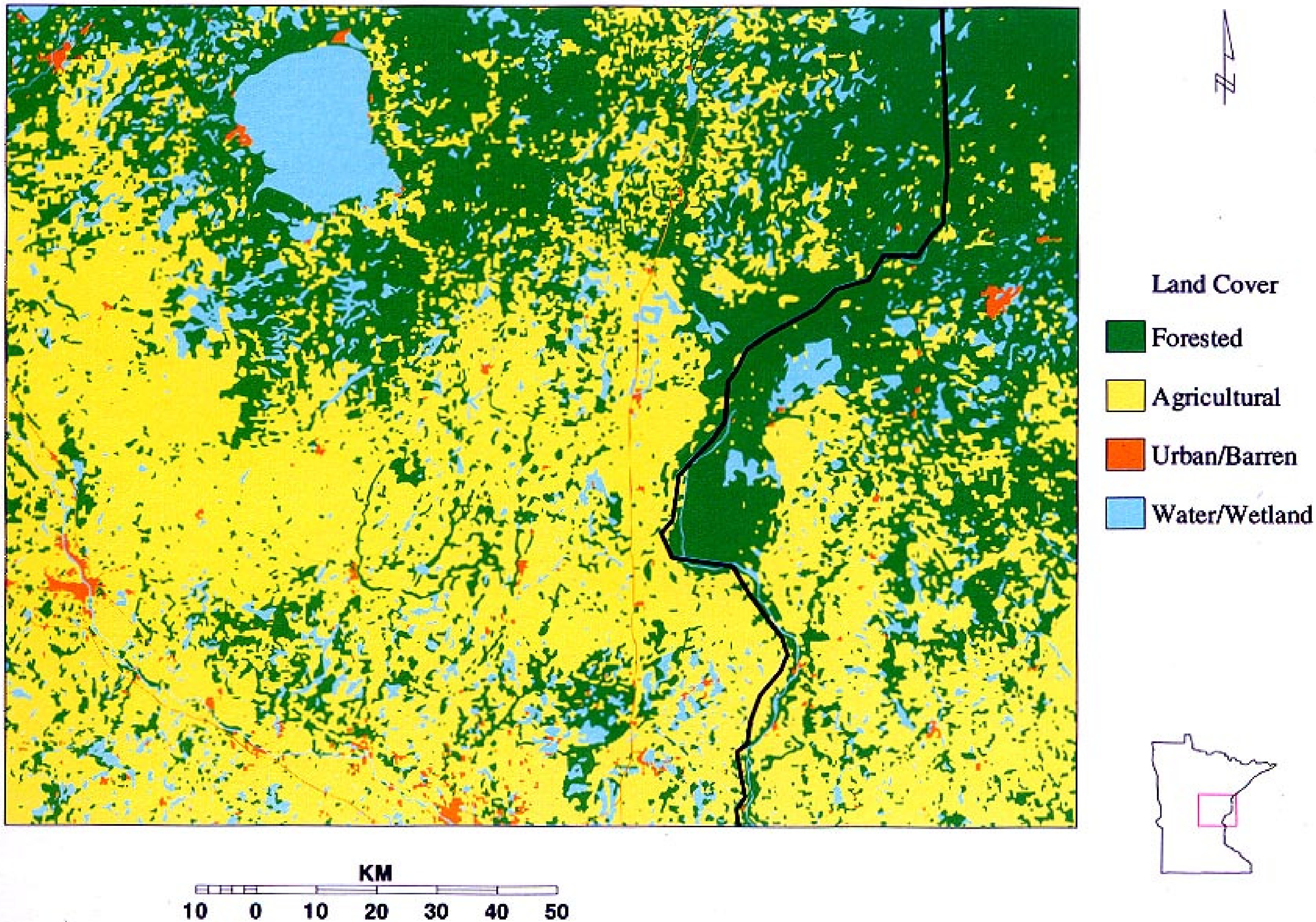




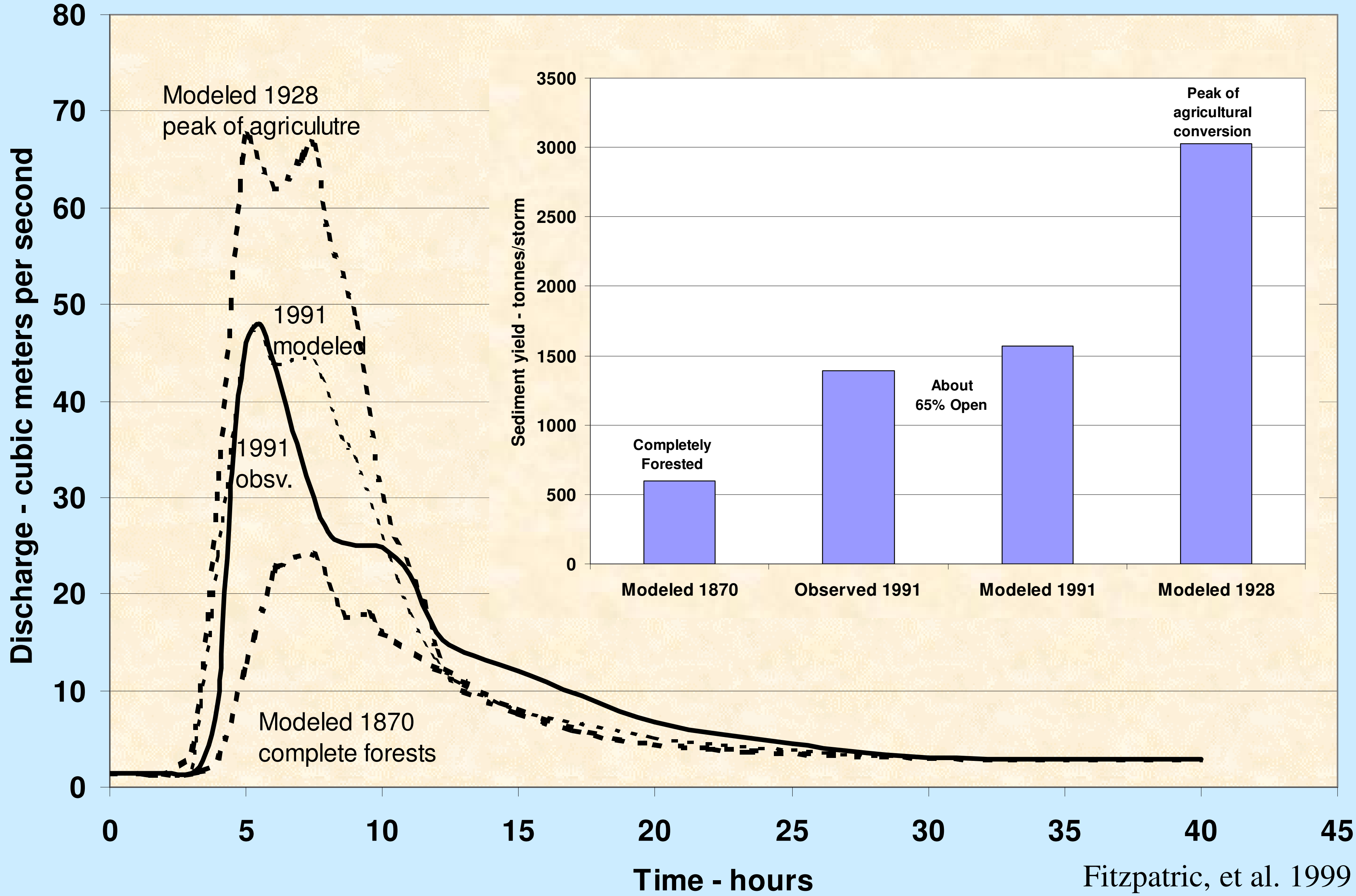

New paradigm for frequency analysis has extended these results to the 50-year flood
Annual Max.-Daily Snowmelt (m3/sec)
0.1
0.01
0.001
95% C.I.
Aspen Harvested
150% Increase
New Bankfull
Mature As
Old Bankfull
Greata
Redfish
Camp
Rocky Mountains
Lat. N49.700 Lon. W119.700
240
Fool
E. St. Louis
Kilometers
Figure 1. Location and topography of study areas.
1
1.5
2
5
10
20
30
50
100
Return Period (years)
. . . effects of forest harvesting on floods in snow environments. Kim Green, Younes Alila. 2012. Water Resources Research vol.28

Land Fragmentation in Southeast MN & Southwest WI




Land Cover
Forested
Agricultural
Urban/Barren
Water/Wetland
N
KM
10 0 10 20 30 40 50

