THE MORPHODYNAMICS E-BOOK: A LABOR OF LOVE THAT NEVER QUITE GETS FINISHED

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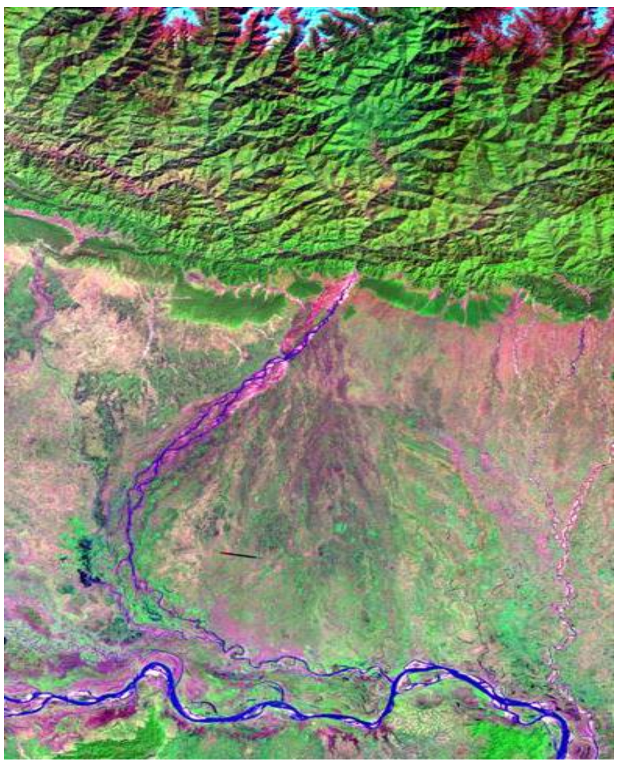
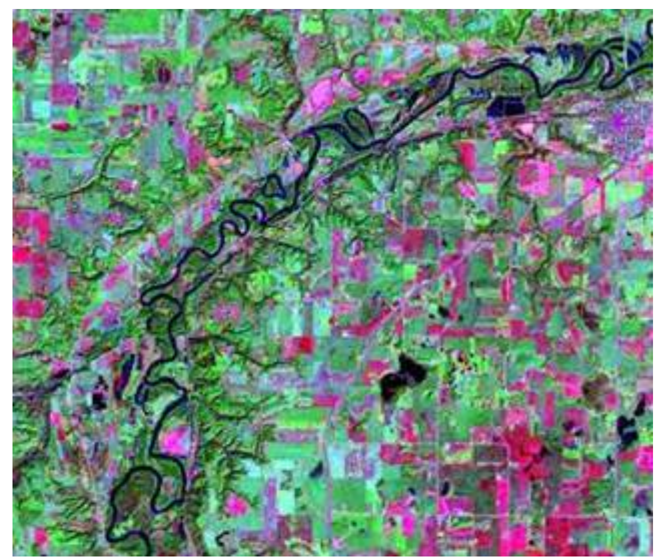


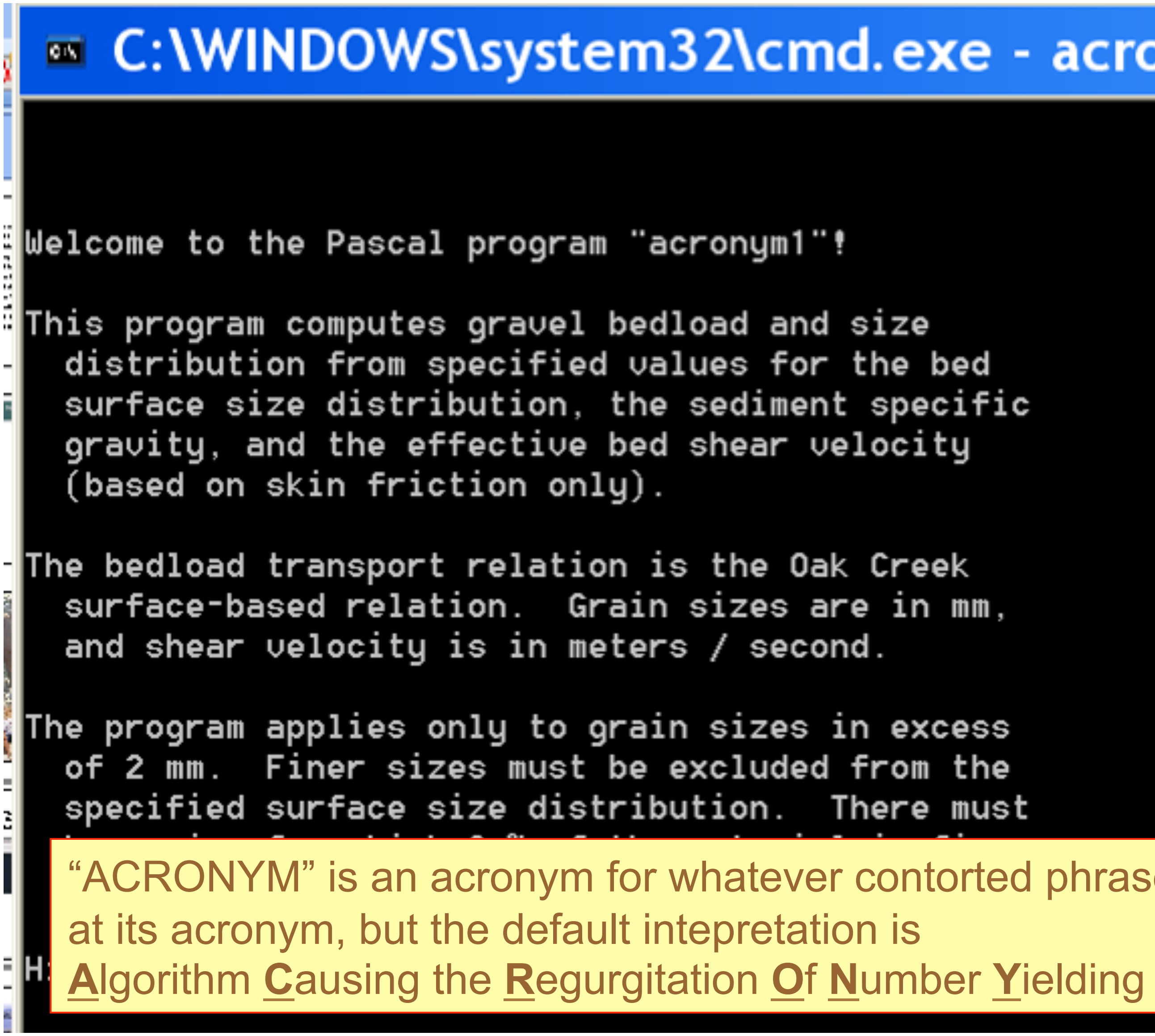
Acknowledging the help of
Enrica Viparelli
Ruiyu Wang
Greg Wilkerson
Wes Lauer
Chris Paola
and many others



GETTIN' TIME TO PUT THIS OLD HORSE OUT TO PASTURE
(me not the e-book)

1990

The "ACRONYM" series of Pascal programs for computing bedload transport in gravel rivers. G. Parker, External Memorandum M-220, St. Anthony Falls Hydraulic Laboratory, University of Minnesota, February 1990.



“ACRONYM” is an acronym for whatever contorted phrase that has “ACRONYM” at its acronym, but the default intepretation is
Algorithm **C**ausing the **R**egurgitation **O**f **N**umber **Y**ielding **M**onstrosities

2002

MIT
(Crosby Fellow, Kelin Whipple)

Hi, Nicole,
There was a priest, a nun and a camel…

TIT
(summer intensive course)
Syunsuke Ikeda

MIT

An Introduction to
Moving Boundary Formulation
In the context of knickpoint migration in bedrock and
Migrating bedrock-alluvial transitions

The traditional formulation for bedrock incision

$$(1-\lambda_p)\left(\frac{\partial \eta}{\partial t} - \upsilon_b\right) = -E_I$$

$$\upsilon_b = \frac{\partial \eta_b}{\partial t}$$

$$E_I = E_I(A, S)$$

A = drainage area upstream of a point
S = bed slope at the point

e.g. $E_I = aA^m S^n \qquad S = -\frac{\partial \eta}{\partial x}$

CALCULATION OF 1D AGGRADATION AND DEGRADATION IN RIVERS: NORMAL FLOW AND BACKWATER FORMULATIONS

沖積河川における河床変動（上昇、低下）の１次元数値計算 等流と漸変流によるモデル化

TIT

Ok Tedi Copper Mine, Papua New Guinea

パプア・ニウギニにある銅山

Aggradation in gravel-bed reaches of Ok Tedi

銅山の排砂によるれき床領域内のテディ川の河床上昇


Gary Parker's Morphodynamics Web Page Last update April 13, 2006
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http://vtchl.uiuc.edu/people/parkerg/
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The views and opinions expressed in this page are strictly those of the page author. The contents of this page have not been reviewed or approved by the University of Illinois.
Gary Parker's Morphodynamics Web Page Last update April 13, 2006
Click hyperlink for my resume.
Morphodynamics: Morphodynamics is the study of the evolution of landscapes and seascapes in response to the erosion and deposition of sediment. My interests are in morphodynamics associated with rivers, debris flows and turbidity currents.
I am based at the University of Illinois. My appointment here is in the Department of Civil and Environmental Engineering (75%) and the Department of Geology (25%). My new e-mail address is parkerg@uiuc.edu .
The 4th IAHR Symposium on River, Coastal and Estuarine Morphodynamics, University of Illinois, was held in the period October 4-7, 2005. Click here to order a copy of the proceedings.
Tableland in Western Unite
taken by author.
¬ Click to see an
¬ Click for a list o
for ordering.
¬ Click for versions of recent PowerPoint seminar presentations and posters.
¬ Click for informal writeups of random research ideas.
¬ Click for my e-book: 1D Morphodynamics of Rivers and Turbidity Currents.
¬ Click for various short course notes.
¬ Click for my e-book: 1D Morphodynamics of Rivers and Turbidity Currents.

Oh, shit…..

I am presently writing an e-book;

1D SEDIMENT TRANSPORT MORPHODYNAMICS
with applications to
RIVERS AND TURBIDITY CURRENTS

The main lectures are in PowerPoint. These lectures are linked to Excel files, most of which serve as graphical user interfaces for code in Visual Basic for Applications. Extended explanation is given in Word. Phenomena are illustrated with mpeg video clips.

�@

As I finish the material, I will upload it to this web site.

