THE CHANNEL EVOLUTION MODEL (CEM), CHANNEL INCISION, ENVIRONMENTALLY COMPATABLE GRADE CONTROL,

GC BUT NO BANK STABILIZATION,

& SYSTEM-WIDE GC

MY PERSONAL HEADCUT WORKING ITS WAY TOWARD MY HOUSE

SETTING THE STAGE FOR THE HARTMAN DITCH HEADCUT VIDEO

Note height of soil. THIS STARTED THE EXCITEMENT!!!

CONSTRUCTION – HARTMAN DITCH-REACH #1 - DERRICK 9-20-2012

Headcut moved upstream & underneath the bridge in minutes!

CONSTRUCTION – HARTMAN DITCH-REACH #1 - DERRICK 9-20-2012

SHOW THE HARTMAN DITCH HEADCUT VIDEO

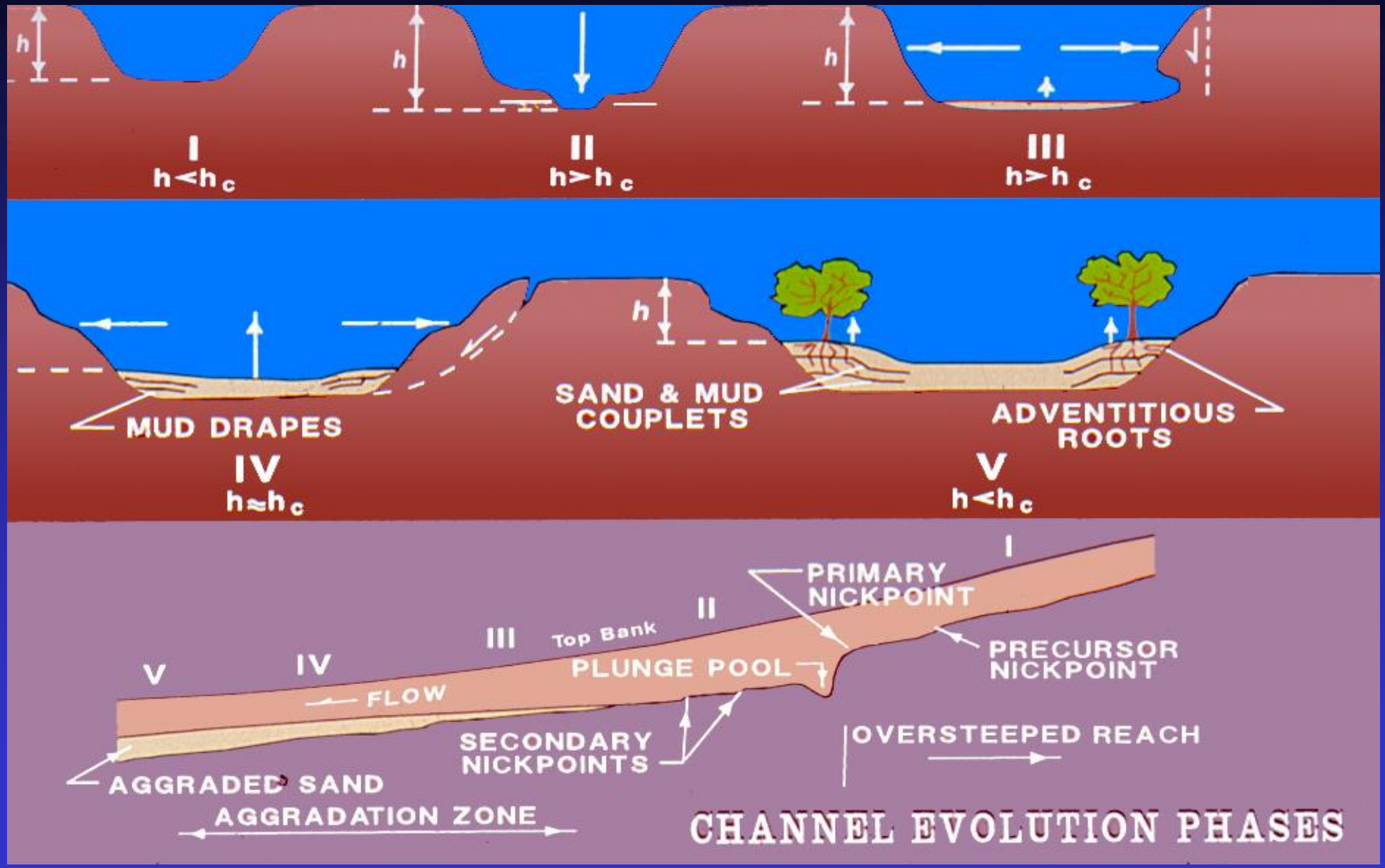
Channel Evolution Model (Schumm, et al. 1984)

Originally developed to describe erosion evolution of Oaklimiter Creek, Calhoun City/Derma, MS.

A location-time substitution conceptualization is used to generate a five-reach type incised channel evolution model

In an idealized stream Types I-V will occur in sequence (series)

Channel Evolution Model

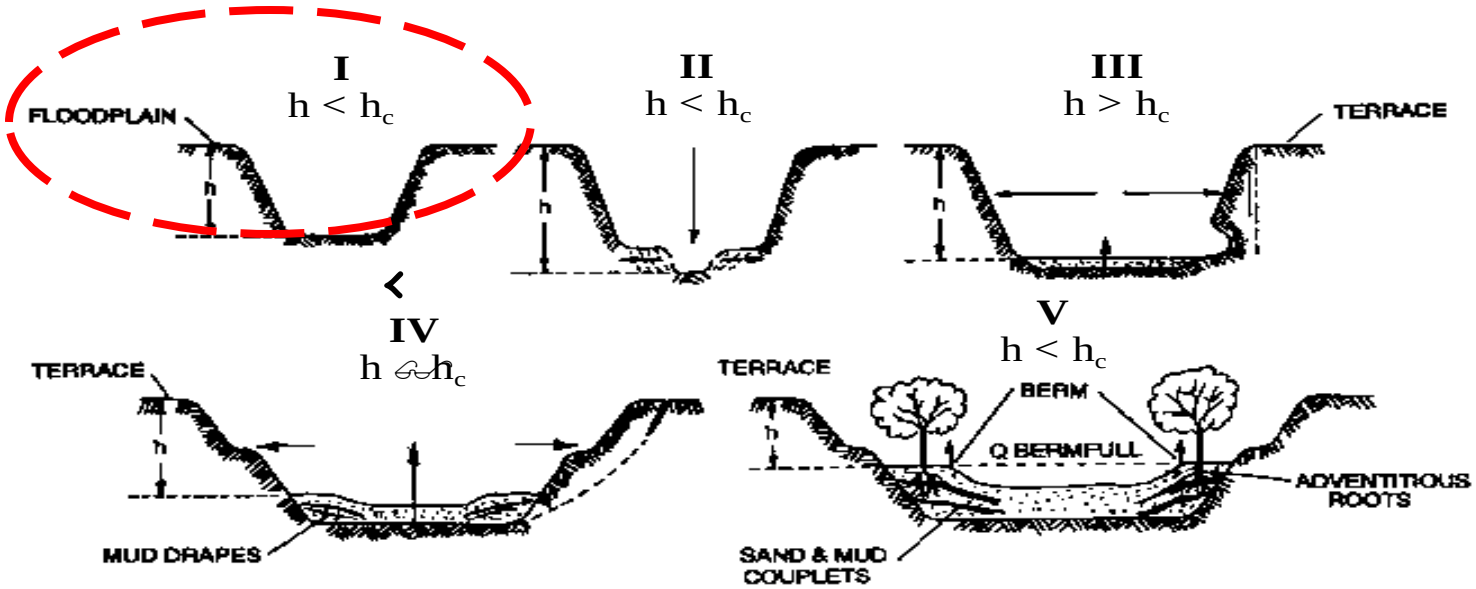


Channel Evolution Model
Type I Reach Characteristics

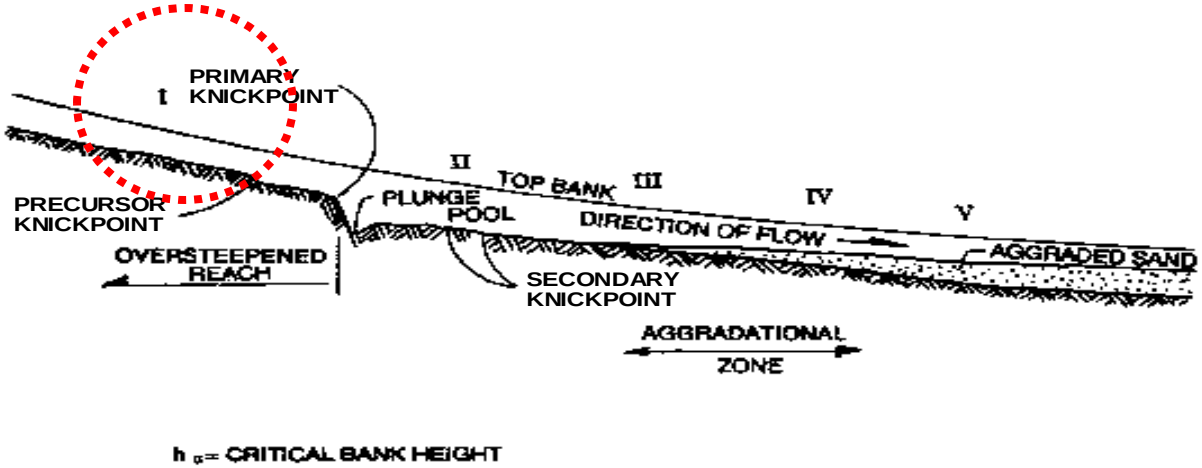
Type I reaches are generally characterized by a U-shaped cross section with little or no sediment stored in the channel bed.

Type I reaches are located upstream of the actively degrading reach and have not yet experienced significant bed or bank instabilities.

From C. Watson



Type I is upstream of active incision




Stream connected with its floodplain, bed stable
CEM Type I

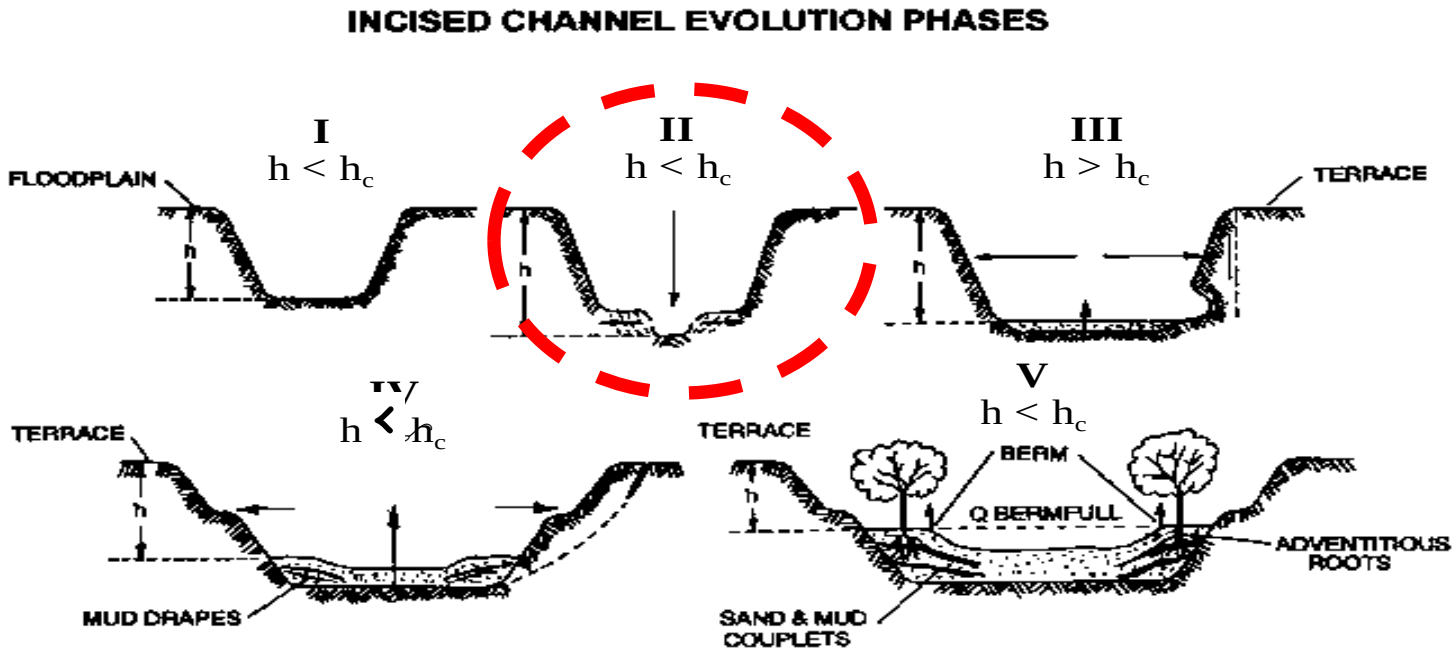
Channel Evolution Model Type II Reach Characteristics

Immediately downstream of Type I reaches, Type II reaches are encountered. Bed degradation is the dominant process in the Type II reach.