North Fish Creek, near Moquah, WI

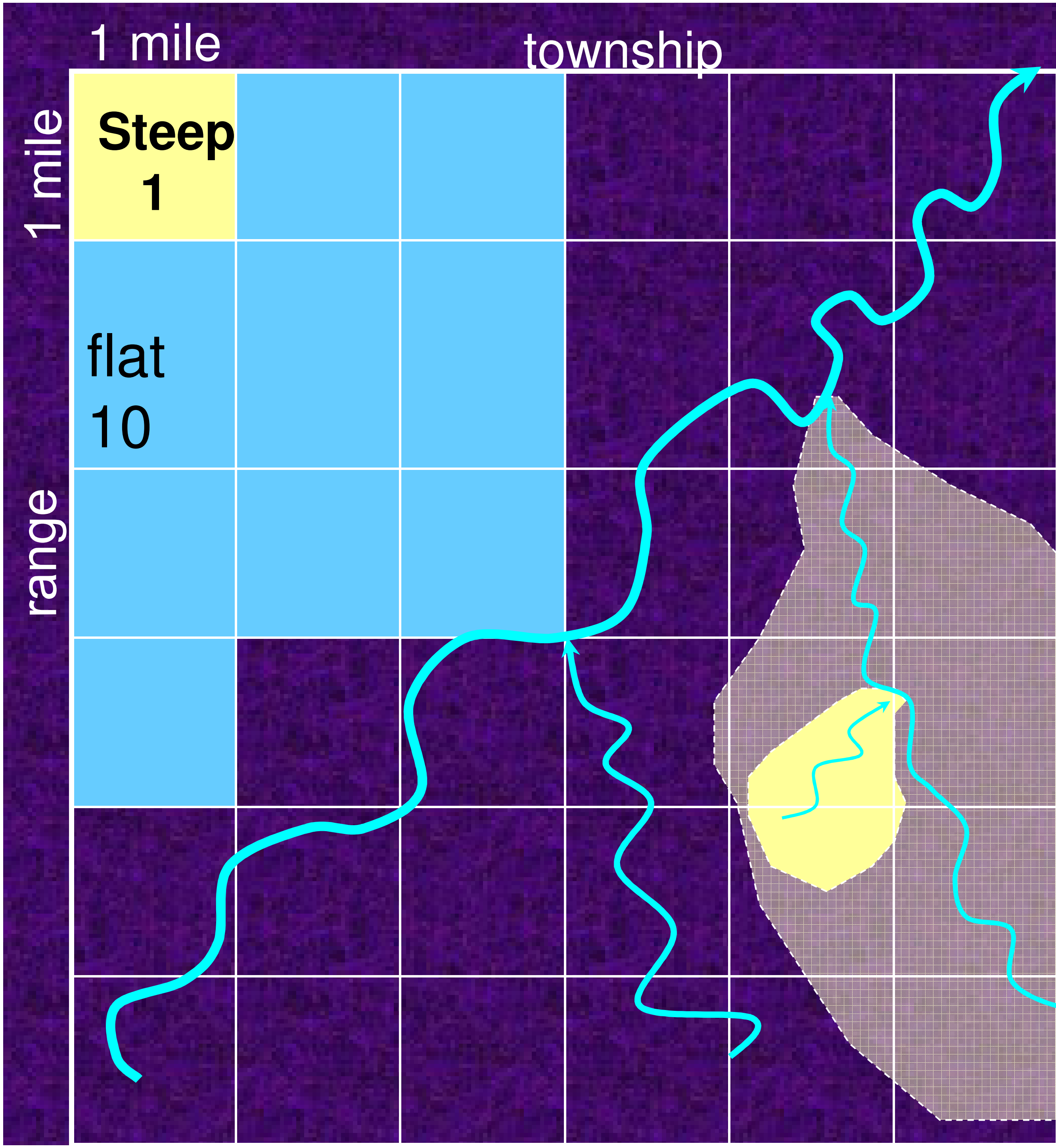


Fitzpatric, et al. 1999

On How Small of a Basin Will Land Use Change Actually Cause In-channel Erosion?

- For flat outwash or lake bed basins (< 3% slopes) they need to be 10 sq. Miles before there is enough power in the flowing water to cause excessive in-channel erosion