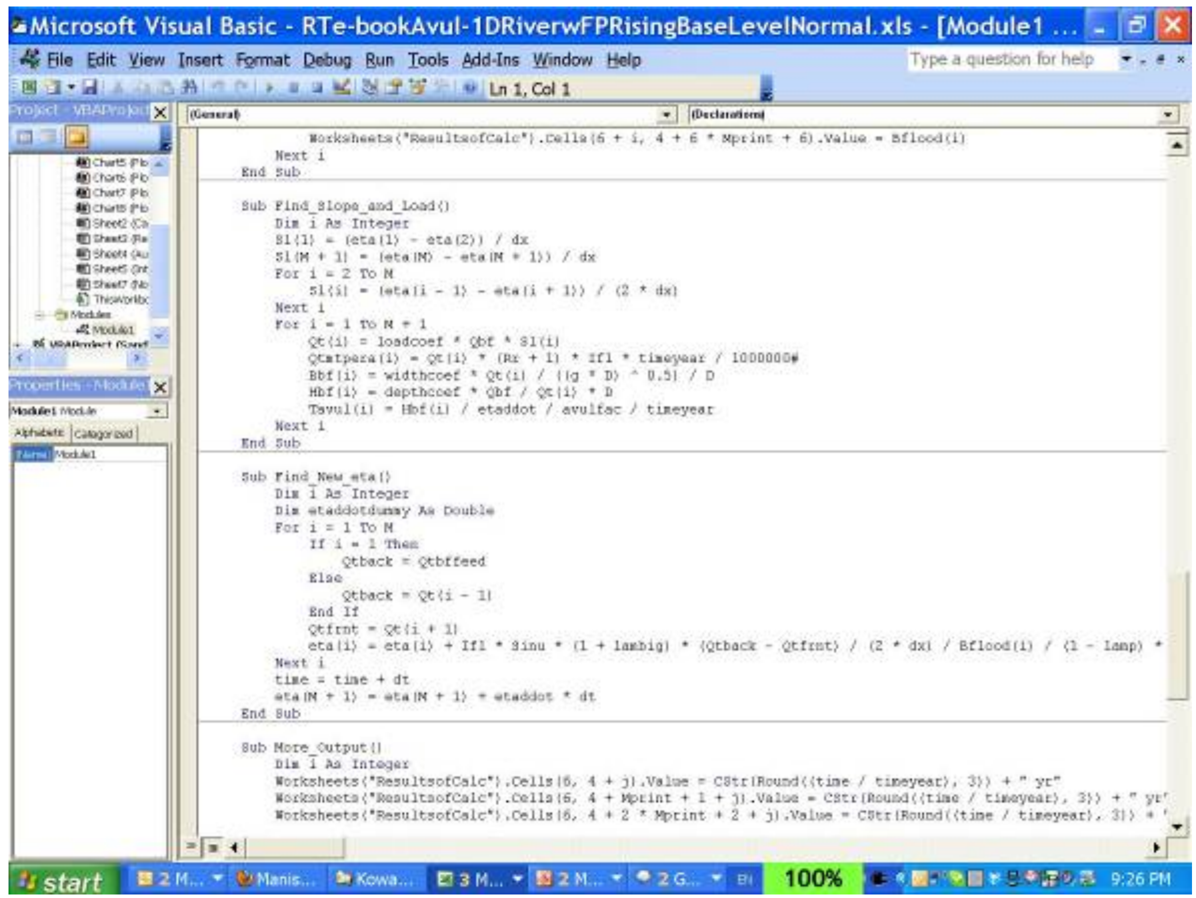
¬ Click for downloadable PowerPoint lectures.	35 files available
¬ Click for downloadable Excel files with embedded VBA code.	28 files available
¬ Click for downloadable Word files with extended explanation.	5 files available
¬ Click for downloadable video clips in mpg format.	13 files available

What the hell??.....

~~Fortran?~~ ~~C++?~~ ~~Python?~~ ~~Matlab?~~ ~~C#?~~ ~~Java?~~

VISUAL BASIC FOR APPLICATIONS (VBA) IN EXCEL

The Manischewitz Wine of Programming



UH, IT NEVER GOT QUITE FINISHED

Part 1: 1D Sediment Transport

13 Chapters (All Loaded)

Part 2: Morphodynamics of Rivers

18 Chapters (All Loaded)

Part 3: Fluvial Fans and Fan-deltas

4 Chapters Loaded

4 Chapters ***Done but not Loaded***

6 Chapters ***Not Done***

Part 4: Morphodynamics of Subaqueous Fans and Fan-deltas Deposited by Turbidity Currents, and Co-evolving Fluvial/Turbidity Current Fan-deltas

8 Chapters, ***more or less Done, none Loaded***

IT'S NOT A TOY, REALLY, IT'S GOOD FOR RESEARCH AS WELL AS TEACHING…

I mean like, rilly

AVULSION FREQUENCY OF THE MIDDLE MISSISSIPPI RIVER DURING HOLOCENE SEA LEVEL RISE, 10,000 – 4,000 BP

Eric Prokocki, Geology, University of Illinois
(but based on MS with Mike Blum, then at LSU)

CHANNEL-FORMING FLOW: SOME E-BOOK PARAMETERS

Q_{bf} = bankfull discharge
Q_{tbf} = total bed material load at bankfull discharge
I_f = flood intermittency for bankfull discharge ($I_f Q_{tbf}$ = mean annual bed material load)
B_{bf} = bankfull width
H_{bf} = bankfull depth
U_{bf} = bankfull flow velocity
S = bed slope
D = characteristic surface grain size

ν = kinematic viscosity of water
R = (ρ_s/ρ – 1) = sediment submerged specific gravity (~ 1.65 for natural sediment)
g = gravitational acceleration
λ_p = porosity of bed sediment

EQUATIONS AND DIMENSIONLESS PARAMETERS

Chezy-type resistance relation: C_f and $Cz = C_f^{-1/2}$ are resistance coefficients

$$C_f U_{bf}^2 = gH_{bf}S \quad \text{or} \quad U_{bf} = Cz\sqrt{H_{bf}S}$$

Bankfull Shields number

$$\tau_{bf}^* = \frac{H_{bf}S}{RD}$$

Dimensionless grain size

$$D^* = \left(\frac{\sqrt{RgD}\,D}{\nu}\right)^{2/3} = \mathbf{Re}_p^{2/3}$$

Dimensionless bankfull discharge bankfull bed material discharge, width, depth

$$\hat{Q} = \frac{Q_{bf}}{\sqrt{gD}\,D^2} \quad , \quad \hat{Q}_t = \frac{Q_{tbf}}{\sqrt{gD}\,D^2} \quad , \quad \hat{B} = \frac{B_{bf}}{D} \quad , \quad \hat{H} = \frac{H_{bf}}{D}$$

CHAPTER 3:
BANKFULL CHARACTERISTICS OF RIVERS

Alluvial rivers construct their own channels and floodplains. Channels and floodplains co-evolve over time.

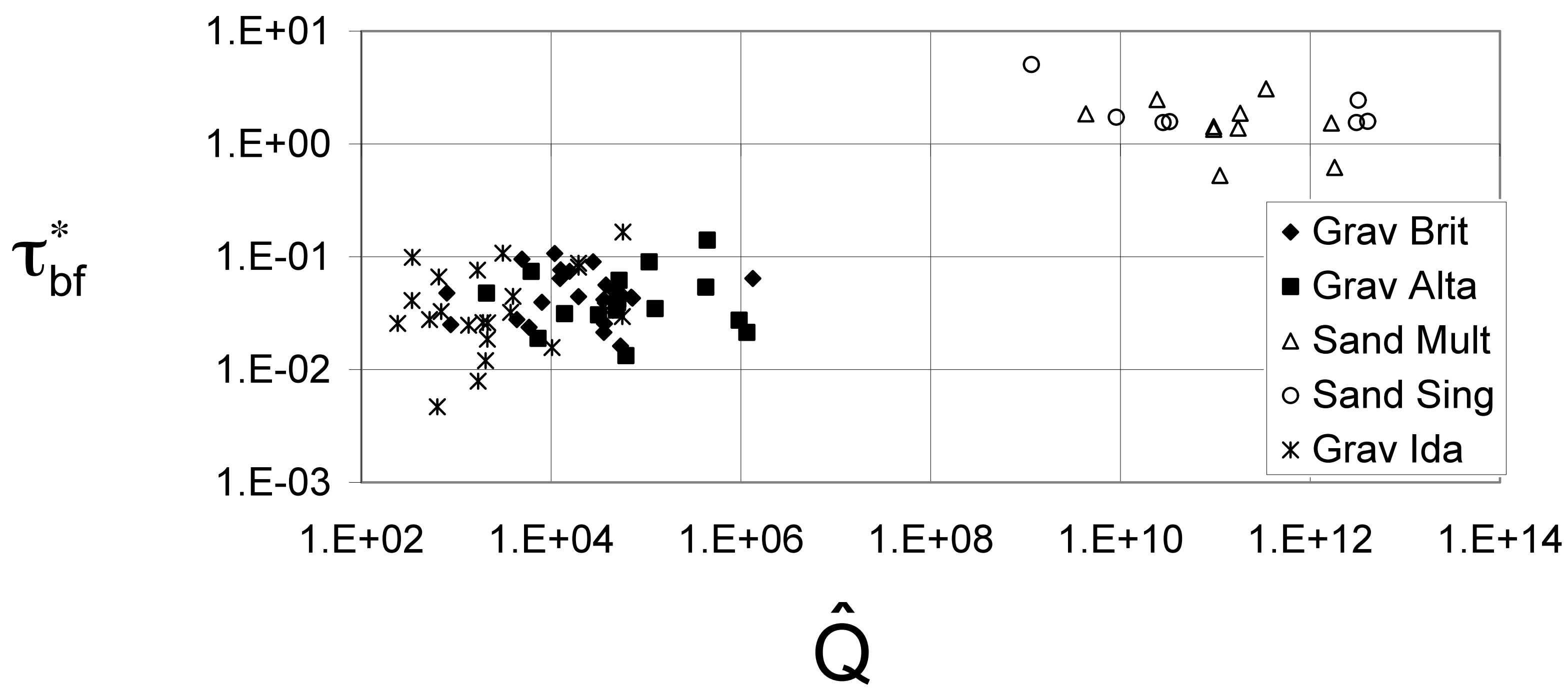
Nameless Siberian stream and floodplain. Image courtesy A. Alabyan and A. Sidorchuk.