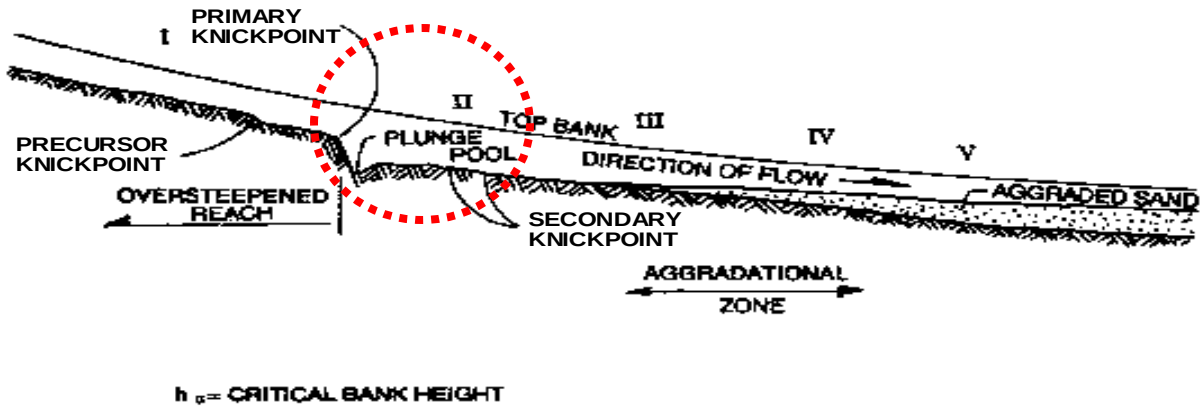
Type II channels are steepened reaches where the sediment transport capacity exceeds the sediment supply.

Although the channel is actively degrading in a Type II reach, the bank heights (h) have not exceeded the critical bank height (hc). Therefore, banks are not geotechnically unstable.

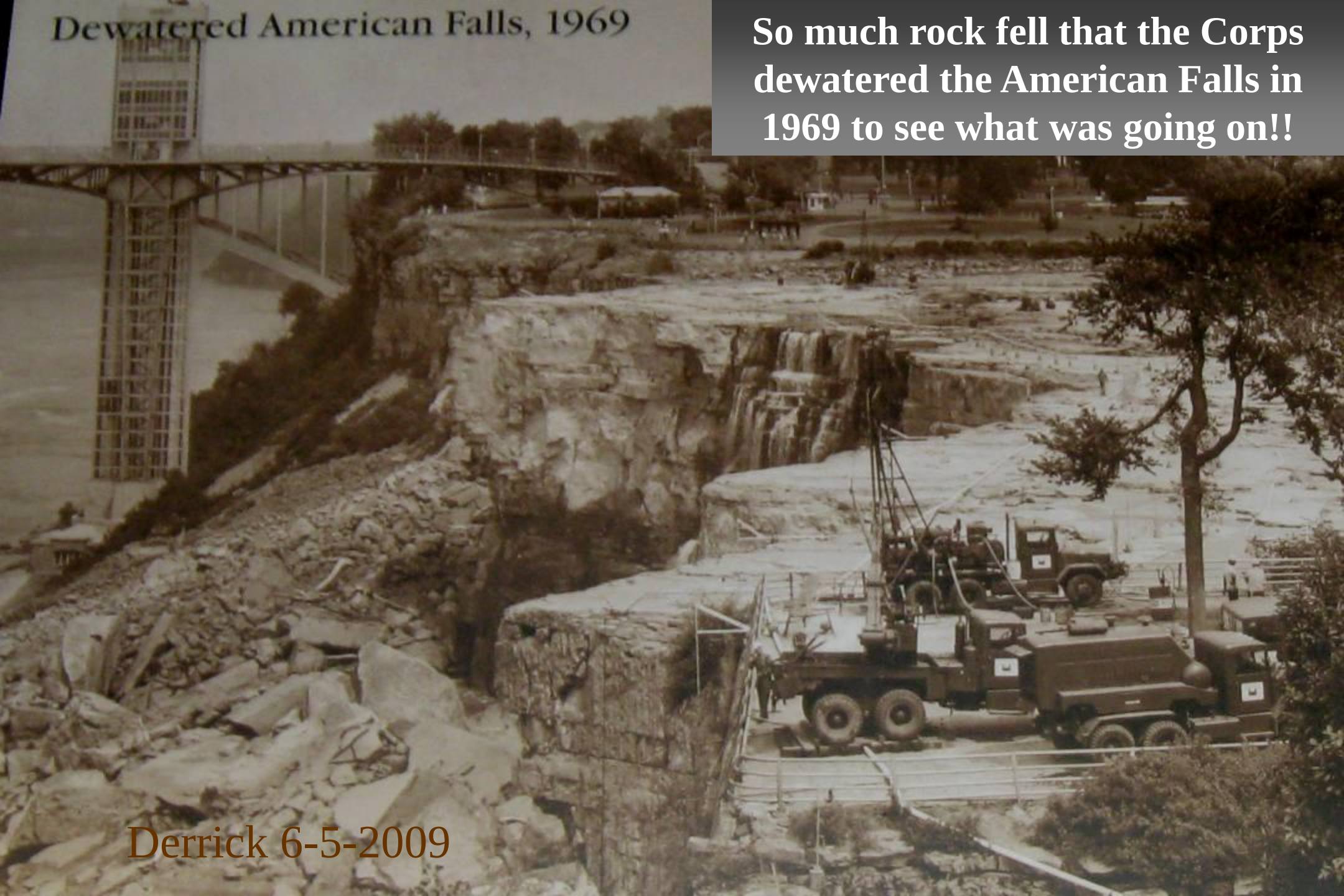
From C. Watson



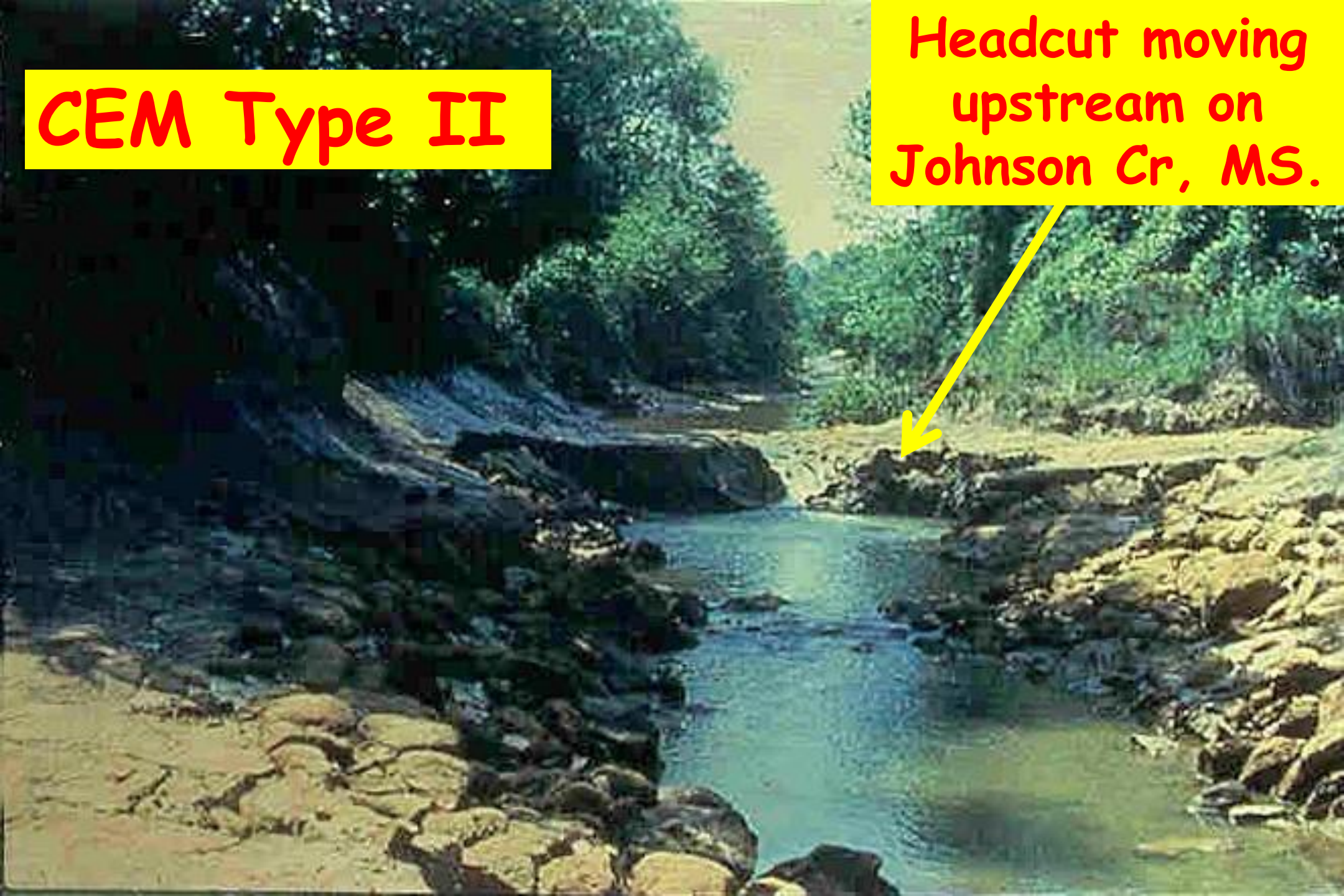
Type II reaches are actively incising, although mass wasting of bank has not been initiated ($h<h_c$)



A large knickpoint, Niagara Falls (American Falls) (This headcut moves on average 2.5 ft per year)


Dewatered American Falls, 1969
So much rock fell that the Corps dewatered the American Falls in 1969 to see what was going on!!
Derrick 6-5-2009

A headcut has to move upstream over time (toward the headwaters of the stream), if the waterfall does not move, it is not a headcut!!!

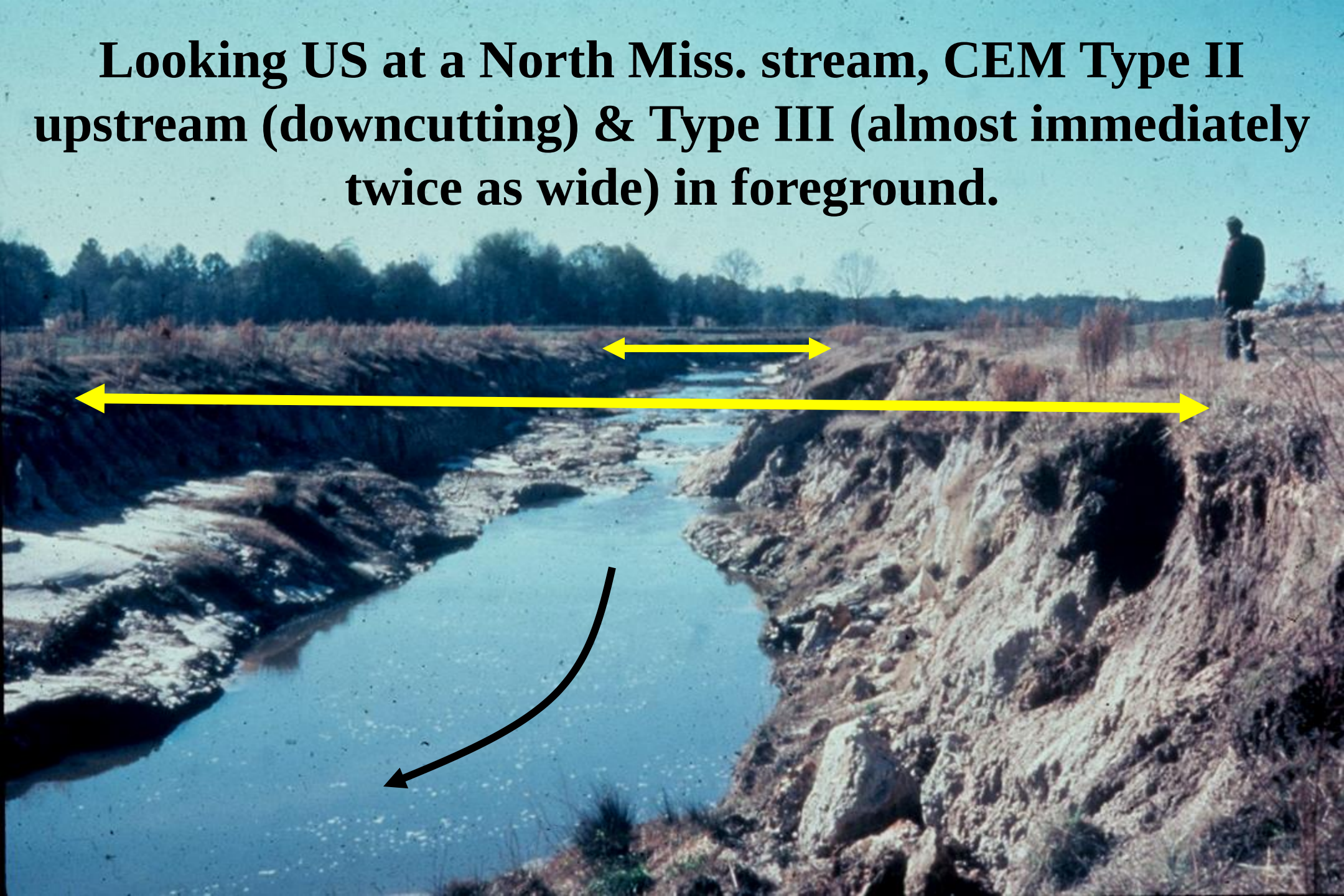

CEM Type II
Headcut moving upstream on Johnson Cr, MS.