- For steep glacial moraine basins (3-40% hillslopes) they need to be 1 sq. Mile



Fragmentation of landscapes impacts bankfull flow at all scales

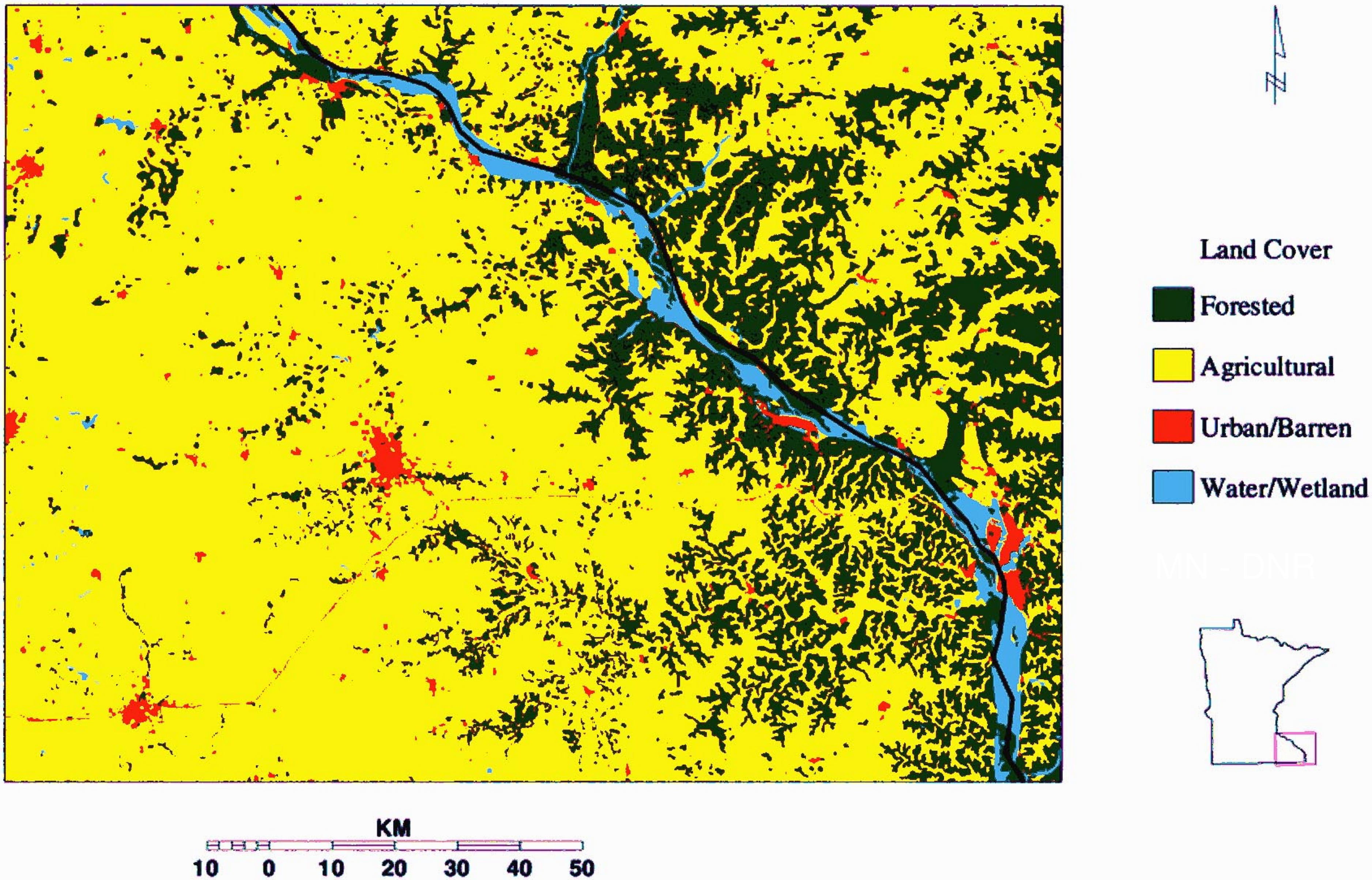
Causing changes in:
Sediment regime
Physical channel condition
Biota abundance
& diversity