Browns Gulch, Montana

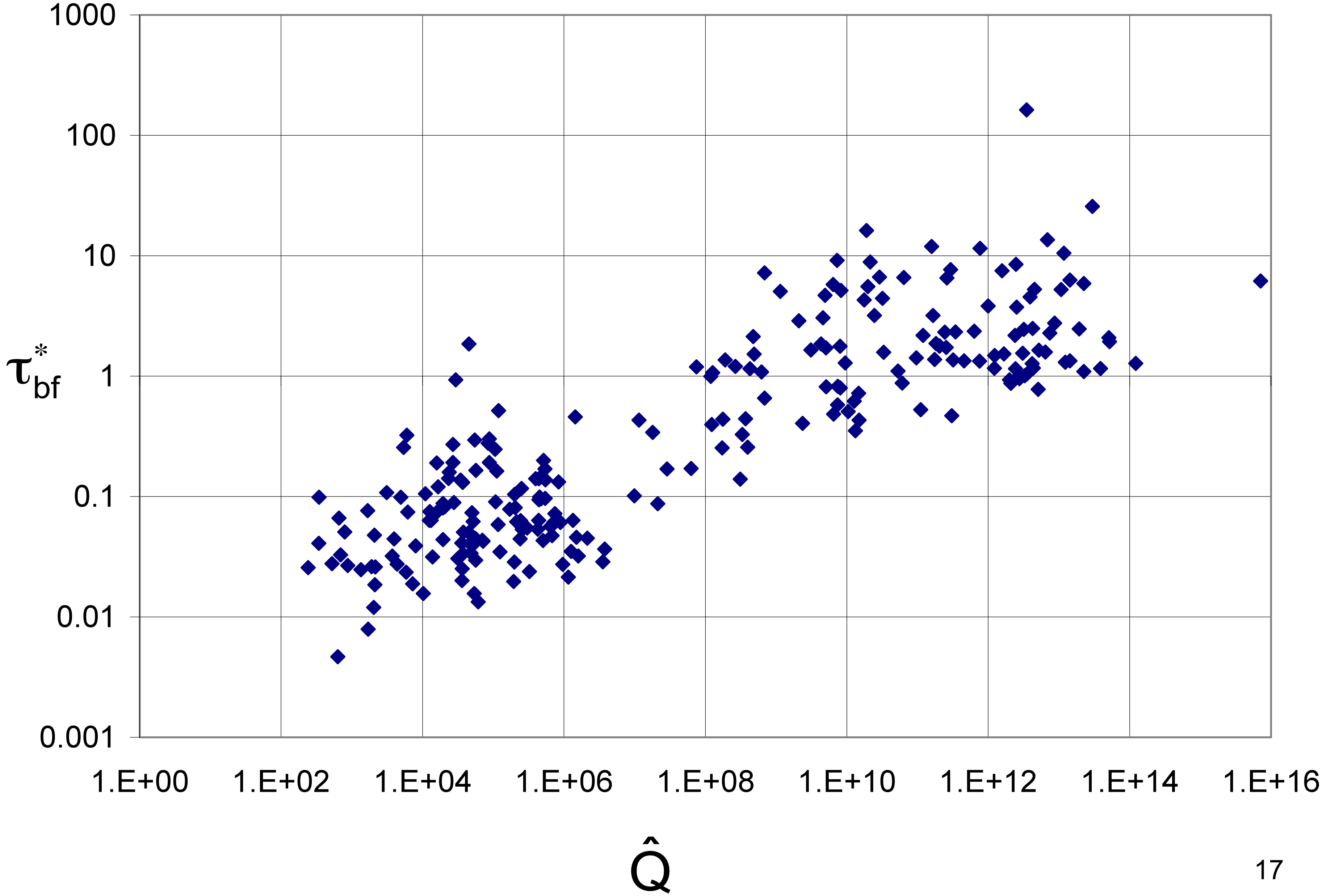
THEN: BANKFULL SHIELDS NUMBER

BANKFULL SHIELDS NUMBER VERSUS DIMENSIONLESS DISCHARGE

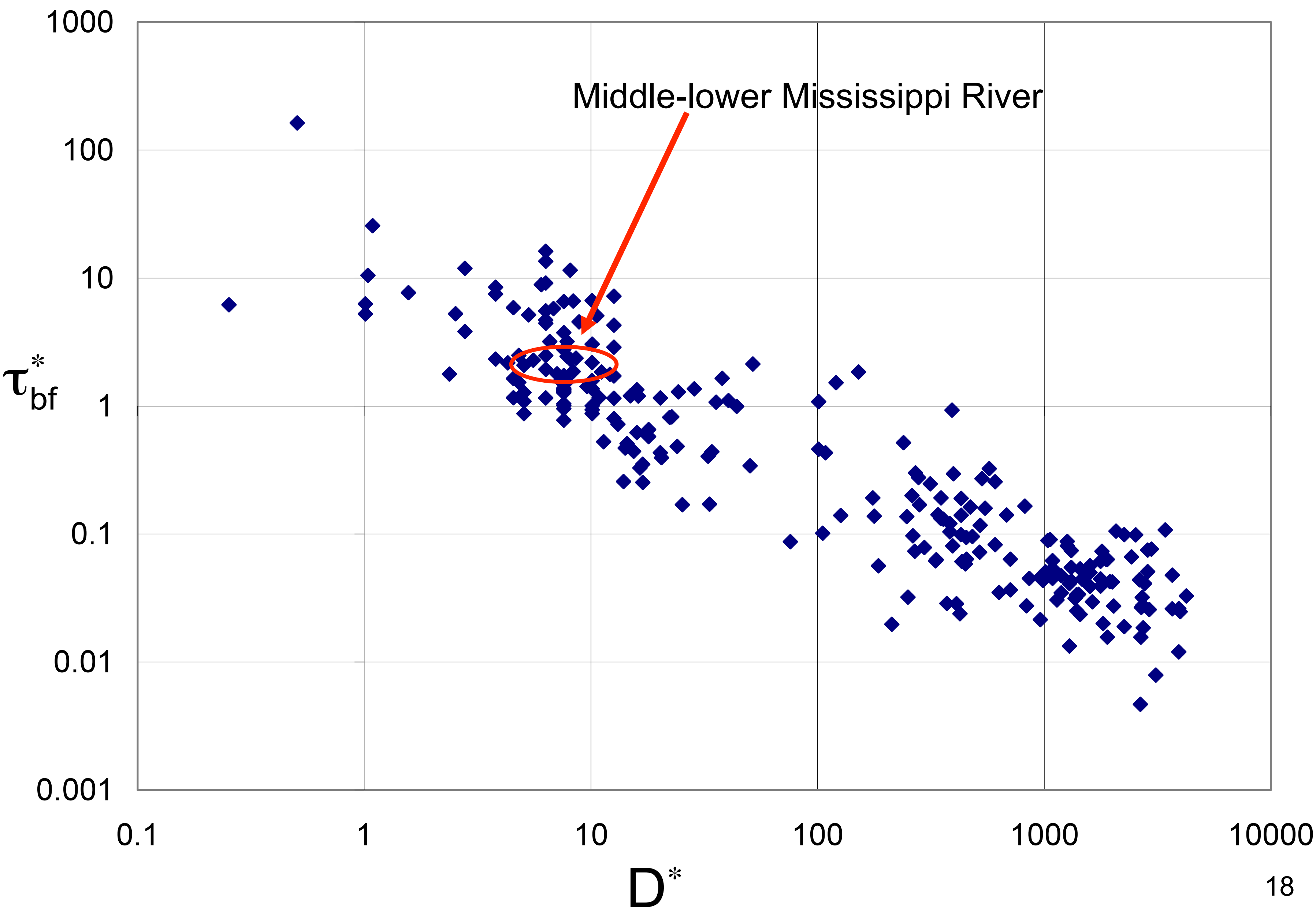
“Gravel-bed streams maintain a bankfull Shields stress that is loosely about 0.05. Sand-bed streams maintain a bankfull Shields stress that is loosely about 1.9.”



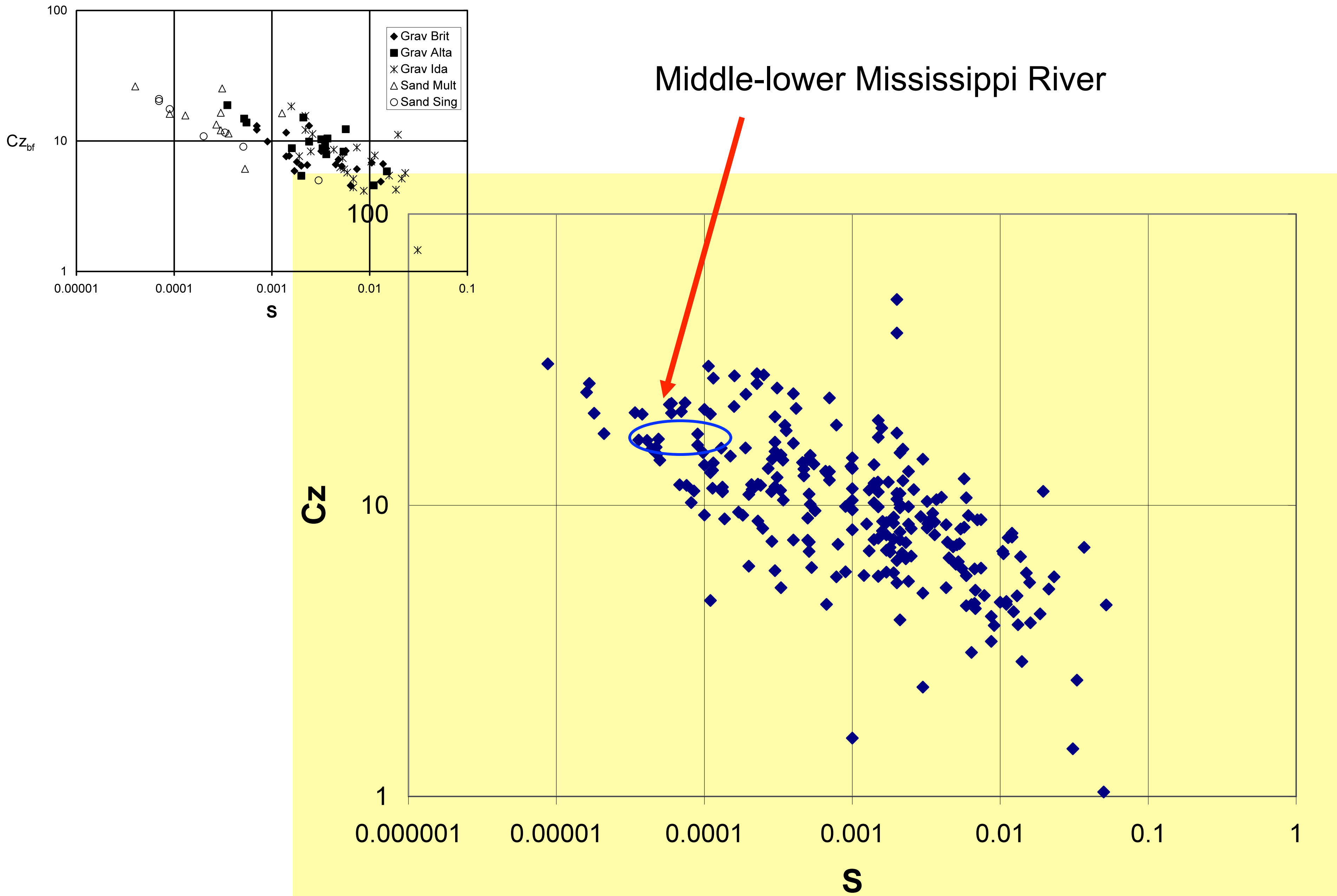
NOW: BANKFULL SHIELDS NUMBER



NOW: BANKFULL SHIELDS NUMBER



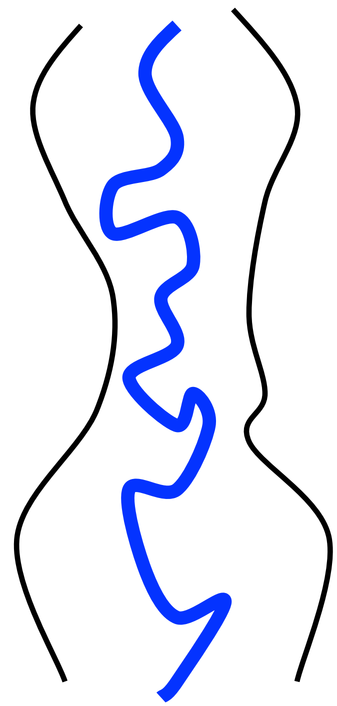
THEN AND NOW: CHEZY RESISTANCE COEFFICIENT



THE PROBLEM

Middle Mississippi River during late Holocene sea level rise.

- 10,000 – 4,000 years BP
- 3.5 mm/year sea level rise
- Apparently 5 avulsions over 6000 years near Memphis, Tennessee

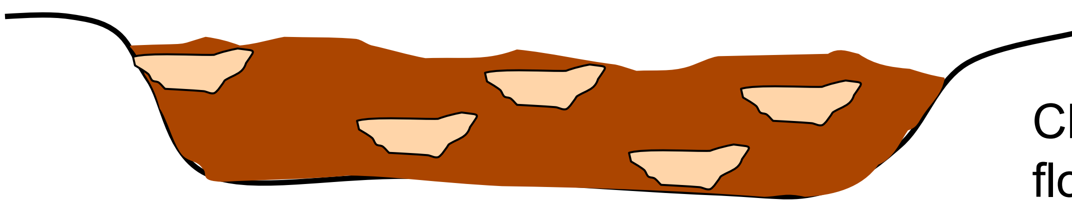


Questions

1. Why a mean avulsion period T_a of ~ 830 years, frequency F_a ~ 0.0012 per year?
2. Do large-scale variations in floodplain width influence local avulsion frequency?

SOME PARAMETERS

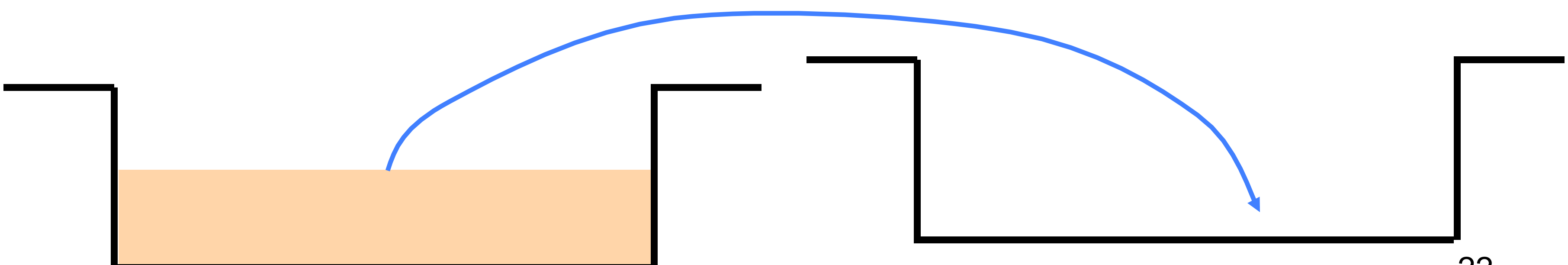
Parameter	Now?	Then?
Reach length L km	> 600	~ 500 km (transgression)
Floodplain width B_f km	30 km	30 km
Q_{bf} m^3/s	30,000	40,000?
Q_{tbf} Mt/a	30	70?
Cz	15	15?
D mm	0.25	0.25?
τ_{bf}^*	1.9	1.9?
Sinuosity Ω	1.5 – 2.0	1.5? (quasi-braided?
Mud contained per unit sand Λ In channel-floodplain complex	1.5	1.5?