Typically knickpoints will not occur in non-cohesive materials (sands, etc.). Sand will not stand vertically with water flowing over it.


CEM Type II
A series of small headcuts

Dr. Watson with large headcut in a CEM Type II stream, Johnson Creek, MS. Banks bad upstream

Looking US at a North Miss. stream, CEM Type II upstream (downcutting) & Type III (almost immediately twice as wide) in foreground.



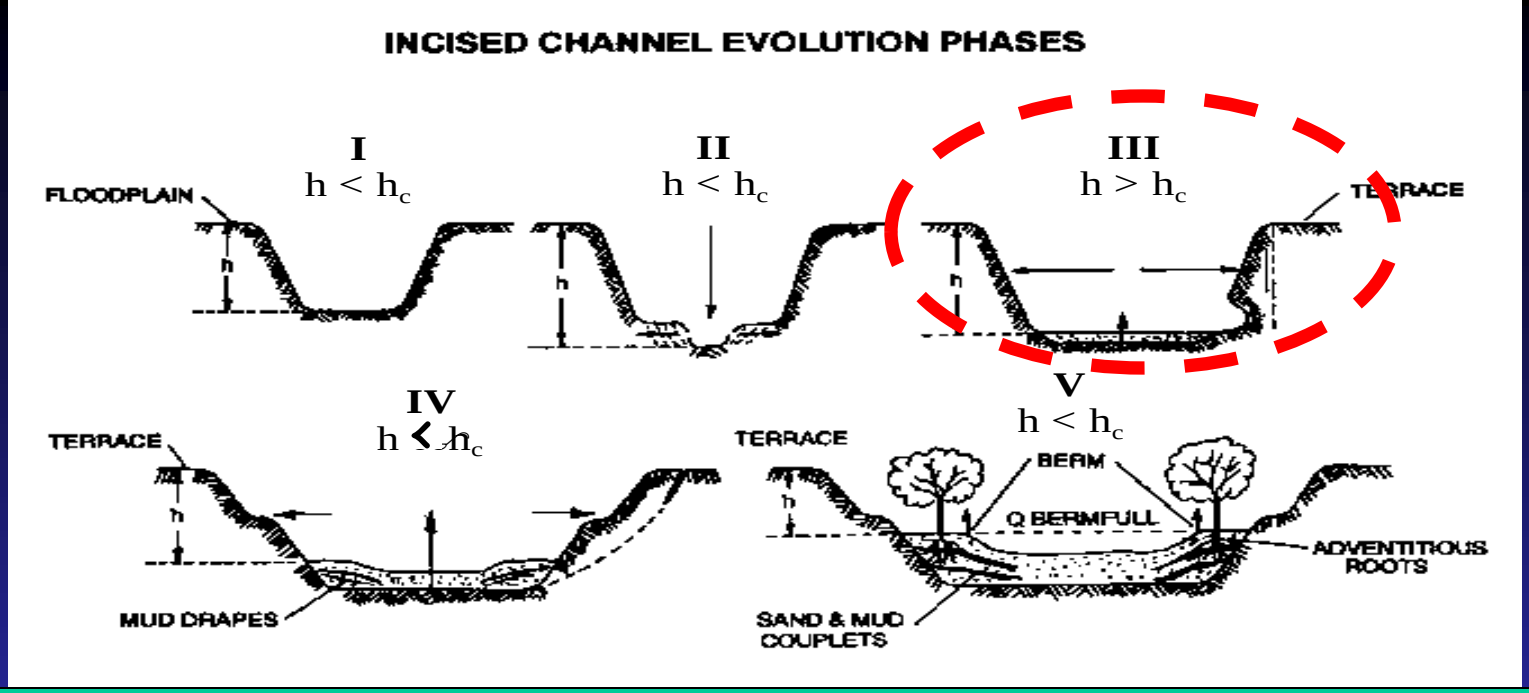
Channel Evolution Model
Type III Reach Characteristics

As bed degradation continues, the bank heights and angles will continue to increase.

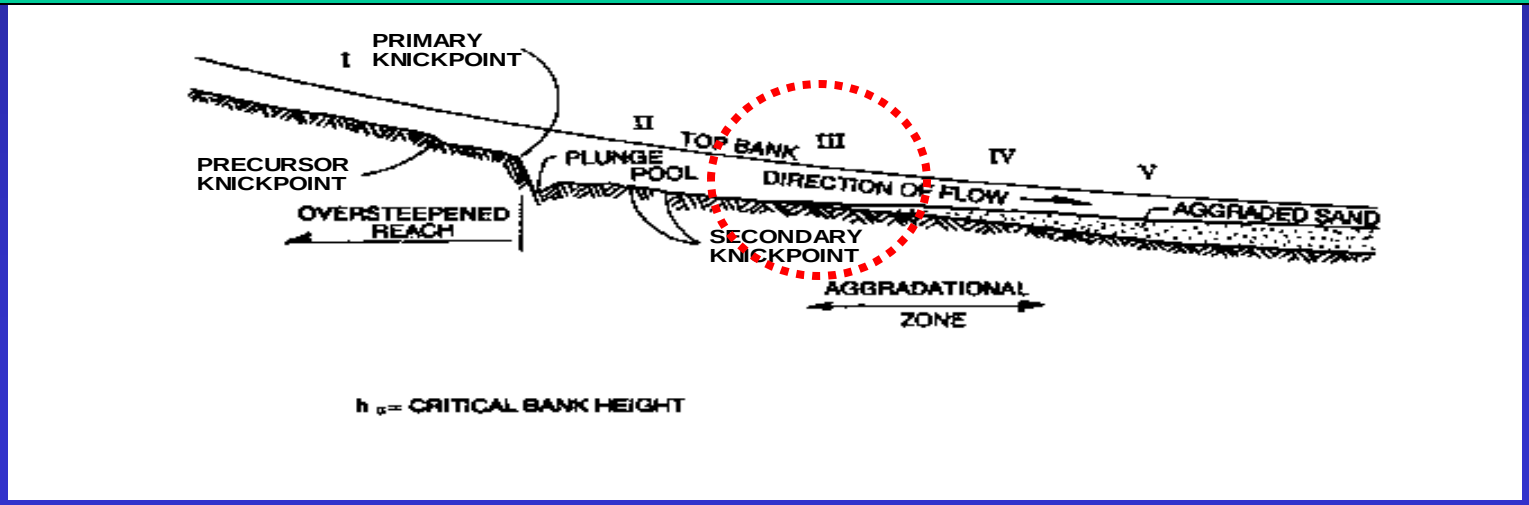
When the bank heights have exceeded the critical bank height for stability, mass failures (geotechnical instability) begin to occur in the Type III reaches.

The dominant process in the Type III reach is channel widening.

From C. Watson



In the Type III reach, mass wasting of the banks with rapid channel widening is the dominant process



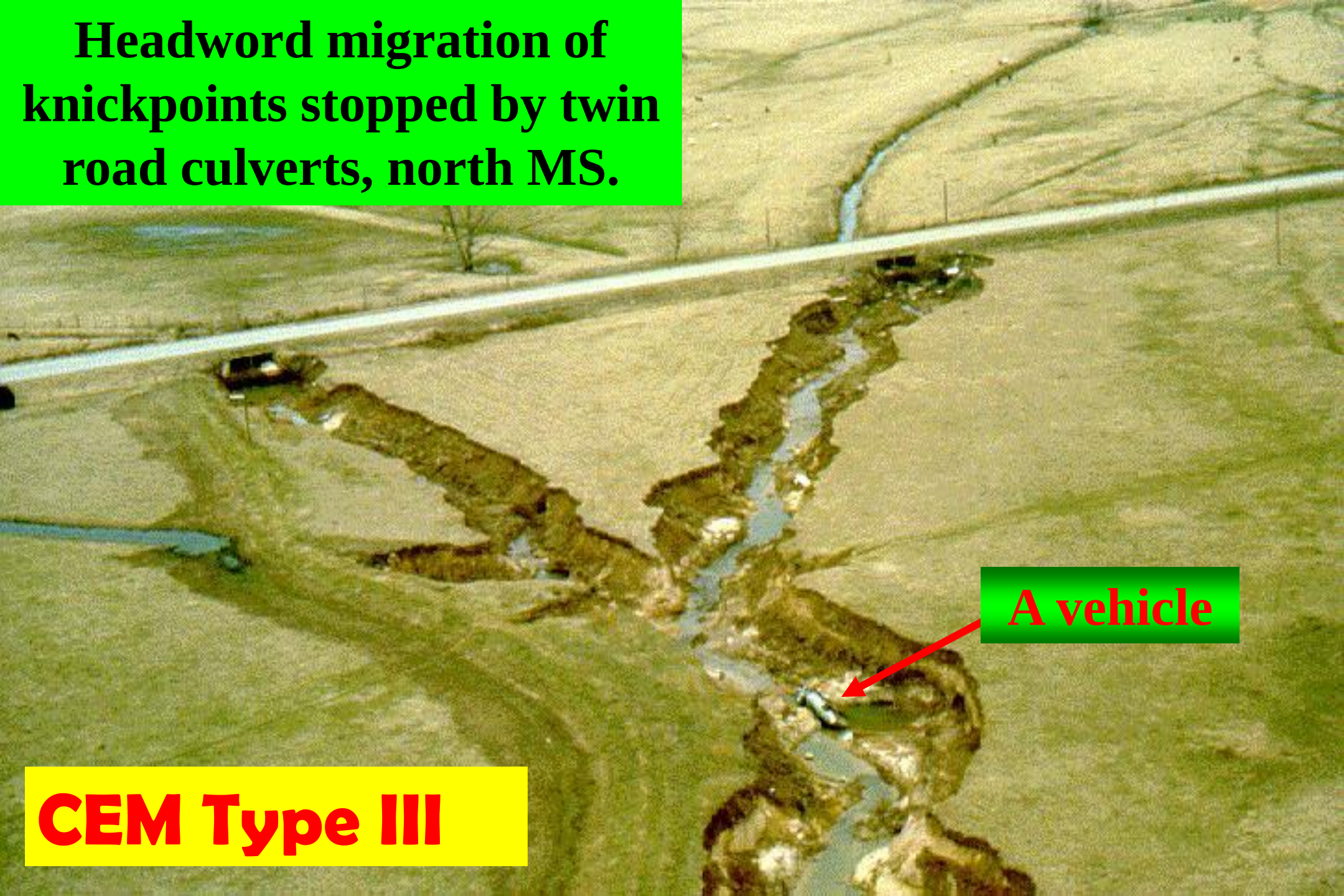
CEM Type III, rapid over widening of stream