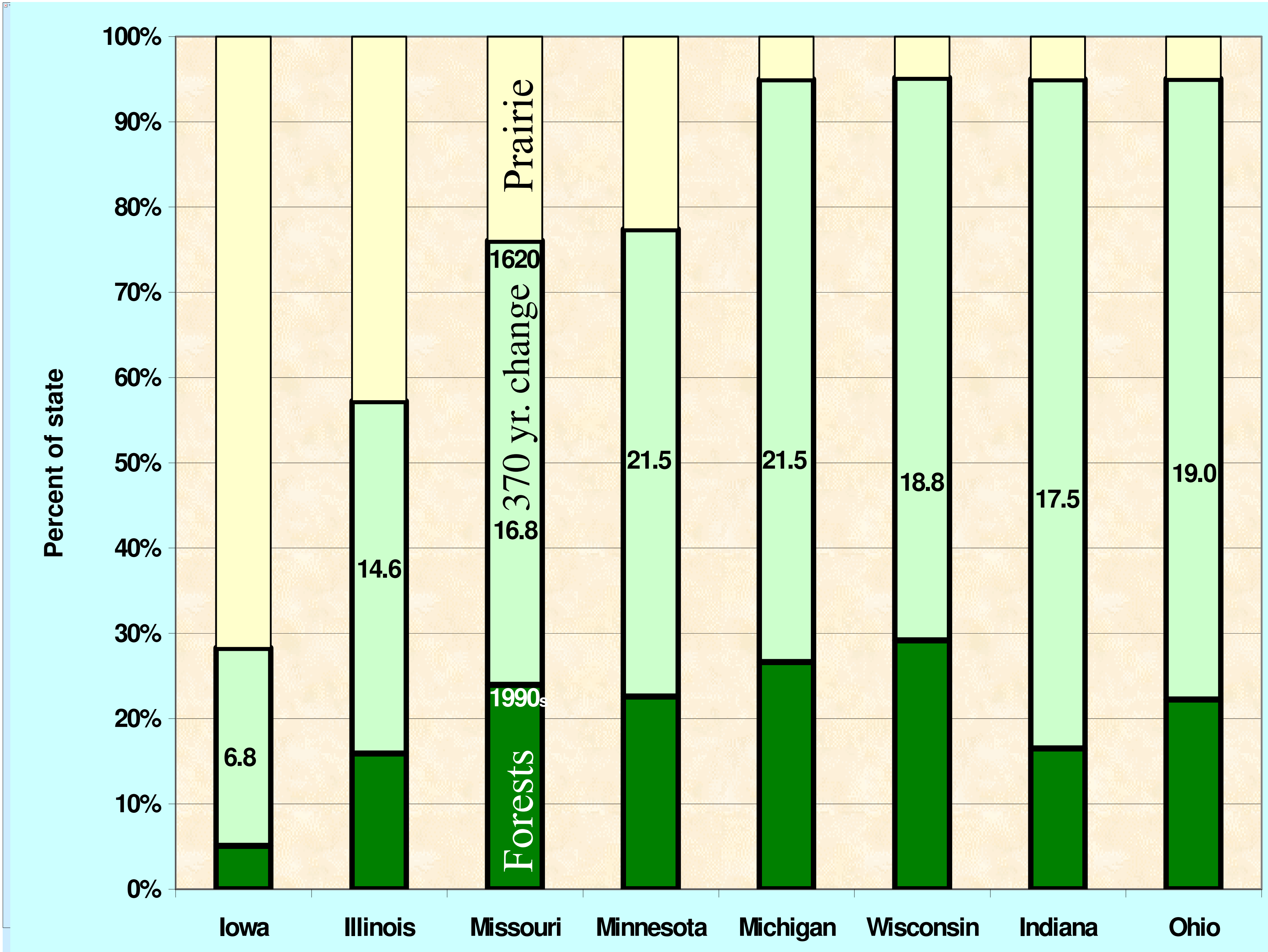

7 29 '97


7 29 '97

United States
except for Hawaii and Alaska
Canada
Mexico
Pacific Ocean
Atlantic Ocean
Gulf of Mexico
Lake Superior
Lake Michigan
Lake Huron
Lake Ontario
Lake Erie
Bahamas
Cuba
Tropic of Cancer
Key West
0 500 km
0 500 mi
120°
105°
90° W
75°
45°
30° N
WA
OR
ID
MT
WY
NV
UT
CA
AZ
CO
NM
ND
SD
NE
KS
OK
TX
MN
IA
MO
AR
LA
WI
IL
MI
IN
OH
KY
TN
MS
AL
GA
FL
SC
NC
VA
WV
PA
NY
VT
NH
ME
MA
CT
RI
NJ
DE
MD
Olympia
Seattle
Spokane
Portland
Salem
Eugene
Boise
Helena
Bismarck
Fargo
Pierre
Cheyenne
Carson City
Sacramento
San Francisco
Salt Lake City
Denver
Los Angeles
San Diego
Phoenix
Tucson
Santa Fe
Albuquerque
El Paso
Omaha
Lincoln
Topeka
Kansas City
Jefferson City
Oklahoma City
Tulsa
Dallas
Austin
San Antonio
Houston
Corpus Christi
Duluth
Minneapolis
St. Paul
Des Moines
Madison
Milwaukee
Chicago
Springfield
St. Louis
Little Rock
Memphis
Baton Rouge
New Orleans
Jackson
Birmingham
Montgomery
Nashville
Frankfort
Indianapolis
Columbus
Lansing
Detroit
Cleveland
Charleston
Atlanta
Tallahasse
Jacksonville
Tampa
Miami
Columbia
Raleigh
Richmond
Norfolk
Washington, D.C.
Annapolis
Dover
Philadelphia
Harrisburg
Trenton
New York
Hartford
Providence
Boston
Concord
Albany
Montpelier
Augusta