Channel deposits within floodplain

SIMPLEST FIRST-ORDER FORMULATION
(Can add many other factors in a refined model)

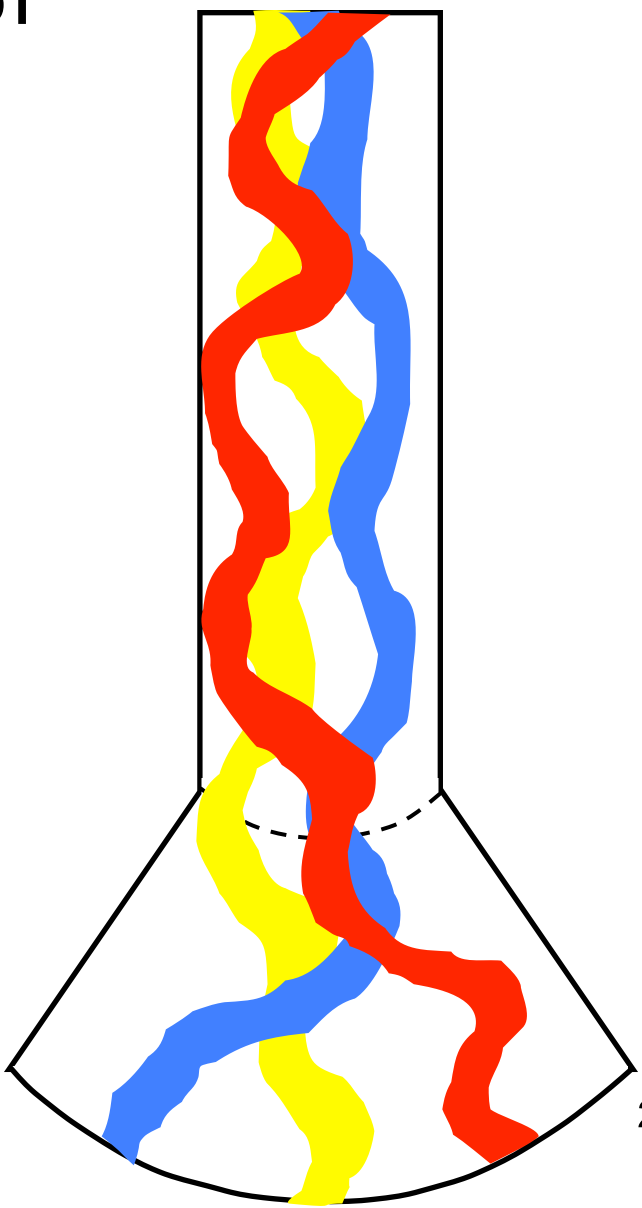
1. Normal flow model (easy to add backwater)
2. Set base level rise rate at downstream end: throw out details of delta formation/progradation/transgression/regression for now
3. No tributaries
4. Single sand grain size (not too difficult to add multiple grain sizes
5. Assume that evolution is slow enough to use a *virtual channel*
6. Assume that channel and floodplain have time to co-evolve in long term
7. Base avulsion period on time for channel to aggrade to **half of bankfull depth** (Paola, Mohrig, Straub etc.)



THE CHANNEL(s) HAS (have) SPECIFIED BANKFULL CHARACTERISTICS, BUT NOT POSITION

- The channel (or amalgamated channels) are assumed to avulse across the available space and fill it by deposition.

- The model is designed to capture the **long-term** evolution of the system, and not the details at any specific time



CHAPTER 24:

APPROXIMATE FORMULATION FOR SLOPE AND BANKFULL GEOMETRY OF RIVERS

$$C_f \frac{Q_{bf}^2}{B_{bf}^2 H_{bf}^2} = g H_{bf} S$$

momentum balance

$$Q_{tbf} = B_{bf} q_{tbf} = \frac{\alpha_{EH}}{C_f} B_{bf} \sqrt{RgD}\, D \left(\tau_{bf}^*\right)^{5/2}$$

bed material transport:
Engelund-Hansen

$$\tau_{bf}^* = \frac{H_{bf} S}{RD} = \text{const.} \equiv \tau_{form}^*$$

τ_{form}^* = *channel-formative Shields number*

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APPROXIMATE FORMULATION FOR SLOPE AND BANKFULL GEOMETRY OF RIVERS

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$$\tau_{bf}^* = \frac{H_{bf} S}{RD} = \text{const.} \equiv \tau_{form}^*$$

$\rightarrow$

$$\hat{B} = \frac{C_f}{\alpha_{EH} \left(\tau_{form}^*\right)^{2.5}} \hat{Q}_t$$

$$S = \frac{R^{3/2} C_f^{1/2}}{\alpha_{EH} \tau_{form}^*} \frac{\hat{Q}_t}{\hat{Q}}$$

$$\hat{H} = \frac{\alpha_{EH} \left(\tau_{form}^*\right)^2}{\left(R C_f\right)^{1/2}} \frac{\hat{Q}}{\hat{Q}_t}$$

where

$$\hat{Q} = \frac{Q_{bf}}{\sqrt{gD}\, D^2} \quad , \quad \hat{Q}_t = \frac{Q_{tbf}}{\sqrt{gD}\, D^2} \quad , \quad \hat{B} = \frac{B_{bf}}{D} \quad , \quad \hat{H} = \frac{H_{bf}}{D}$$

ENGELO-HANSO-PAOLAESQUE SEDIMENT TRANSPORT RELATION

$$Q_{tbf} = \frac{\alpha_{EH} \tau^{*}_{form}}{R^{3/2} C_f^{1/2}} Q_{bf} S$$

CHAPTER 25:

LONG PROFILES OF RIVERS, WITH AN APPLICATION ON THE EFFECT OF BASE LEVEL RISE ON LONG PROFILES

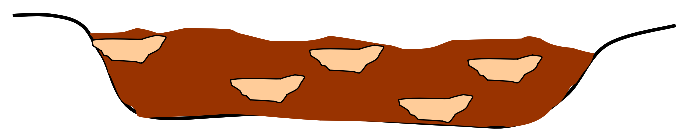
Parameters

η = mean elevation of channel-floodplain complex

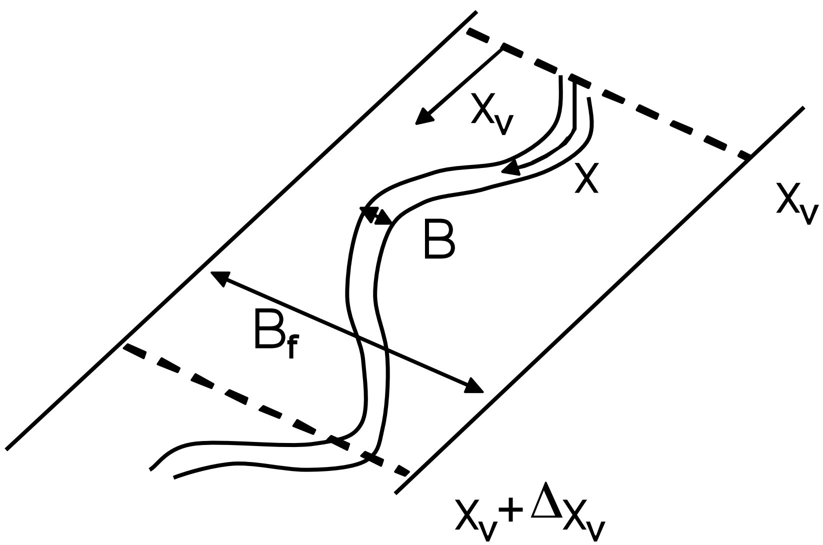
x, x_v = down-channel, down-valley distance

Ω = channel sinuosity

Λ = unit mud (wash load) deposited per unit sand (bed material load) in channel-floodplain complex



Exner equation of sediment balance



$$(1-\lambda_p)B_f\frac{\partial\eta}{\partial t} = -\Omega I_f(1+\Lambda)\frac{\partial Q_{tbf}}{\partial x}$$

REDUCTION OF THE EXNER EQUATION

The Exner equation can be expressed as

$$\frac{\partial \eta}{\partial t} = -\frac{I_f \Omega (1+\Lambda)}{(1-\lambda_p)B_f} \frac{\partial Q_{tbf}}{\partial x}$$

Reducing with the sediment transport relation

$$Q_{tbf} = \frac{\alpha_{EH} \tau^*_{form}}{R C_f^{1/2}} Q_{bf} S$$

it is found that

$$\frac{\partial \eta}{\partial t} = \kappa_d \frac{\partial^2 \eta}{\partial x^2} \quad , \quad \kappa_d = \frac{I_f \Omega (1+\Lambda)}{(1-\lambda_p)B_f} \frac{\alpha_{EH} \tau^*_{form} Q_{bf}}{R C_f^{1/2}}$$

where κ_d denotes a kinematic sediment diffusivity. Note that the resulting form is a *linear* diffusion equation.

BASE LEVEL RISE AS DOWNSTREAM BOUNDARY CONDITION

$\dot{\xi}_d$ = rate of base level rise (here 3.5 mm/year)

L = reach length

$$\eta(L,t) = \xi_{do} + \dot{\xi}_d t$$

Deviatoric bed elevation $\eta_{dev}(x,t) = \eta - \eta(L,t)$

$$\eta = \xi_{do} + \dot{\xi}_d t + \eta_{dev}(x,t)$$

$$\eta_{dev}(L,t) = 0$$

$$\frac{\partial \eta_{dev}}{\partial t} + \dot{\xi}_d = -\frac{I_f \Omega(1+\Lambda)}{(1-\lambda_p)B_f}\frac{\partial Q_{tbf}}{\partial x} \quad \text{or} \quad \frac{\partial \eta_{dev}}{\partial t} + \dot{\xi}_d = \kappa_d \frac{\partial^2 \eta_{dev}}{\partial x^2} \quad , \quad \kappa_d = \frac{I_f \Omega(1+\Lambda)}{(1-\lambda_p)B_f}\frac{\alpha_{EH}\tau^*_{form}Q_{bf}}{RC_f^{1/2}}$$

AVULSION FREQUENCY AND FLOODPLAIN WIDTH VARIATION

F_a = avulsion frequency

B_{fo} = base floodplain width

ε_{BF} = dimensionless amplitude of floodplain width fluctuation

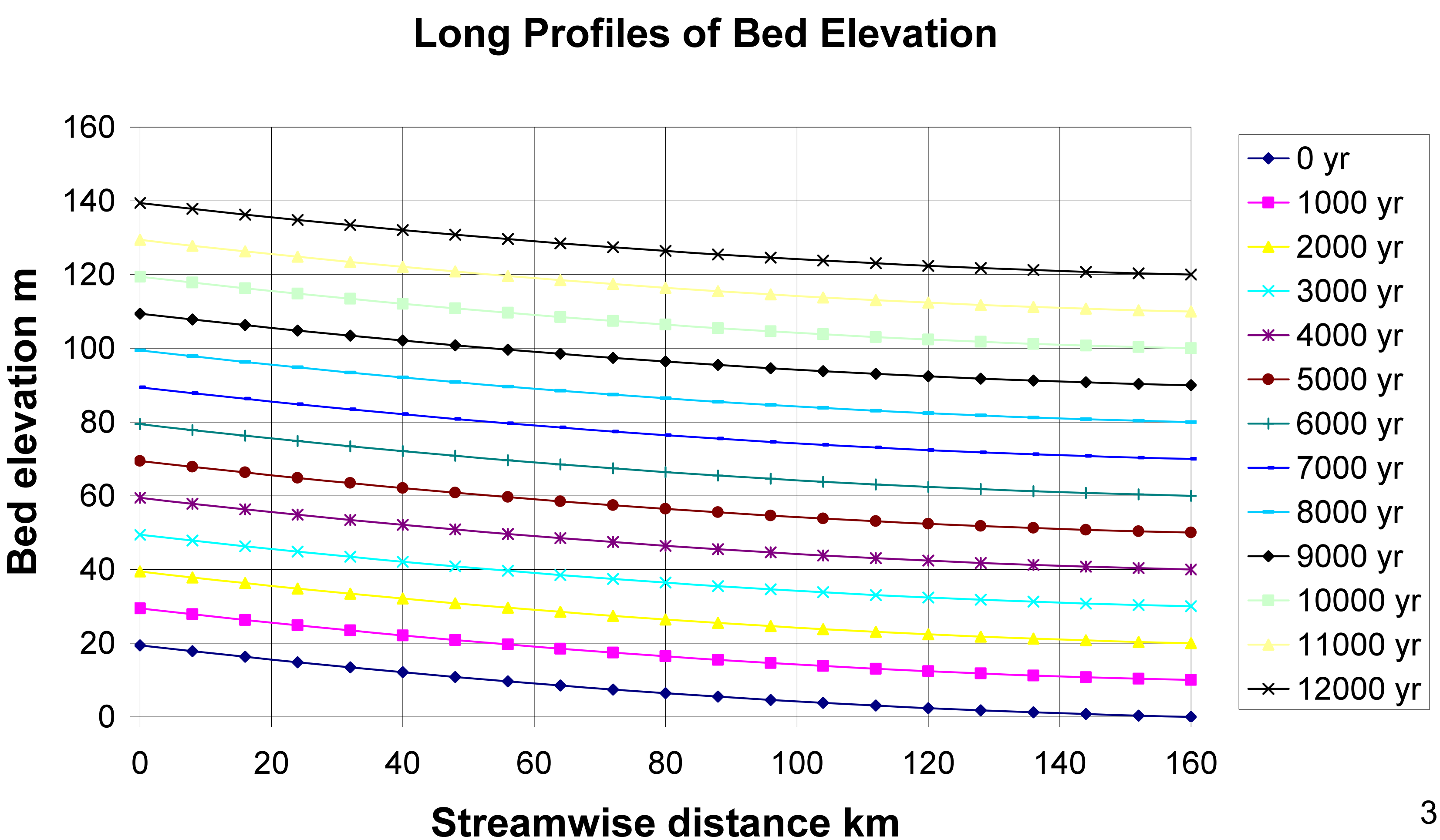
n = number of width variation wavelengths within total reach length L