CEM Type III-
bridges too short

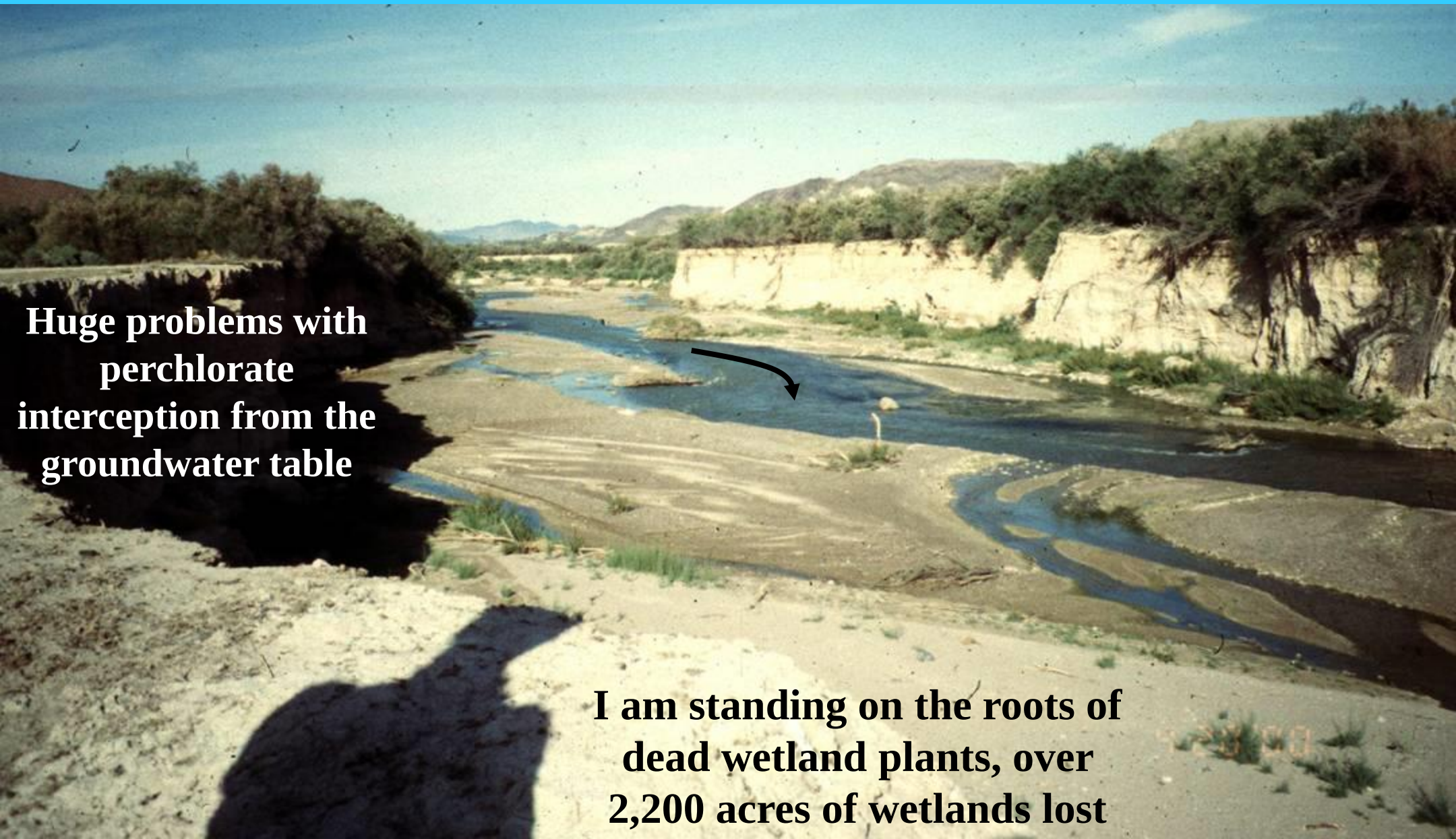

CEM Type III
Bellefontaine Creek,
{sand & clay bed, rural,
slope <1%} April 2005,
rapid widening

Bellefontaine Creek about 700 ft US of the previous picture. CEM Type II, but the headcut is coming, followed by channel widening

HEADCUTS GONE BAD!!


Headword migration of knickpoints stopped by twin road culverts, north MS.
A vehicle
CEM Type III

Las Vegas Wash, NV. has degraded from a 1 ft deep by 100 ft wide channel in 1975, to a 40 ft deep by 1,000 ft wide channel in 1995!!



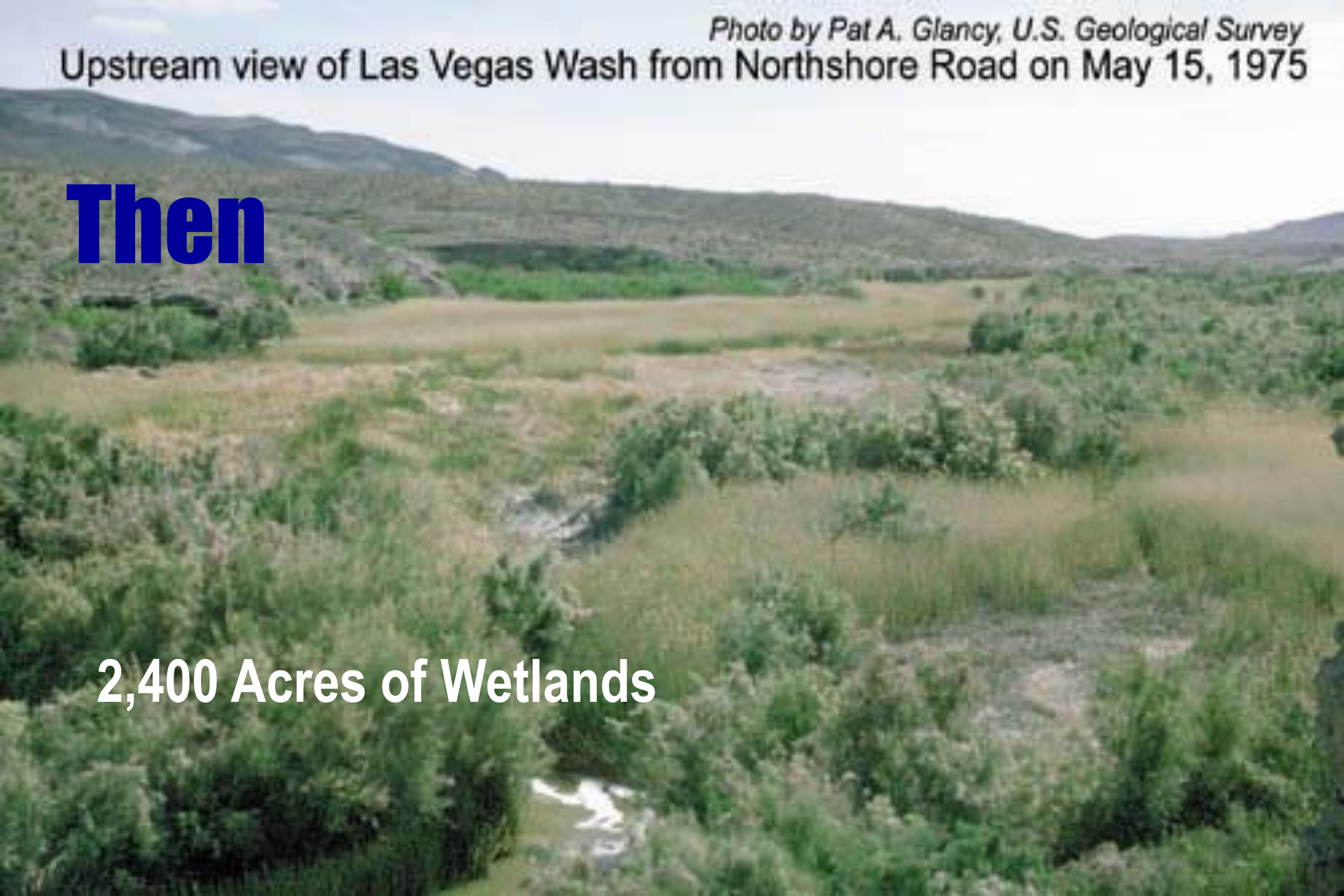


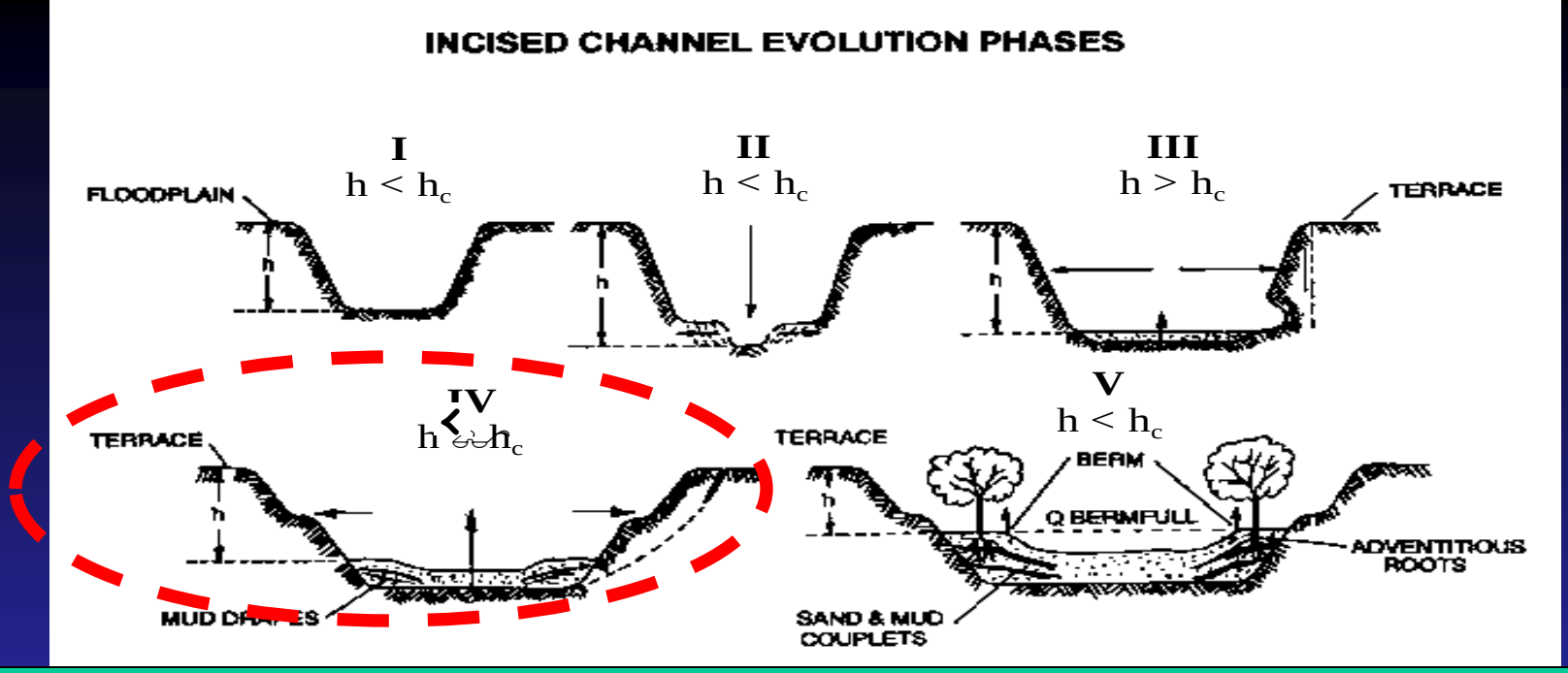
Photo by Pat A. Glancy, U.S. Geological Survey
Upstream view of Las Vegas Wash from Northshore Road on May 15, 1975
Then
2,400 Acres of Wetlands

Channel Evolution Model
Type IV Reach Characteristics

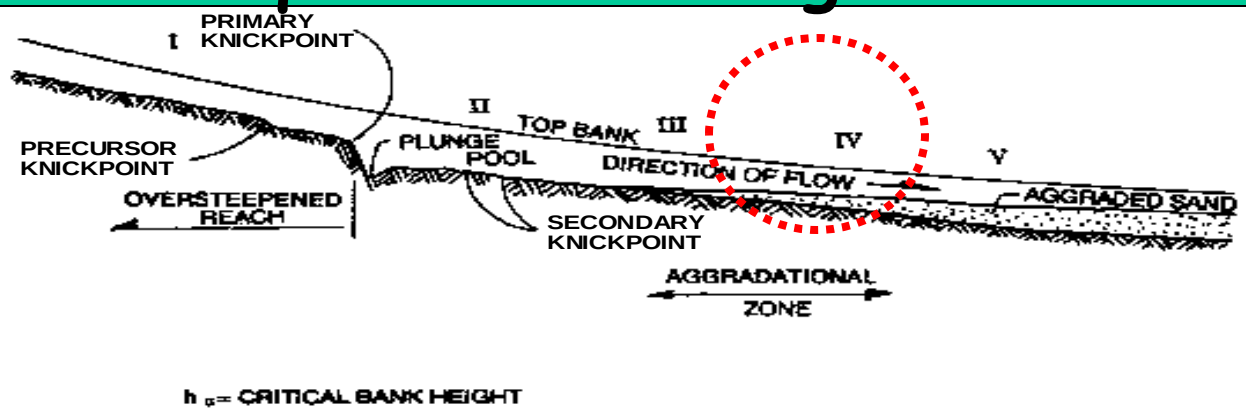
The Type IV reaches are downstream of the Type III reaches and represent the first manifestation of the incised channel returning to a new state of dynamic equilibrium.

In the Type IV reach, geotechnical bank instabilities and channel widening may continue, but at a much reduced rate.

From C. Watson



Channel widening continues at a much reduced rate in the Type IV reach. The first manifestation of a new equilibrium emerges.