Land Fragmentation in the Central and Upper Midwest Impacts to Streams and Fish





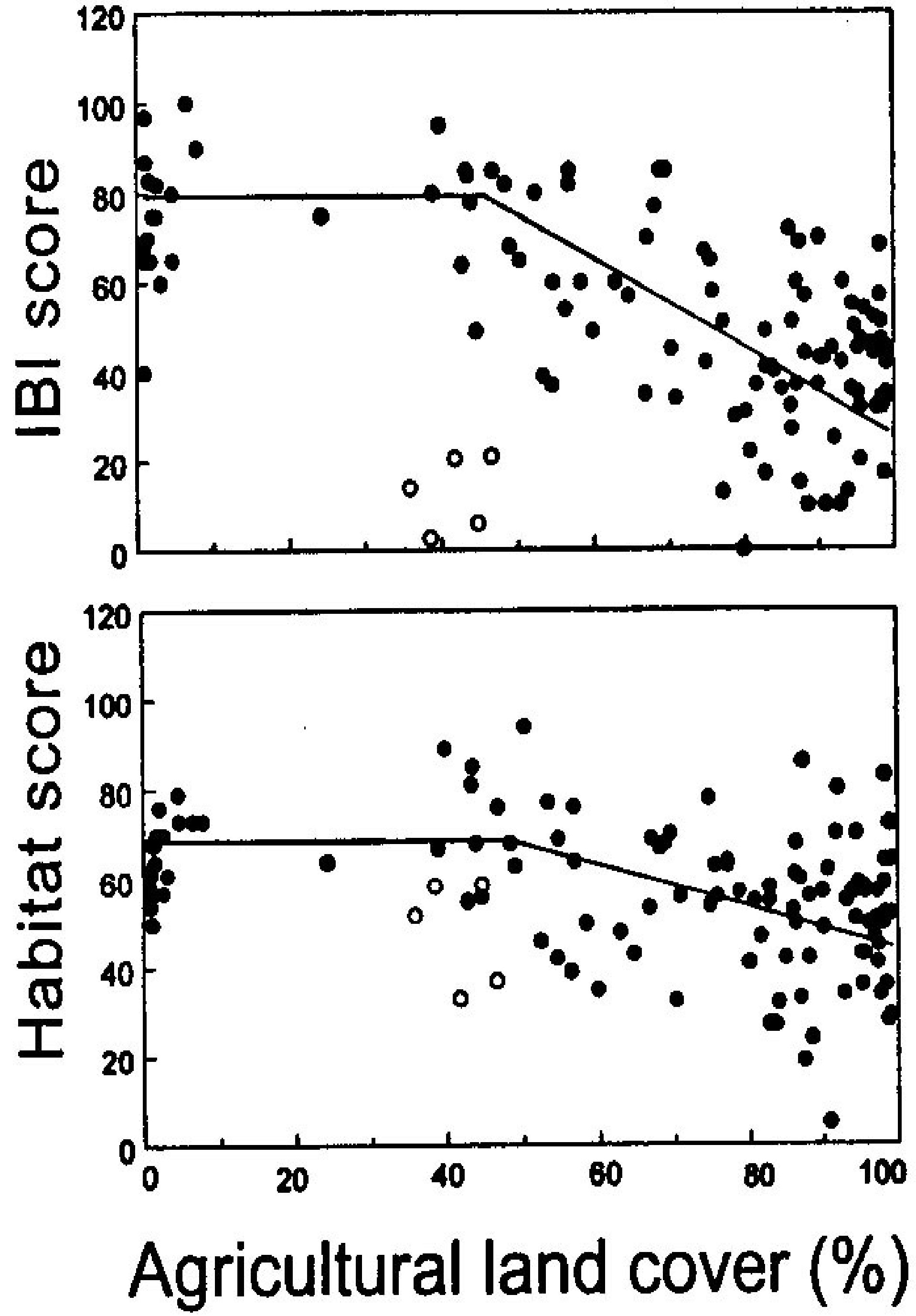
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Percent of state
Prairie
1620
370 yr. change
1990s
Forests
6.8
14.6
16.8
21.5
21.5
18.8
17.5
19.0
Iowa
Illinois
Missouri
Minnesota
Michigan
Wisconsin
Indiana
Ohio

Increases in rainfall & snowmelt bankfull flow may be caused by low infiltration rates (inches/hour)

Location & Soil	Mature Forests	High Compaction Harvest
Lower MI Sands	10	2
Northern MN Sandy Loam	5	0.2
Upper MI Clays	2	0.001

Mungovern, 1996

WISCONSIN STREAMS



Wang, et al. 1997

Kankakee River (NE IL) small mouth bass populations

Years	Adult Bass/ha
1915 -1925	65
1977-1990	27
2060	9

Range in forested watersheds from literature: 84-146

Kwak, et al., 1999

Causes of Decline

- Primarily caused by increases in the mean discharge during the spawning/rearing period (the bankfull discharge rate)
- Climate warming and spawning/rearing air temperature increases had only minor effects
- Variability in winter discharge had only minor effects

Kwak, et al., 1999

Fragmentation of landscapes impacts bankfull flow at all scales

- Causing changes in
  - sediment regime (mostly in-channel generated)
  - physical channel condition
  - biota abundance and diversity

- Cover condition over the watershed, whether at the1000, 100, 10, or 1 sq.mile scale, yields similar changes in channels

Within Mostly Forested Lands

- Forest Roads are, by far, the largest impact to streams
  - Undersized and poorly placed culverts fragment fish communities
  - Fine sand from eroding road surfaces, especially at stream crossings degrades channel habitat

- Roads in Agricultural Lands can also have large impacts to stream channels

DO NOT use Entrenchment Ratio Key Breaks For Floodplain Design Criteria !