$$F_a = \frac{1}{2}\left(\frac{\partial \eta}{\partial t}\right) \Big/ H_{bf}$$

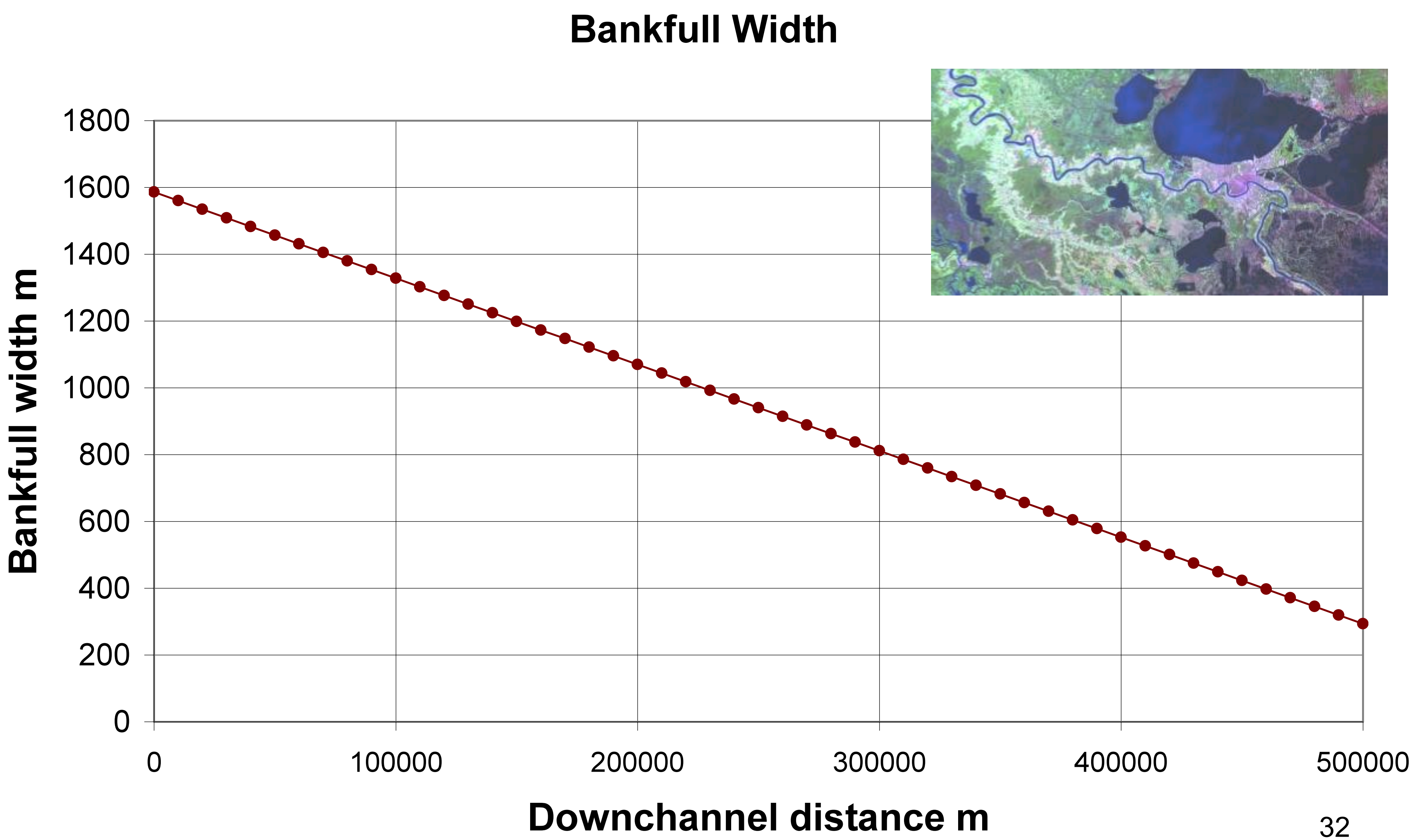
$$B_f = B_{fo}\left[1 + \varepsilon_{BF}\sin\left(2\pi n\frac{x}{L}\right)\right]$$

CALCULATIONS WITH MODIFIED VERSION OF
RTe-book1DRiverwFPRisingBaseLevelNormal.xls

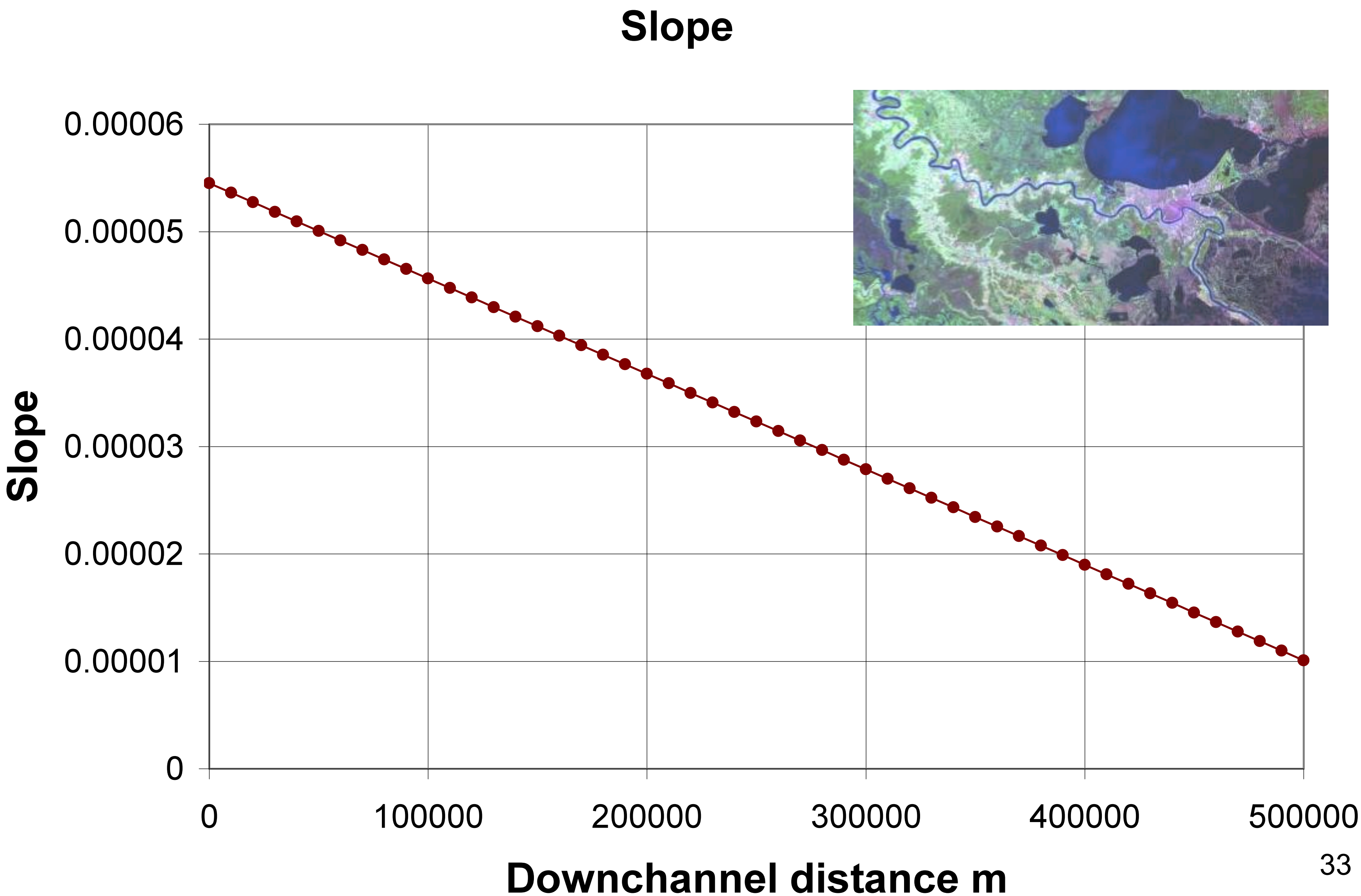
We look only at quasi-equilibrium aggradation, e.g. of the following form (ignore the numbers)



CASE:
today's river with 3.5 mm/year of imposed sea level rise, constant floodplain width

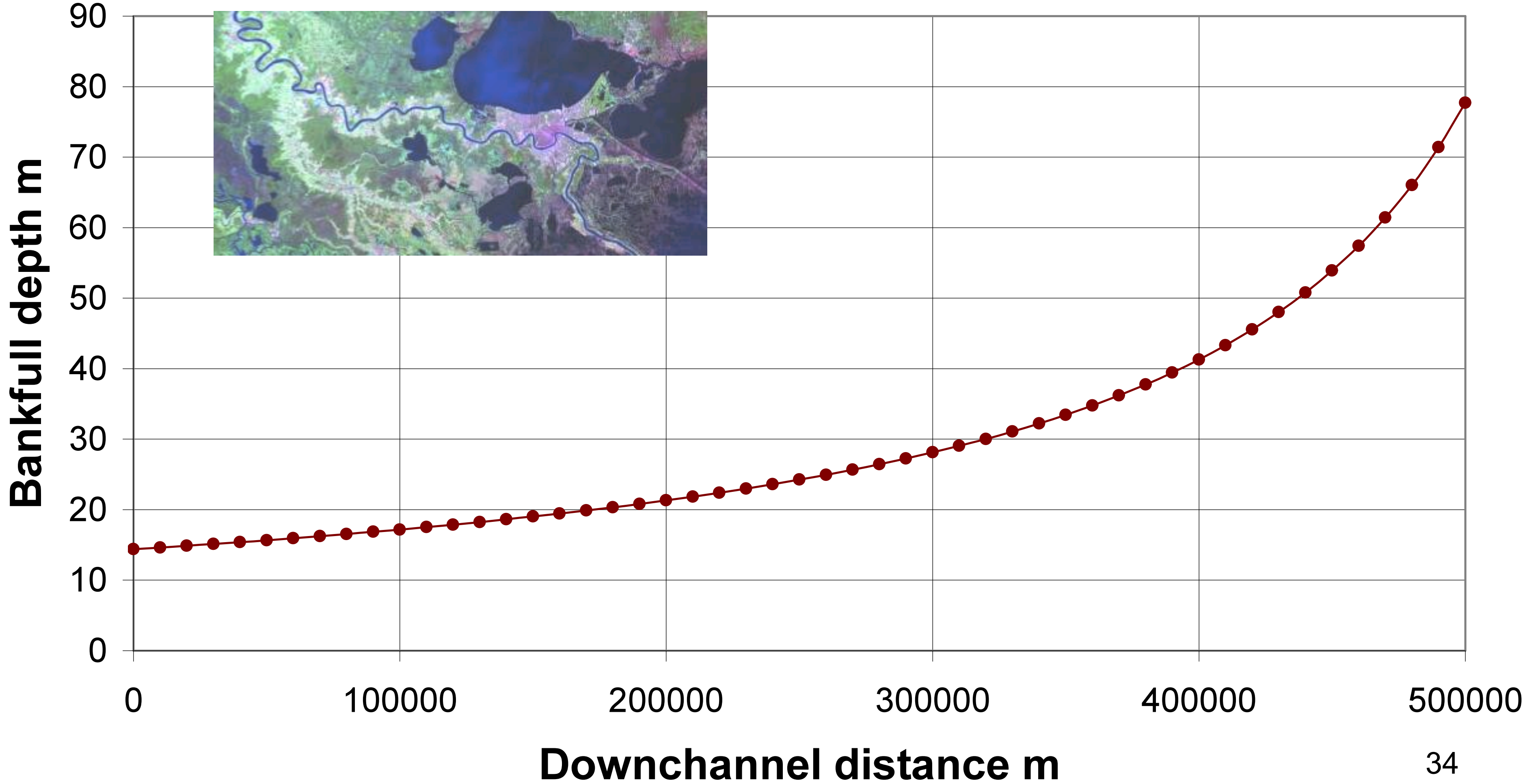


CASE:
today's river with 3.5 mm/year of imposed sea level rise, constant floodplain width