CEM Type IV, MS., should be a single-thread channel

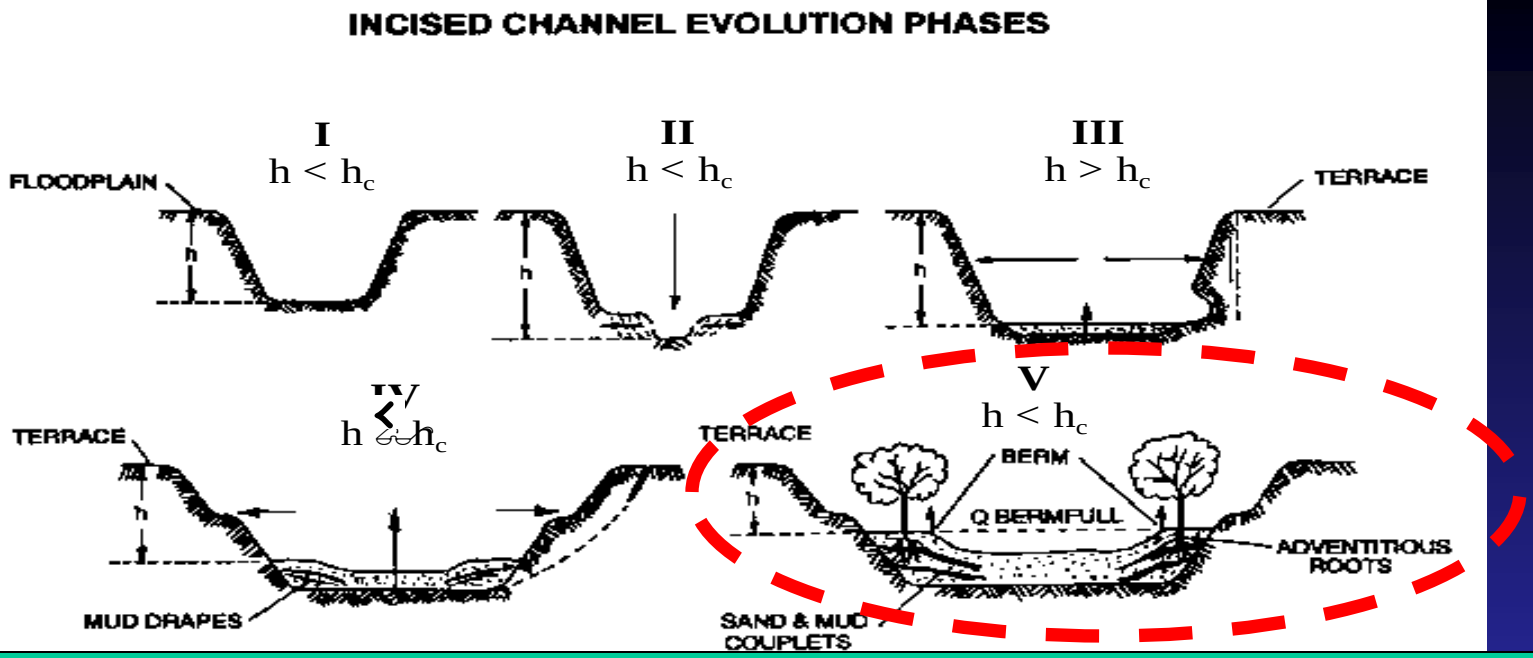

CEM Type IV, Illinois

Channel Evolution Model
Type V Reach Characteristics

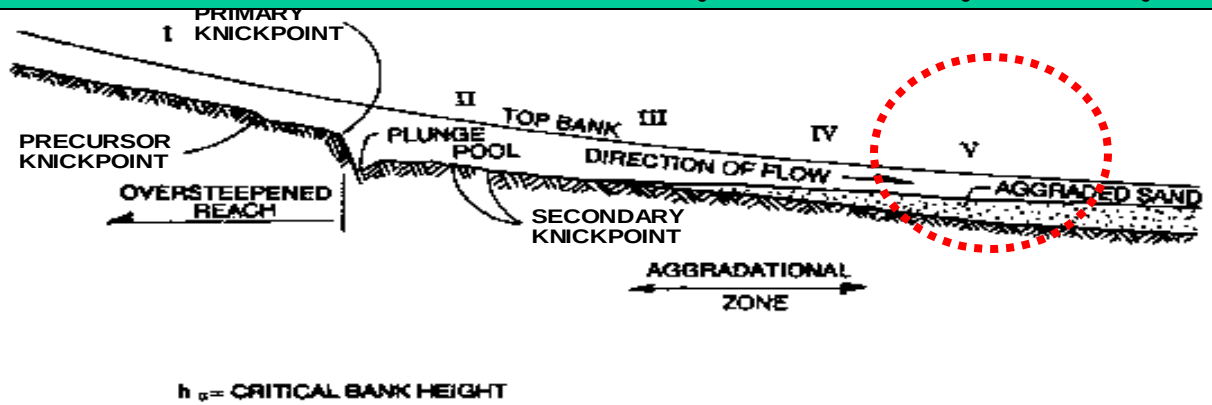
Type V reaches represent a state of dynamic equilibrium with a balance between sediment transport capacity and sediment supply.

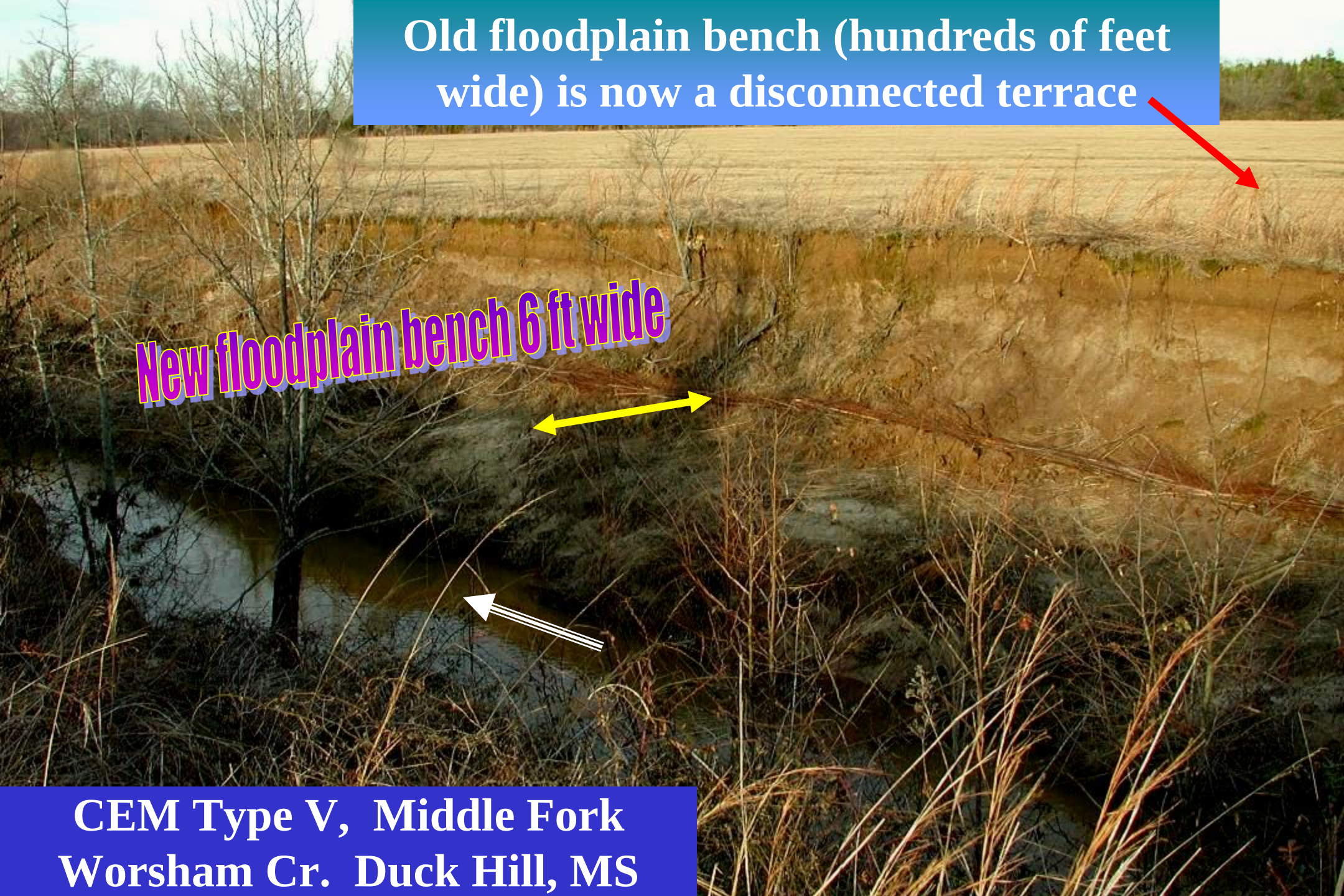
Bank heights in the Type V channel are generally less than the critical bank height, and therefore, geotechnical bank instabilities do not exist.

From C. Watson



Type V reaches represent a state of dynamic equilibrium with a balance between sediment supply and sediment transport capacity.




Old floodplain bench (hundreds of feet wide) is now a disconnected terrace
New floodplain bench 6 ft wide
CEM Type V, Middle Fork Worsham Cr. Duck Hill, MS

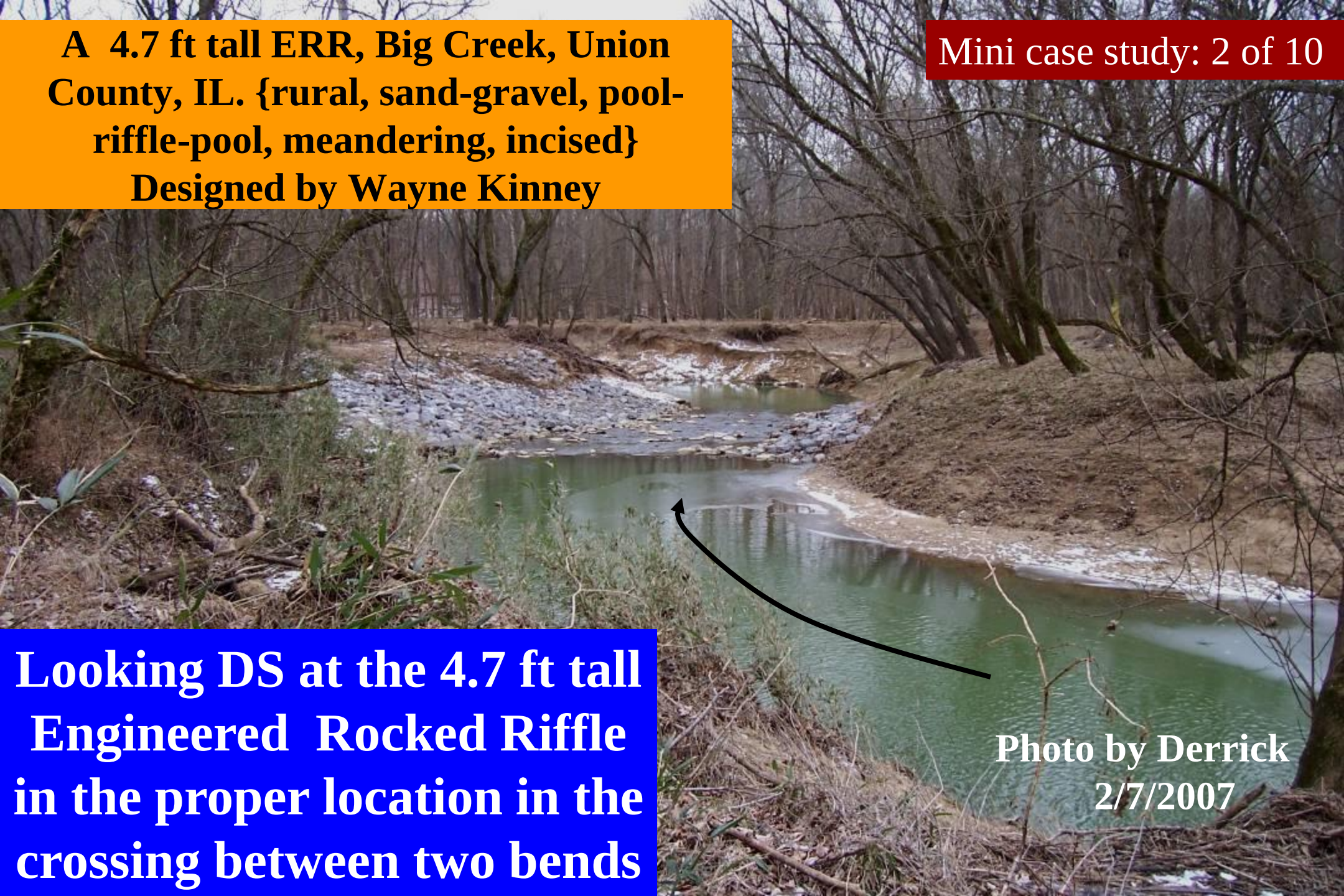
CONCEPTUALLY, STABILIZE HEADCUTS FIRST, THEN WORRY ABOUT BANK INSTABILITY SECOND

GRADE CONTROL SHOULD BE LOCATED IN STRAIGHT REACHES BETWEEN BENDS. LUNA LEOPOLD SAYS SPACING SHOULD BE 5 TO 7 BANKFULL CHANNEL WIDTHS APART (ideally with a bend in between)