Instead Use:

1. Average Floodplain Width Measured along several miles of valley
2. Minimum Floodplain Width Measured along several miles of valley

Verry

3. 10 times Bankfull Channel Width
   doing more really doesn't help with valley flood flows or improve channel habitat quality

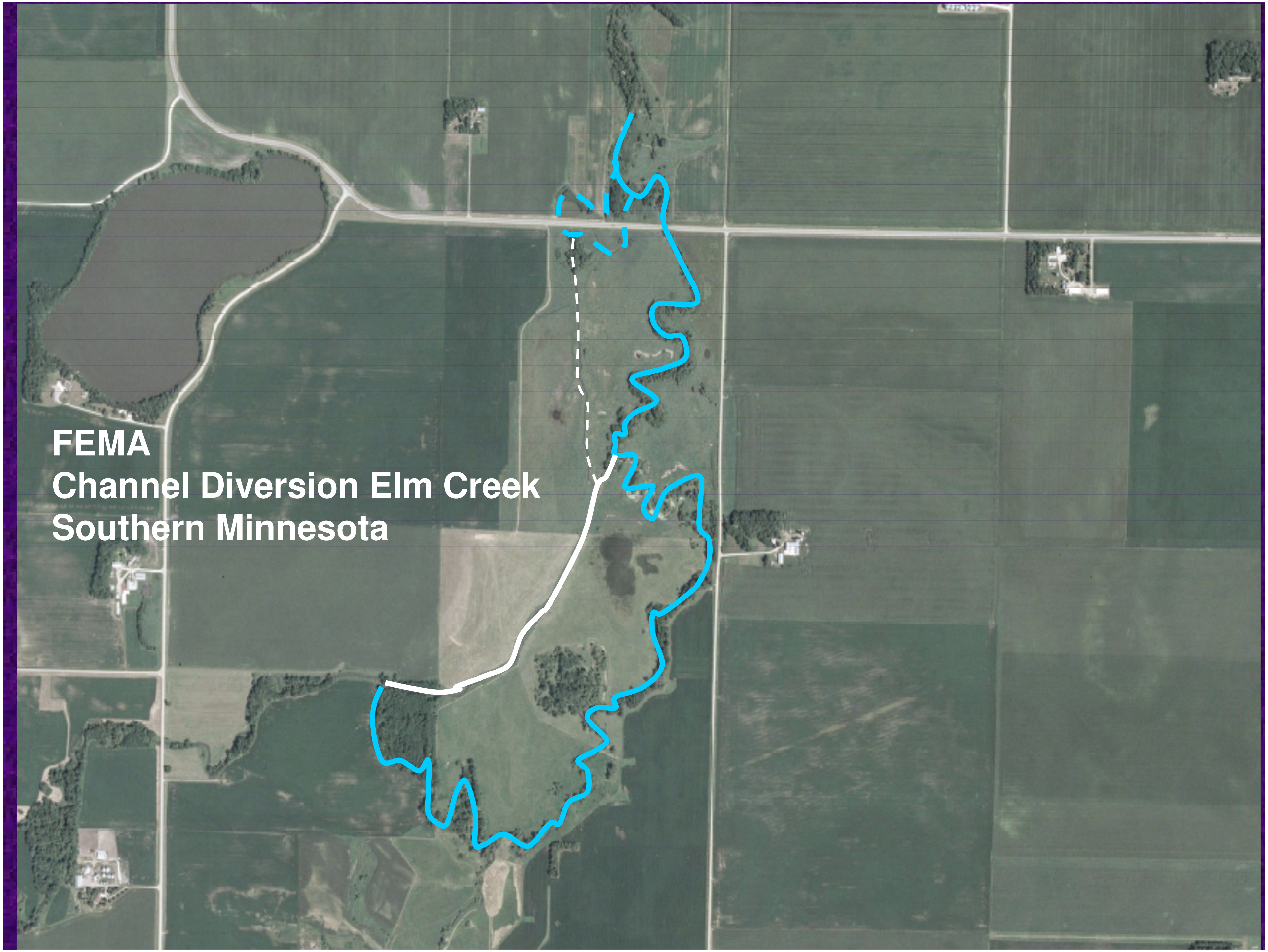
4. 5 times Bankfull Channel Width
   maintains most but not all channel habitat qualities and reduces flood capacity