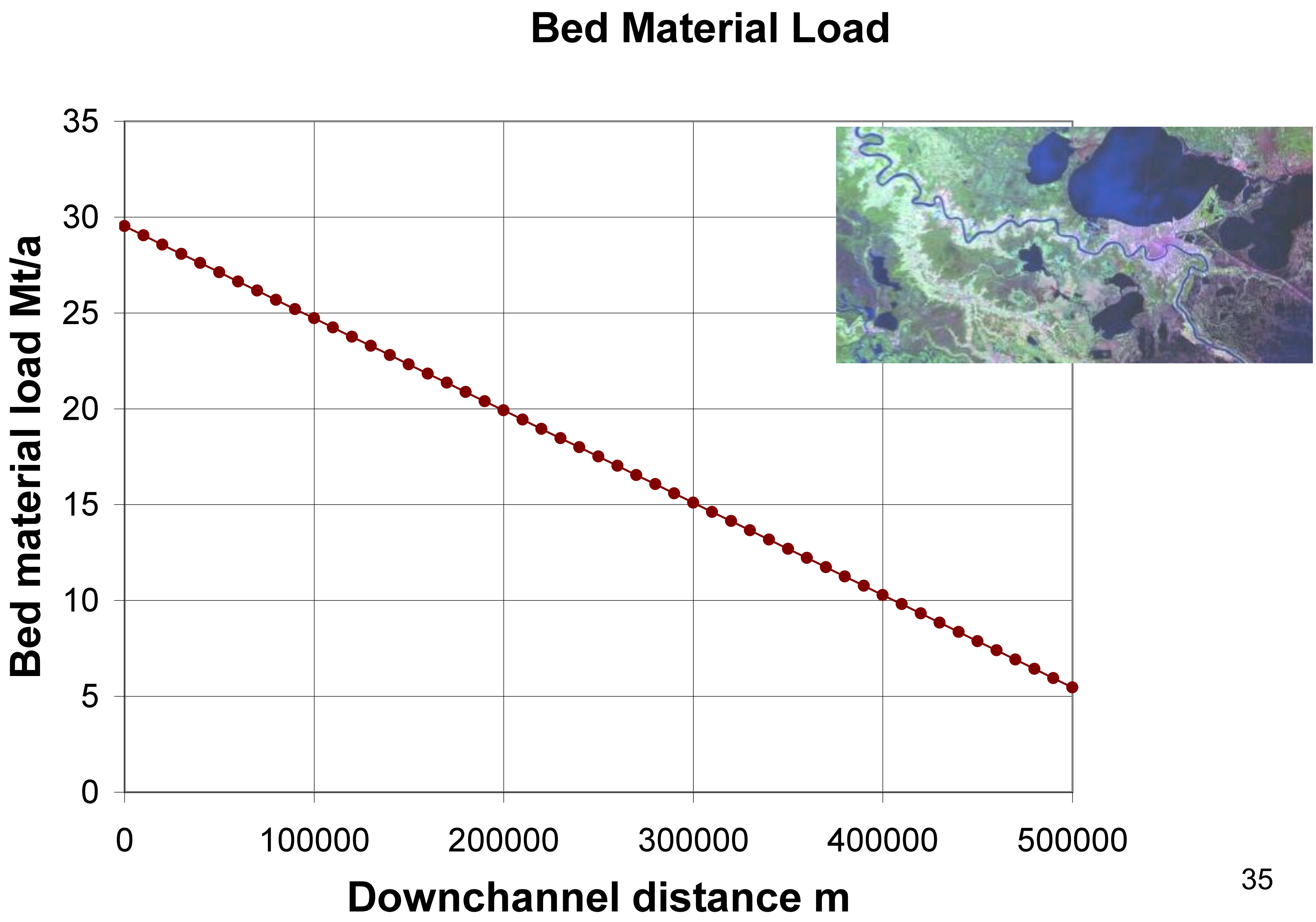


CASE:
today’s river with 3.5 mm/year of imposed sea level rise, constant floodplain width

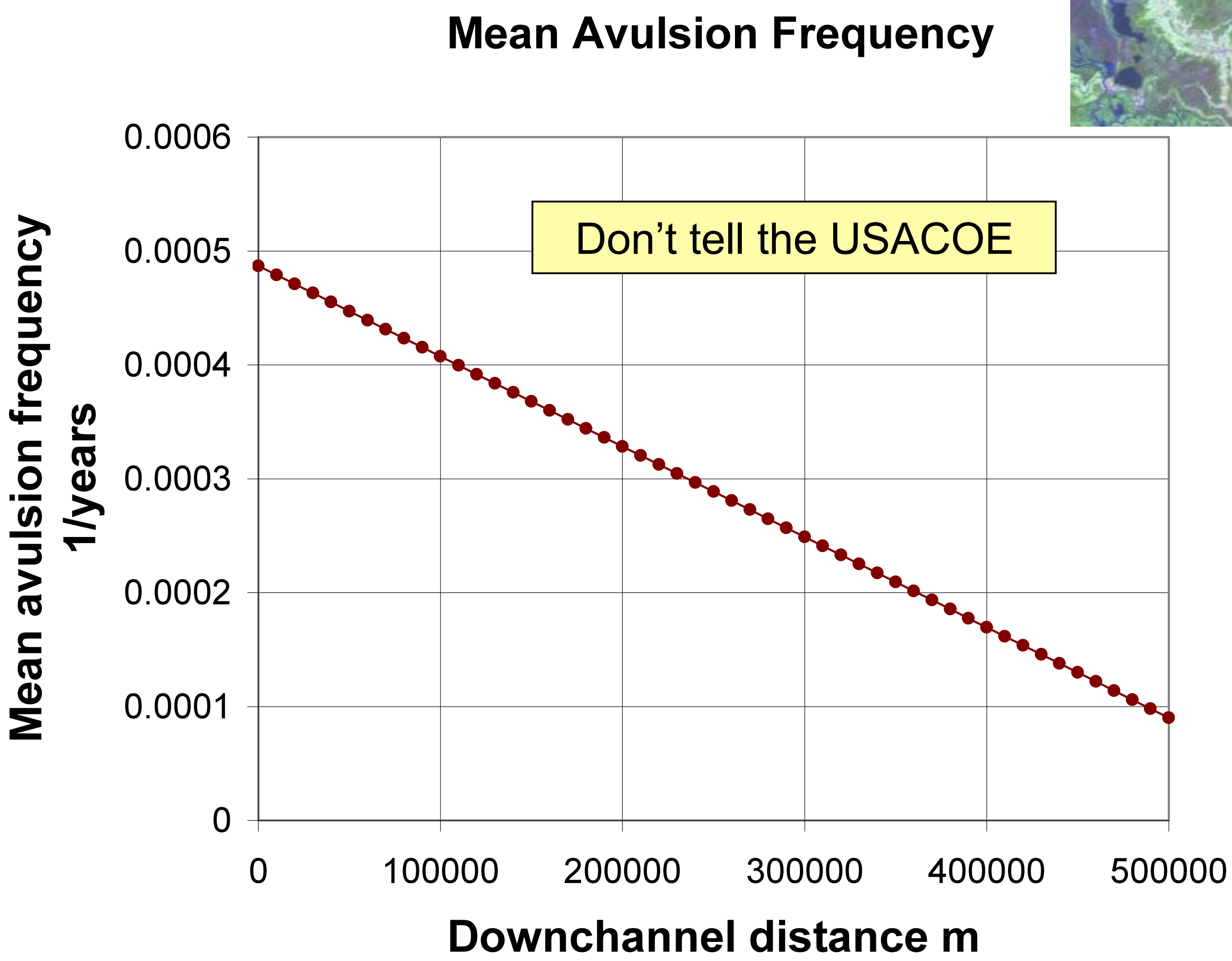
Bankfull Depth



CASE:
today's river with 3.5 mm/year of imposed sea level rise, constant floodplain width

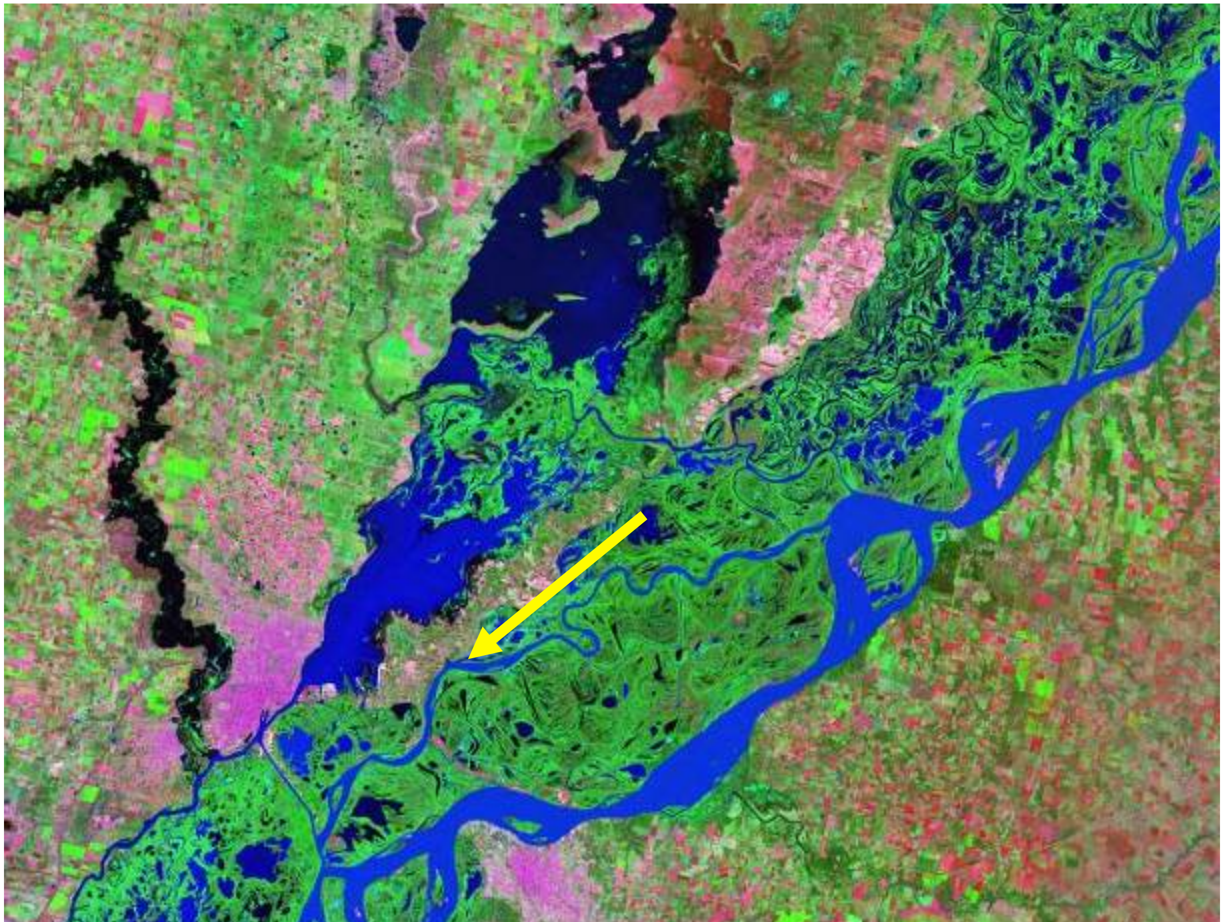


CASE:
today's river with 3.5 mm/year of imposed sea level rise, constant floodplain width



UPSTREAM ON AMAZON RIVER, BRAZIL, WE FIND MEANDERING RIVER ~ present-day Mississippi without levees?