WELL-GRADED LOOSE STONE ENGINEERED ROCKED RIFFLES (ERR)

WAYNE KINNEY'S REALLY TALL ENGINEERED ROCKED RIFFLES (ERR) CASE STUDY: ERR #12, WHICH IS A 4.7 FT TALL STRUCTURE

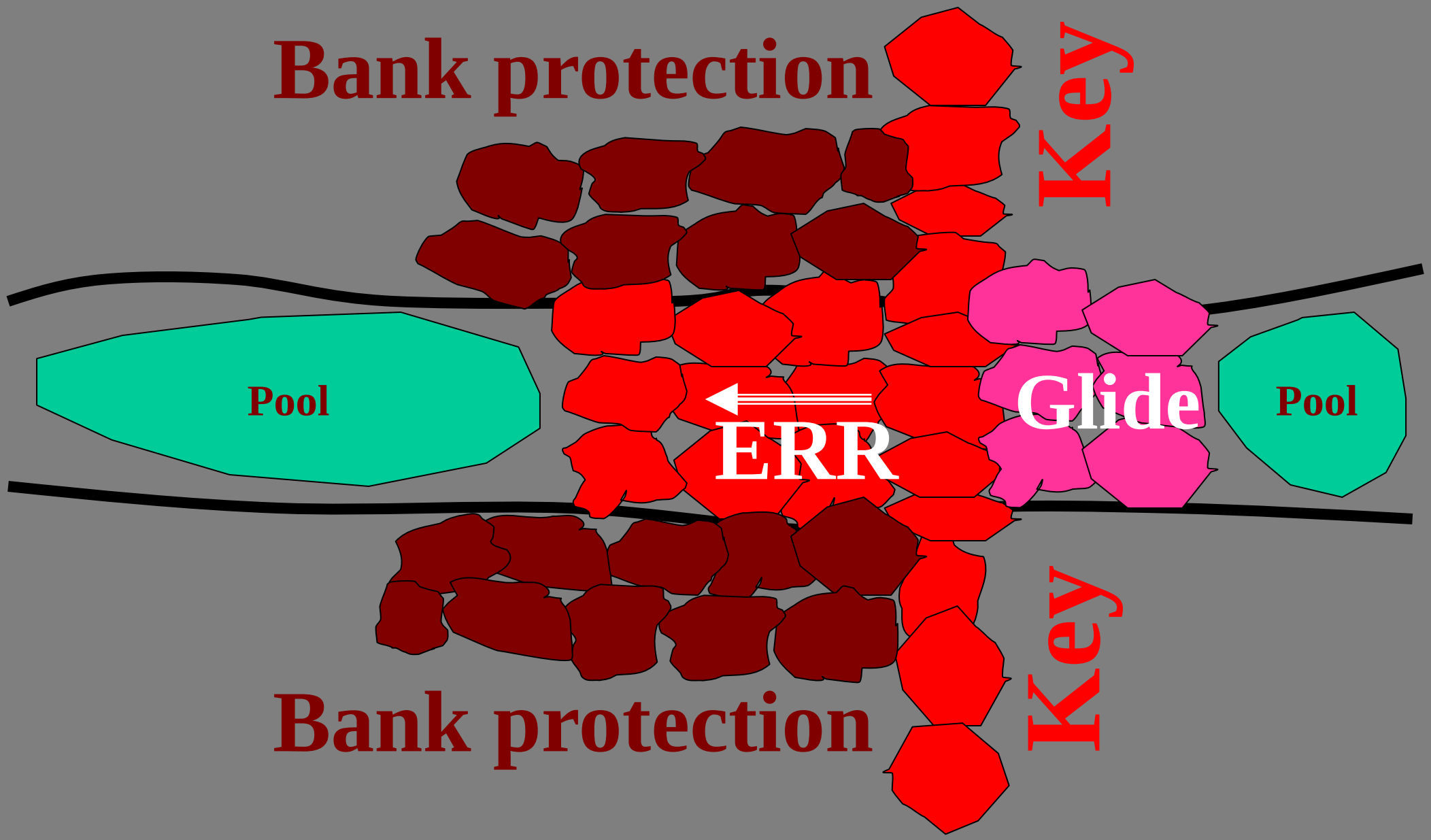
Big Creek, Carbondale area, IL.


A 4.7 ft tall ERR, Big Creek, Union County, IL. {rural, sand-gravel, pool-riffle-pool, meandering, incised}
Designed by Wayne Kinney
Mini case study: 2 of 10
Looking DS at the 4.7 ft tall Engineered Rocked Riffle in the proper location in the crossing between two bends
Photo by Derrick 2/7/2007

Great info on Robert Newbury Rocked Riffles

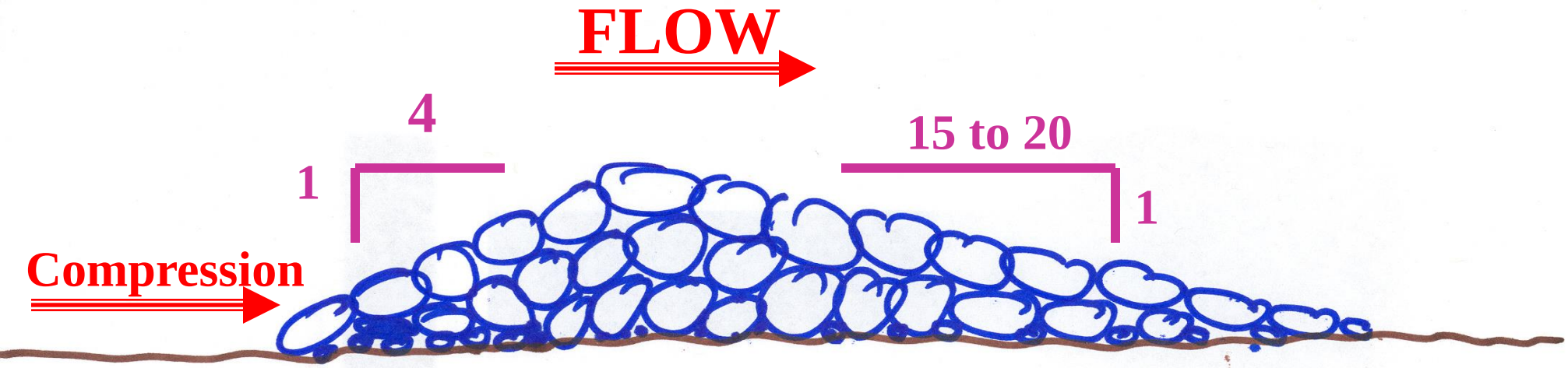
- **http://ouc.collegestoreonline.com/**
- http://www.newbury-hydraulics.com/workshops.htm
- **Bob Newbury's out-of-print "Stream Analysis & Fish Habitat Design Manual" is available at** ftp://ftp.lgl.com/pub/ **under 'Stream Analysis.pdf'**

When building a series of Newbury RR Bob always puts a NRR "at grade" (buried) at the DS end of the project to protect against DS headcuts, max height of a NRR is 1.5 ft, & Bob always puts a tailwater of 1/3 the height of the upstream NRR on the upstream NRR. This provides energy dissipation into the tailwater pool, but also provides sediment continuity (sediment does not deposit between NRR's & stream does not meander & flank the DS NRR)


Bank protection
Key
Pool
ERR
Glide
Pool
Key
Bank protection

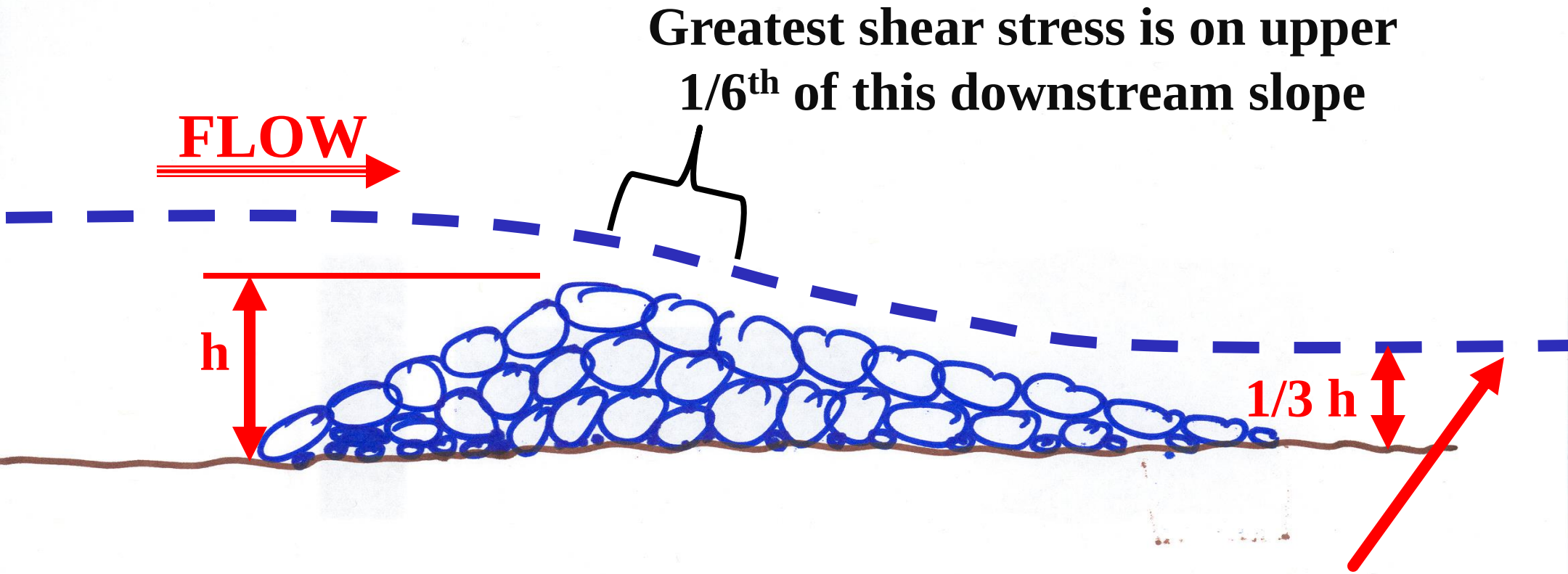

A 4.7 ft tall ERR, Big Creek, Union County, IL. Designed by Wayne Kinney
Mini case study: 4 of 10
Key is dug 3 ft deep into substrate & up each bank. Stone is IL-DOT RR5-well-graded stone with a top size of 400 pounds.
Photo by Derrick 2/7/2007

AN ENGINEERED ROCKED RIFFLE



Use well-graded, self-adjusting stone. Bigger stone is better. Choke stone so all flow goes over the top (not through) the ERR. Upstream face is in compression (due to water flow), so smaller stone or spawning gravel can be used. Slope might have to be flatter for some spawning species.

AN ENGINEERED ROCKED RIFFLE



Newbury says the backwater should be 1/3 the total height of the structure to dissipate energy, & also pass sediment through the system.


A 4.7 ft tall ERR, Big Creek, Union County, IL. Designed by Wayne Kinney
Mini case study: 5 of 10
Looking DS. Uniform 20 to 1 slope, roughness dissipates energy & assists in fish passage.
Photo by Derrick 2/7/2007


A 4.7 ft tall ERR, Big Creek, Union County, IL. Designed by Wayne Kinney
Mini case study: 6 of 10
Photo by Derrick 2/7/2007
Flood flow crested 5 ft above banks (30 ft over the crest of the ERR) with no damage


A 4.7 ft tall ERR, Big Creek, Union County, IL. Designed by Wayne Kinney
Mini case study: 7 of 10
Looking US at the 4.7 ft tall Engineered Rocked Riffle
Photo by Derrick 2/7/2007

A 4.7 ft tall ERR, Big Creek, Union County, IL. Designed by Wayne Kinney

Photo by Derrick
2/7/2007


Mini case study: 9 of 10
Looking US. A thing of beauty!! Stone was track-walked in to increase stability
Photo by Derrick 2/7/2007


A 4.7 ft tall ERR, Big Creek, Union County, IL. Designed by Wayne Kinney
Mini case study: 10 of 10
Looking US, note riprap bank protection.
Photo by Derrick 2/7/2007

WHAT HAPPENS TO AN UNSTABLE STREAM WHEN ONLY GRADE STABILIZATION IS INSTALLED

(no bank stabilization built, a 20 year long study)

Long Creek Grade Control Case Study Near Batesville, MS

From Dr. Dave Biedenharn, BIEDENHARN GROUP, INC.