5. 3 times Bankfull Channel Width
   absolute minimum; any thing less results in degraded channel habitat and inability to maintain a stable floodplain form (channel cut offs, headcutting, degradation, aggradation channel widening)

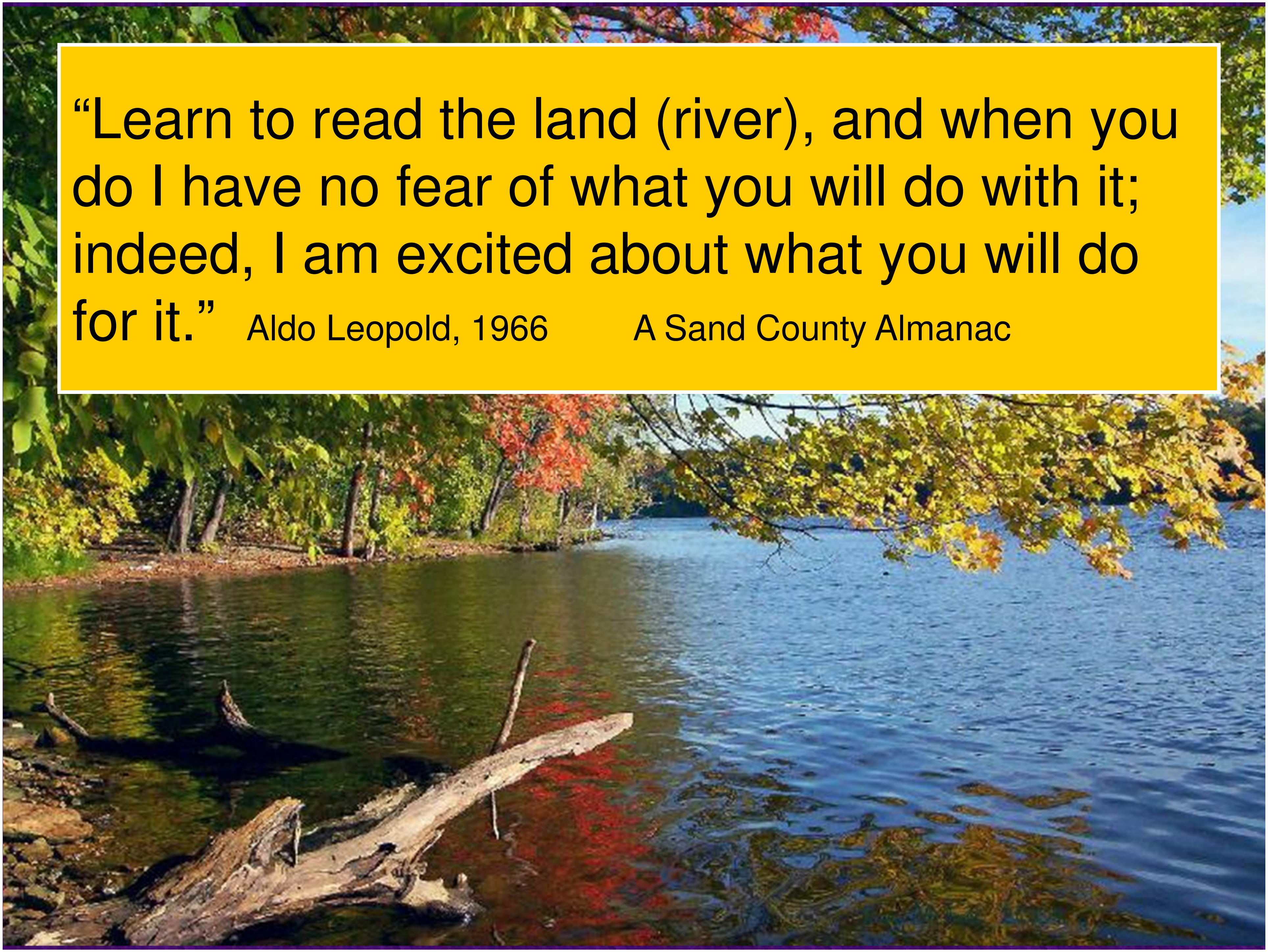
Mathews, 2006 ODNR
& additional criteria using
drainage area. Appendix 7

Bridge and meander cutoff put in in 1982


Highway 15 North of Fairmount, Minnesota
Elm Creek Cutoff


FEMA
Channel Diversion Elm Creek
Southern Minnesota


Loss of
Riparian
Vegetation



"Learn to read the land (river), and when you do I have no fear of what you will do with it; indeed, I am excited about what you will do for it." Aldo Leopold, 1966 A Sand County Almanac