"smaller" B_{bf}/H_{bf} ?

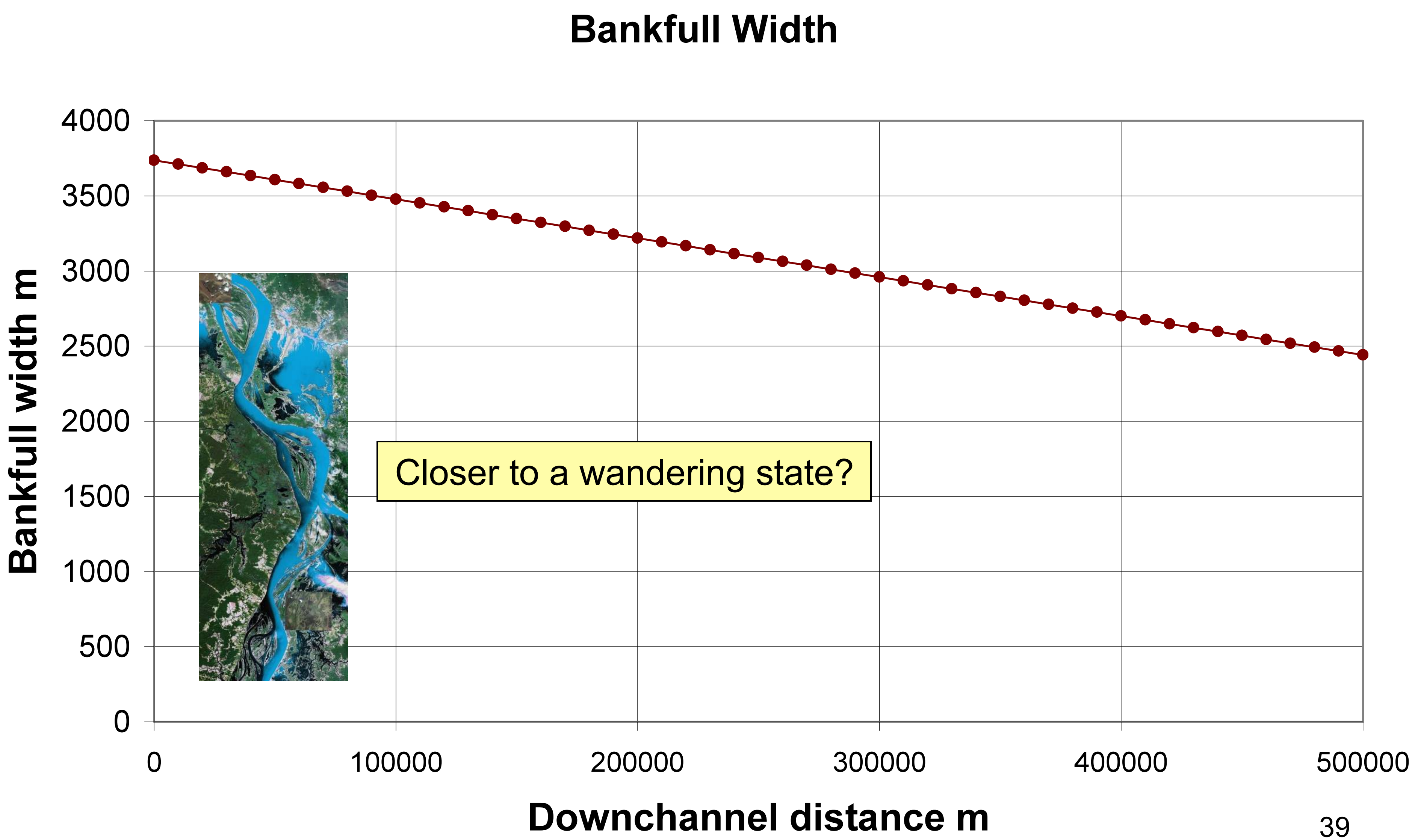


PARANÁ RIVER, ARGENTINA

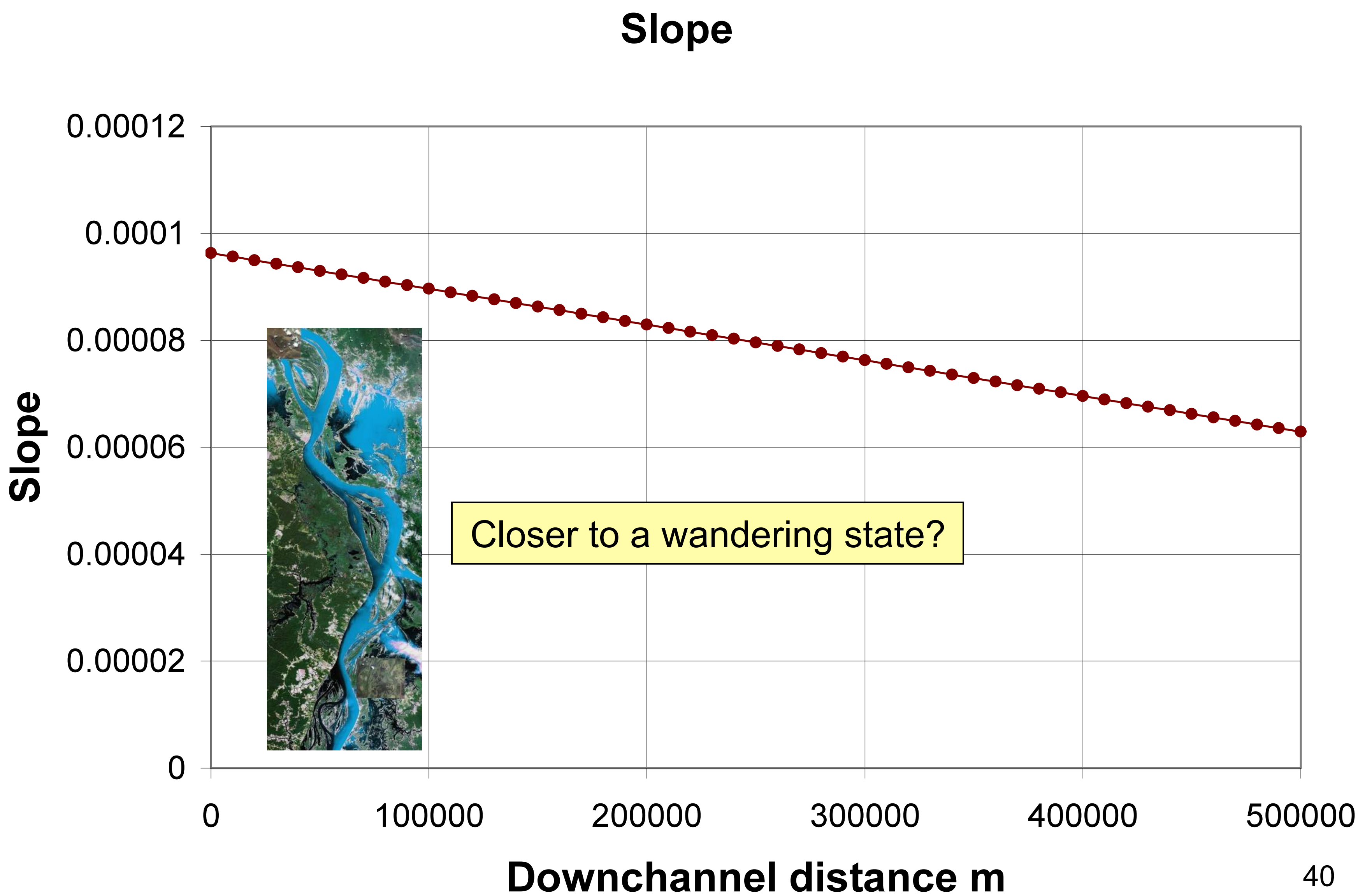
Wandering
Closer to Mississippi River, 10,000 – 4,000 BP?
“Larger B_{bf}/H_{bf}”

DOWNSTREAM AMAZON RIVER, BRAZIL

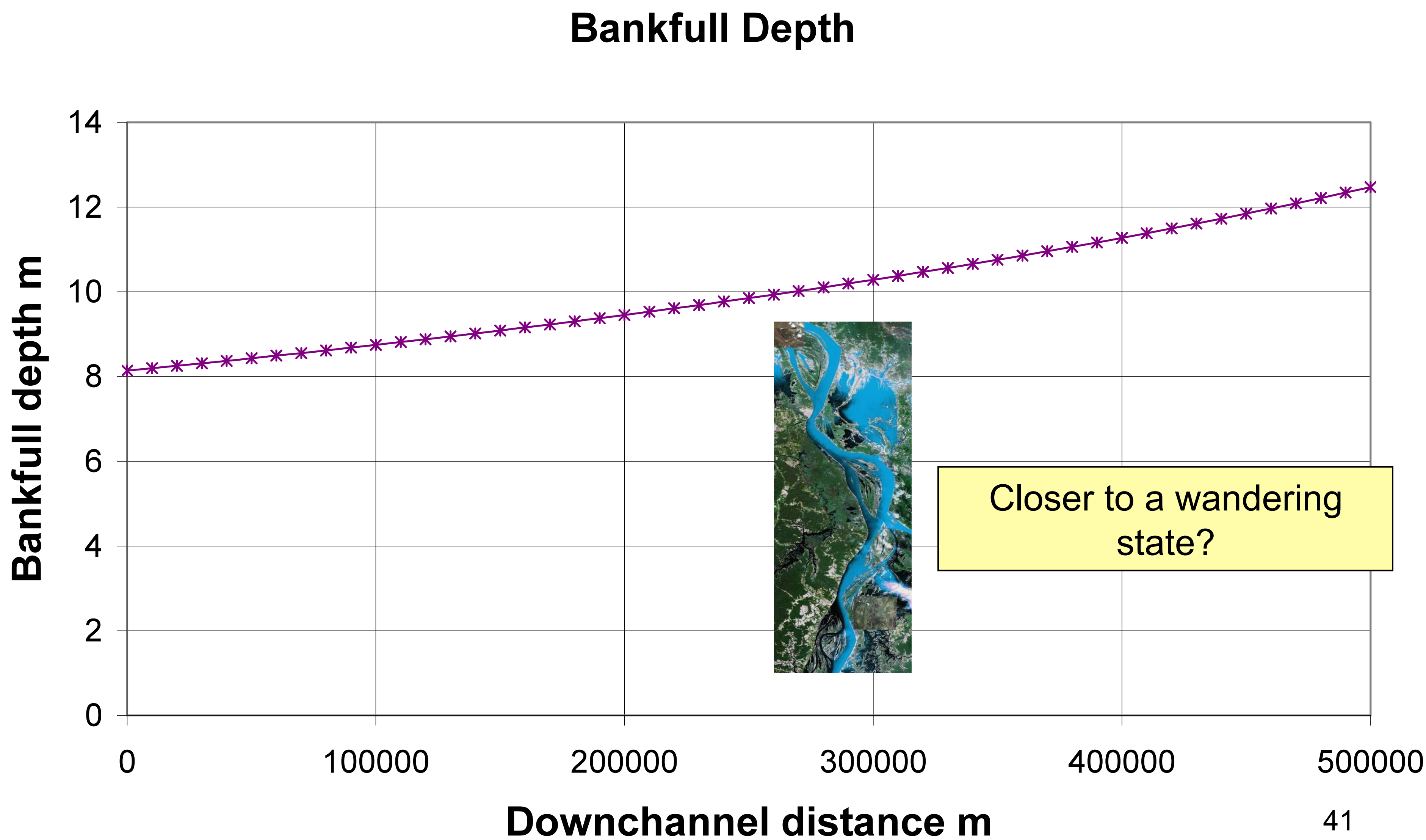
CASE:
10,000 to 4,000 BP with 3.5 mm/year of imposed sea level rise, constant floodplain width: *much wider*