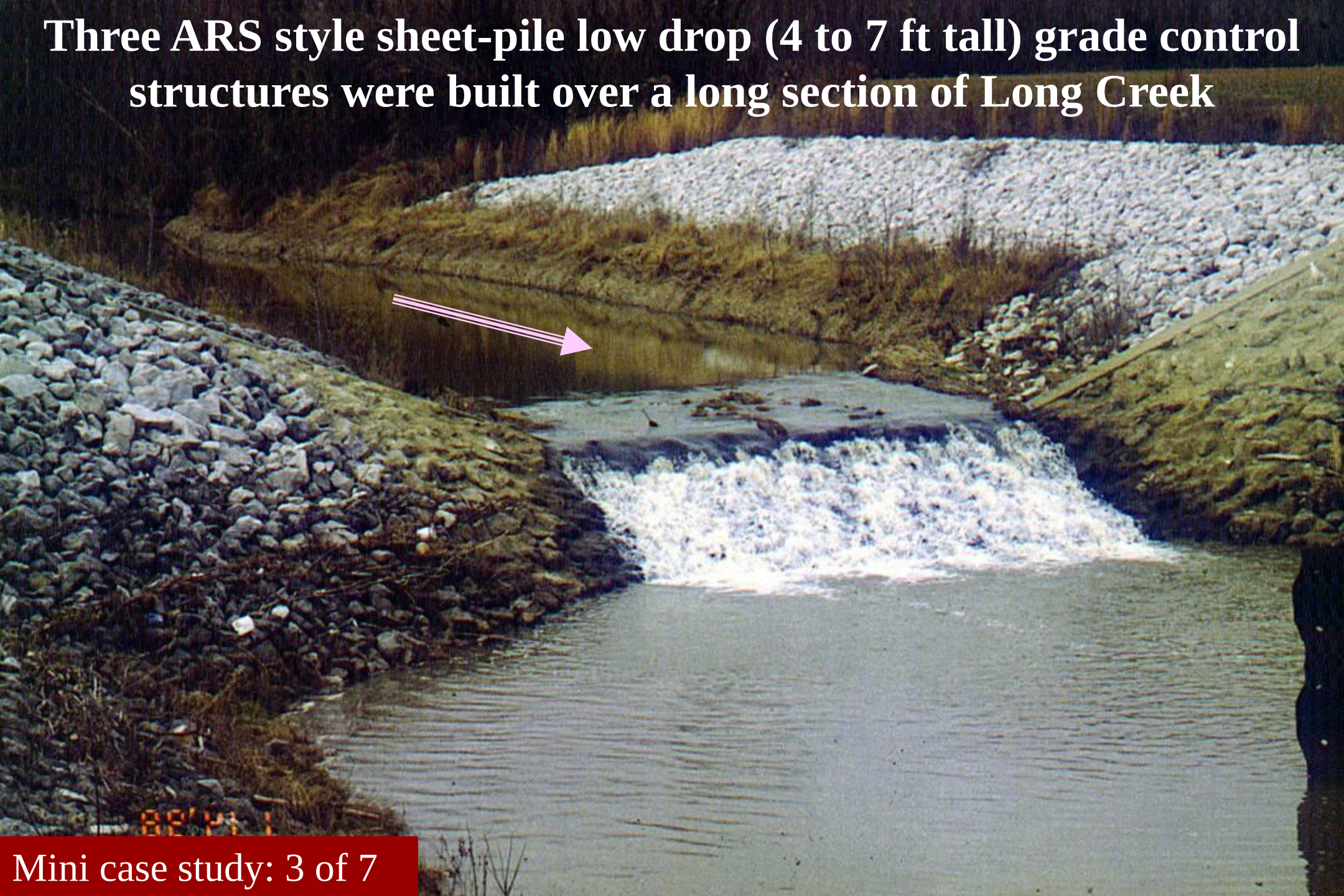
3303 Woodlands Place, Vicksburg, MS 39180 (cel) 601-529-4685

e-mail: BIEDENHARNGROUP@YAHOO.COM

Looking US at a typical section of incised, highly disturbed section of Long Creek (Channel Evolution Model Type 3). Nothing stable in this picture!!

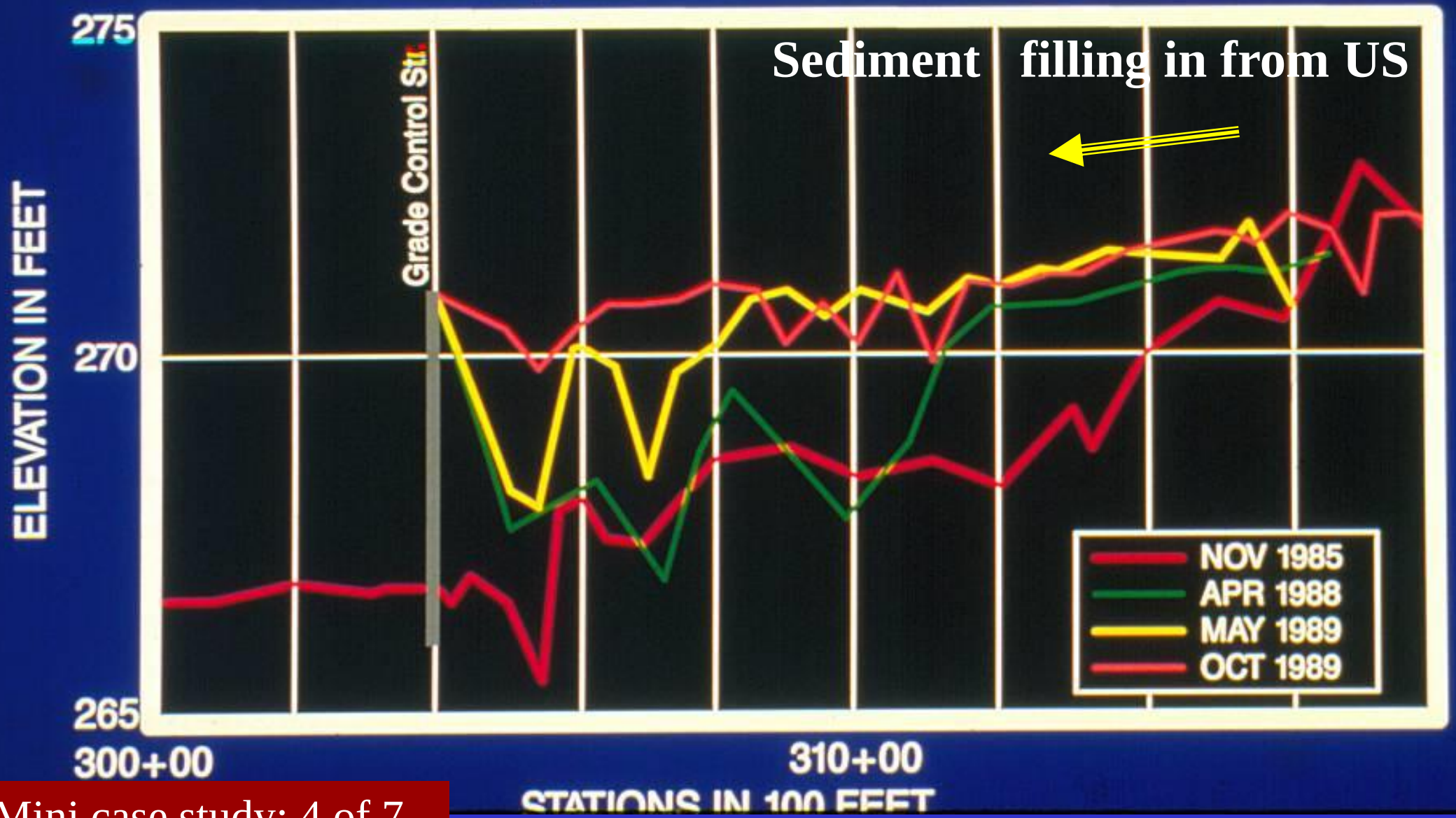
Mini case study: 2 of 7

Three ARS style sheet-pile low drop (4 to 7 ft tall) grade control structures were built over a long section of Long Creek



Mini case study: 3 of 7

Comparative Thalweg Profile Long Creek Upstream of Low Drop Grade Control Structure



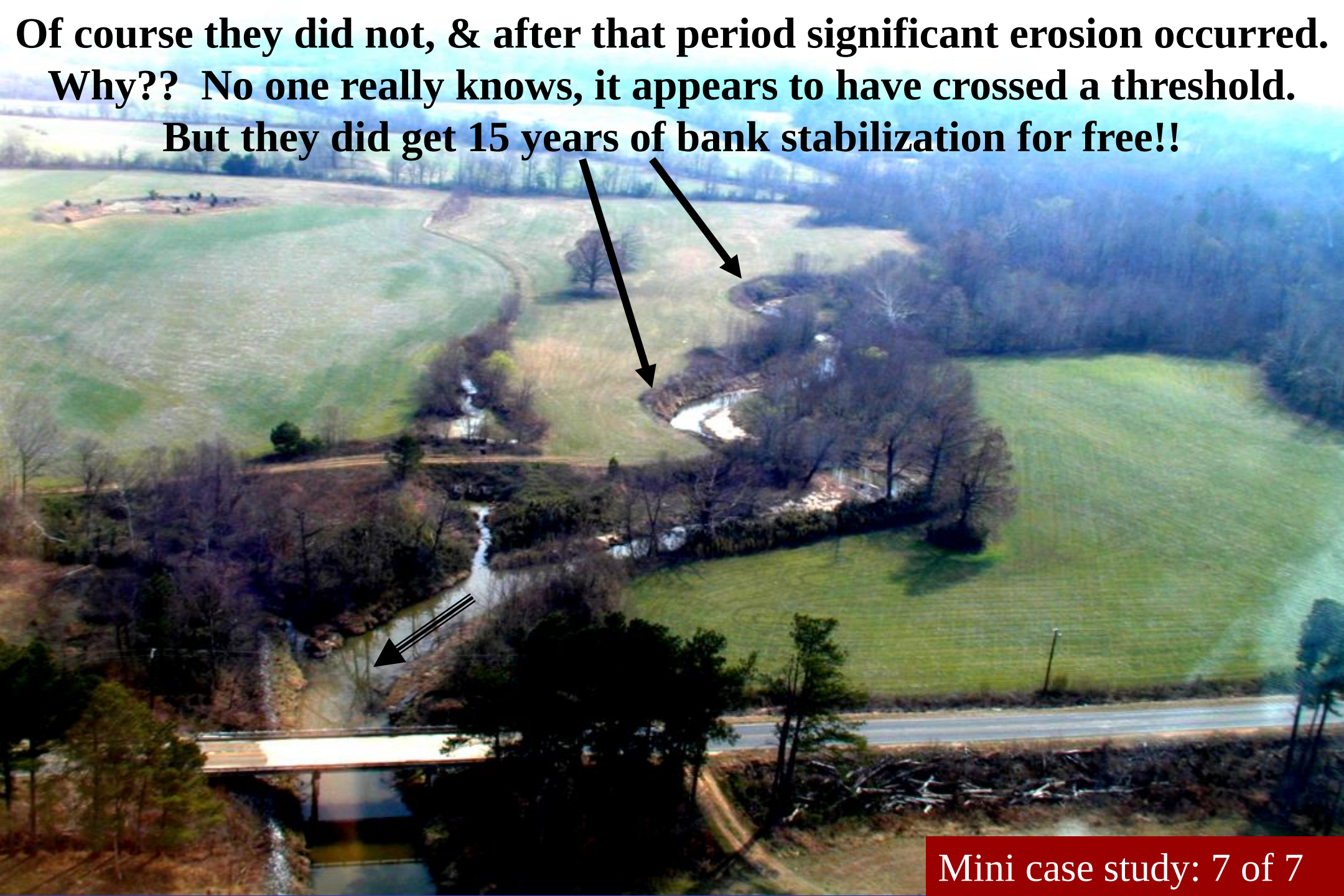
Mini case study: 4 of 7

Long Creek Bank Evolution

Mini case study: 5 of 7

Mini case study: 6 of 7

Of course they did not, & after that period significant erosion occurred. Why?? No one really knows, it appears to have crossed a threshold. But they did get 15 years of bank stabilization for free!!



WHAT HAS HAPPENED TO THE BED OF PRAIRIE CREEK (Washington, IN. area) SINCE STRAIGHTENING IN 1960?

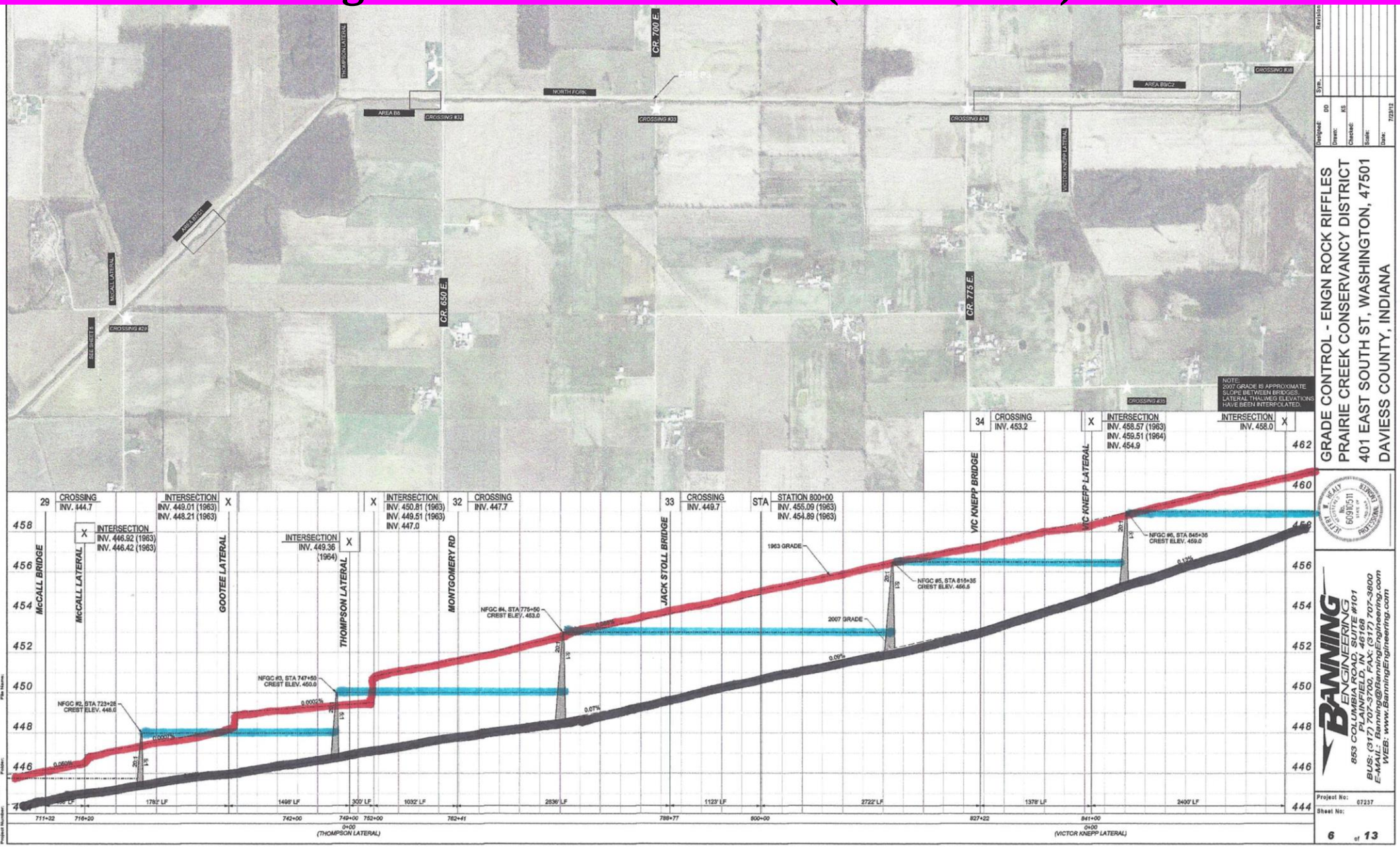
COMPARING THE BED PROFILES FROM 1963 & 2007 SHOW THAT THE BED OF PRAIRIE CREEK HAS DROPPED ANYWHERE FROM 2 TO 9 FT, DEPENDING ON LOCATION.

PART OF THE PRAIRIE CREEK GRADE CONTROL PLAN

(27 grade control structures over 40 miles of straightened stream)

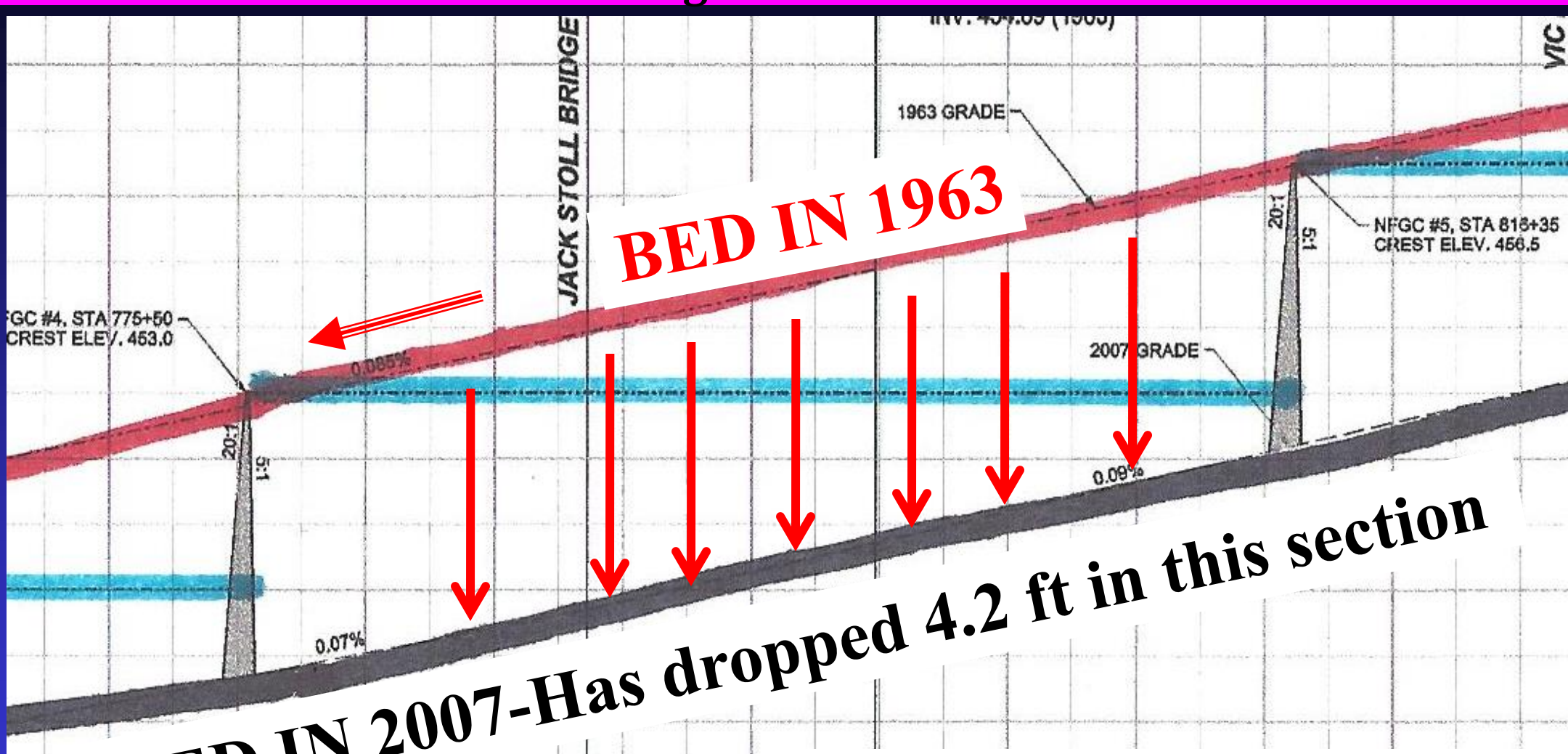
A SYSTEM-WIDE PROBLEM WILL REQUIRE A SYSTEM-WIDE SOLUTION !!

Red line is bed in 1963, black line is bed in 2007. Blue line is water surface after grade control structures (small dams) are installed



ANALYSIS OF RATIOS OF BED DEGRADATION VS. INCREASE IN CHANNEL WIDTH ON DIFFERENT STREAMS NATIONWIDE SHOWS THE RATIO TO VARY FROM 1 to 5, to 1 to 22 (1 ft drop=22 ft wider channel)!!!!

Red line is bed in 1963, black line is bed in 2007. Blue line is water surface after Rocked Riffle grade control structures are installed

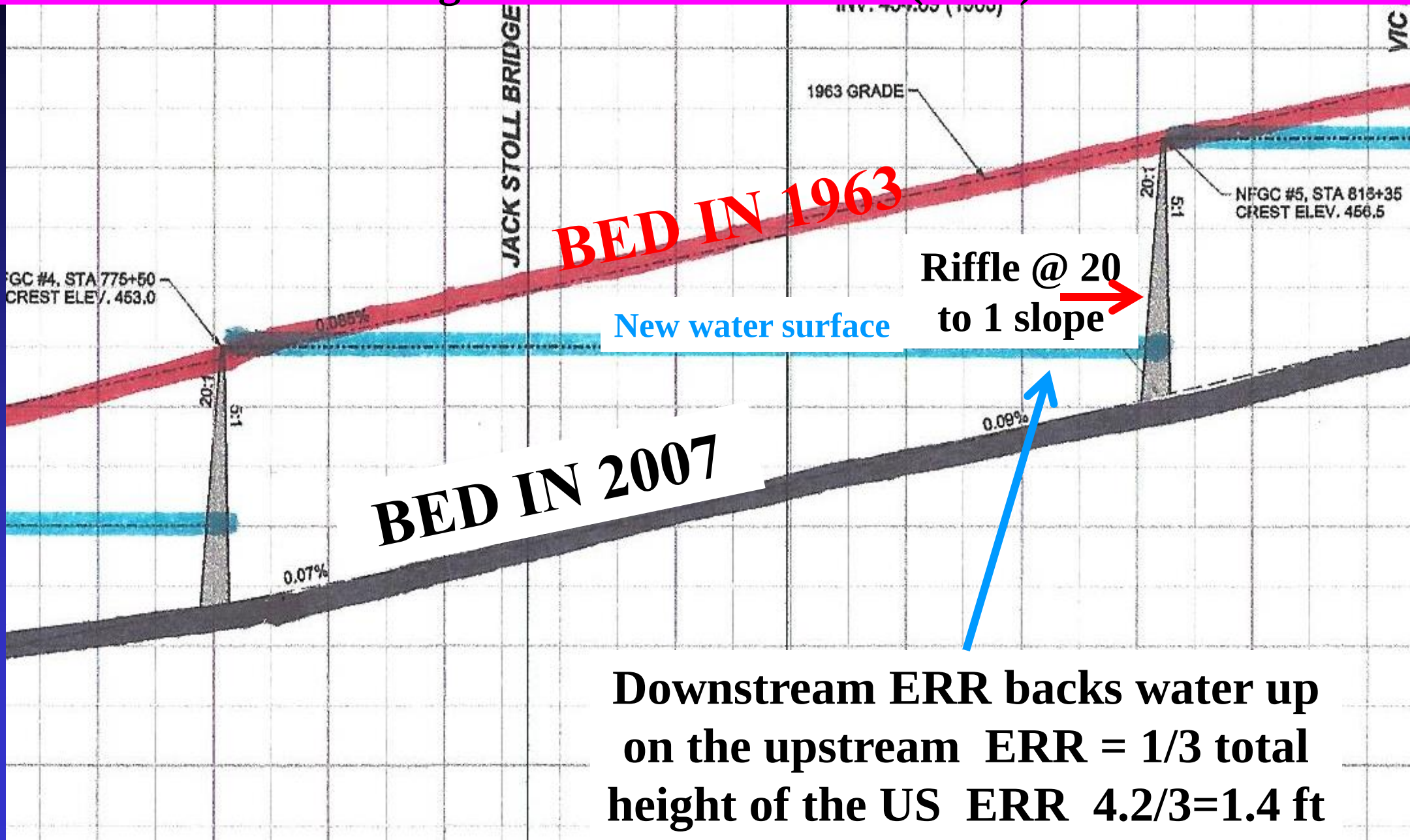


BED IN 2007-Has dropped 4.2 ft in this section

4.2 ft x 5 = 21 ft wider channel

4.2 ft x 22 = 92 ft wider channel

Red line is bed in 1963, black line is bed in 2007. Blue line is water surface after Engineered Rocked Riffles (ERR) are installed



Downstream ERR backs water up on the upstream ERR = 1/3 total height of the US ERR 4.2/3=1.4 ft

From Brian Winkley

MAINTENANCE ON ALLUVIAL RIVERS

1. Most Rivers Operating in a Sedimentary Environment, Develop Sinuous Channels That Look Like This:

MAINTENANCE ON ALLUVIAL RIVERS

2. In An Effort to Drain Lands for Agriculture and Improve Flood Conveyance Many Alluvial Channels Have Been Straightened

MAINTENANCE ON ALLUVIAL RIVERS

3. Straightening a Sinuous Channel Increases Its Slope, Thus Giving It More Energy and the Result Has Often Been An Increase in Bank Caving and Other Problems That Require Intermittent or, in Some Cases Constant Maintenance. The Single Factor That Has Led to the Successful Operation of These Straightened Channels, Has Been to Combine the Good Points of Both the Sinuous and the Straight Channels

S + ||

MAINTENANCE ON ALLUVIAL RIVERS

4. This Combined Symbol Represents the Only Successful Means of Maintaining Straight Channels

This PowerPoint presentation was developed & built by Dave Derrick.

Any questions or comments, call my personal cell @ 601-218-7717, or email @ d_derrick@r2d-eng.com

Enjoy the information!!


Creative
Peyton
Rainer,
age 4