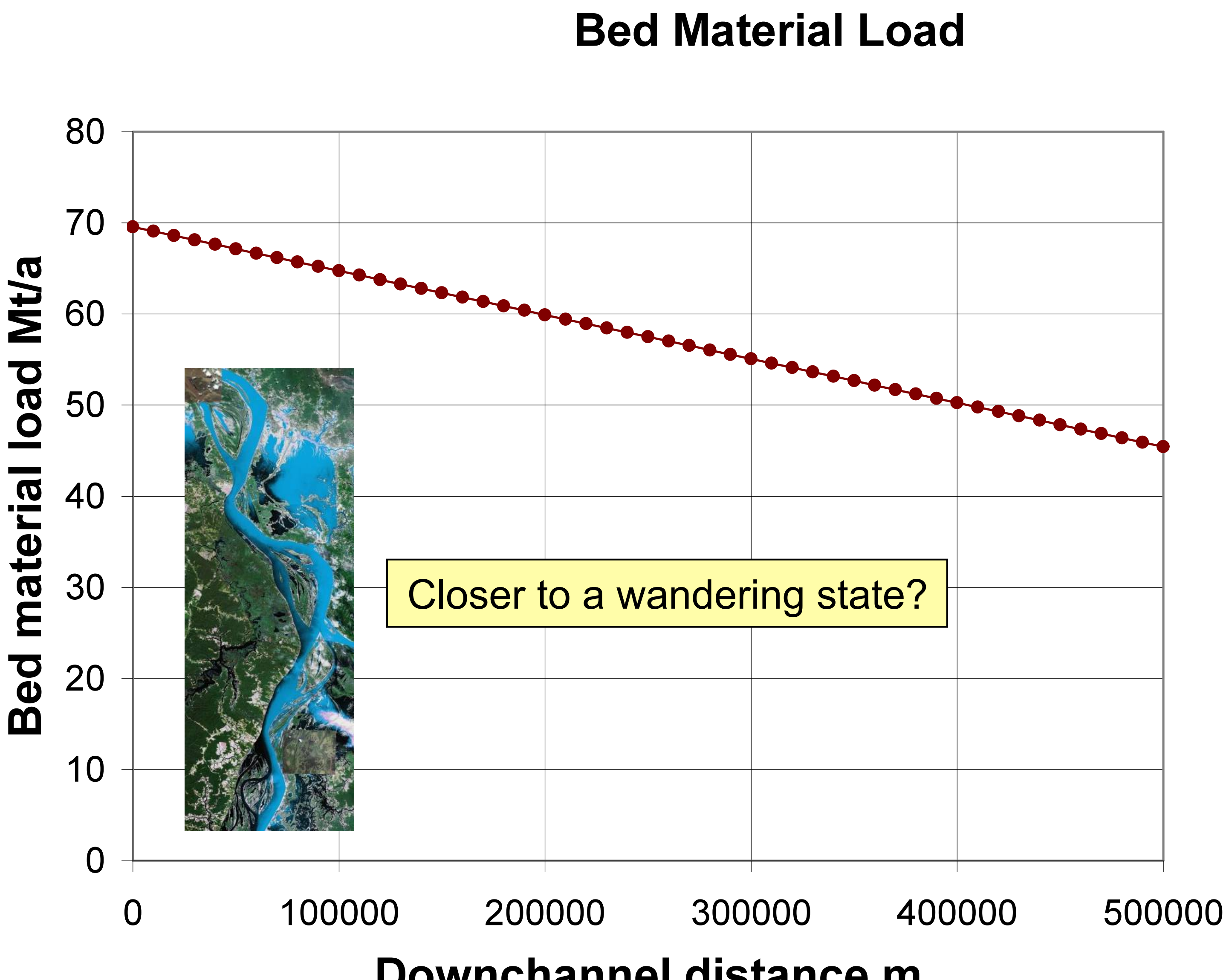
CASE:
10,000 to 4,000 BP with 3.5 mm/year of imposed sea level rise, constant floodplain width: *much steeper*



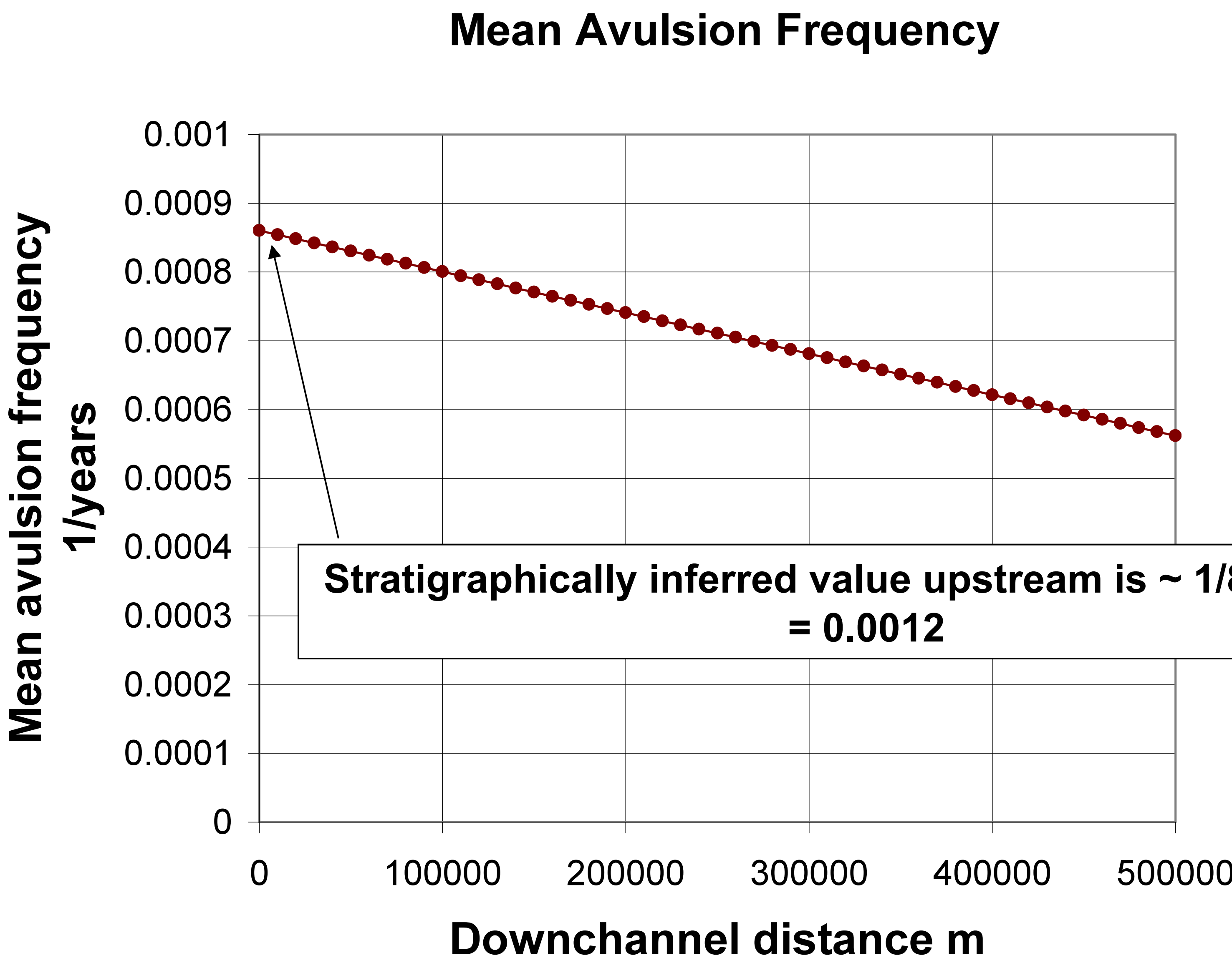
CASE:
10,000 to 4,000 BP with 3.5 mm/year of imposed sea level rise, constant floodplain width: *much shallower*



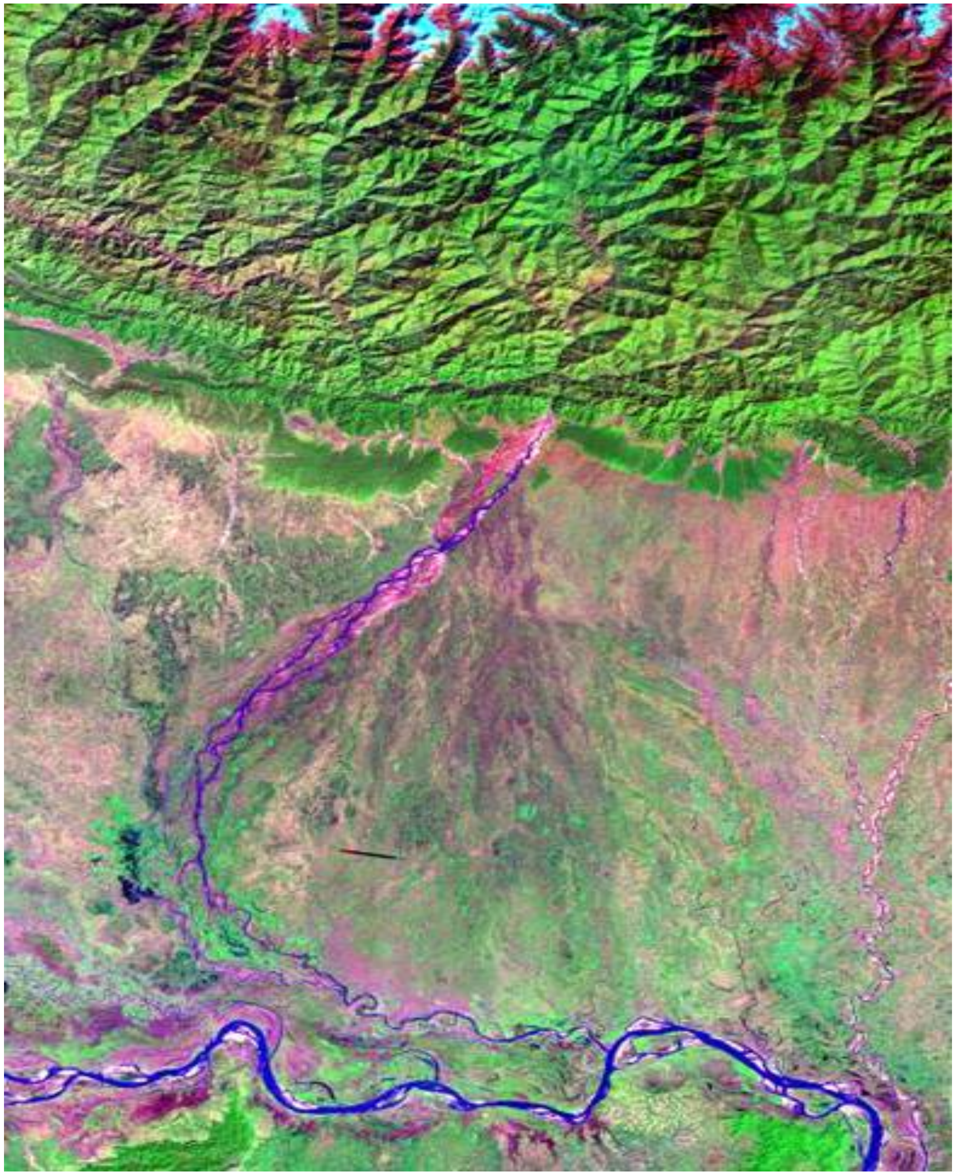
CASE:
10,000 to 4,000 BP with 3.5 mm/year of imposed sea level rise, constant floodplain width: *higher load*



CASE:
10,000 to 4,000 BP with 3.5 mm/year of imposed sea level rise, constant floodplain width

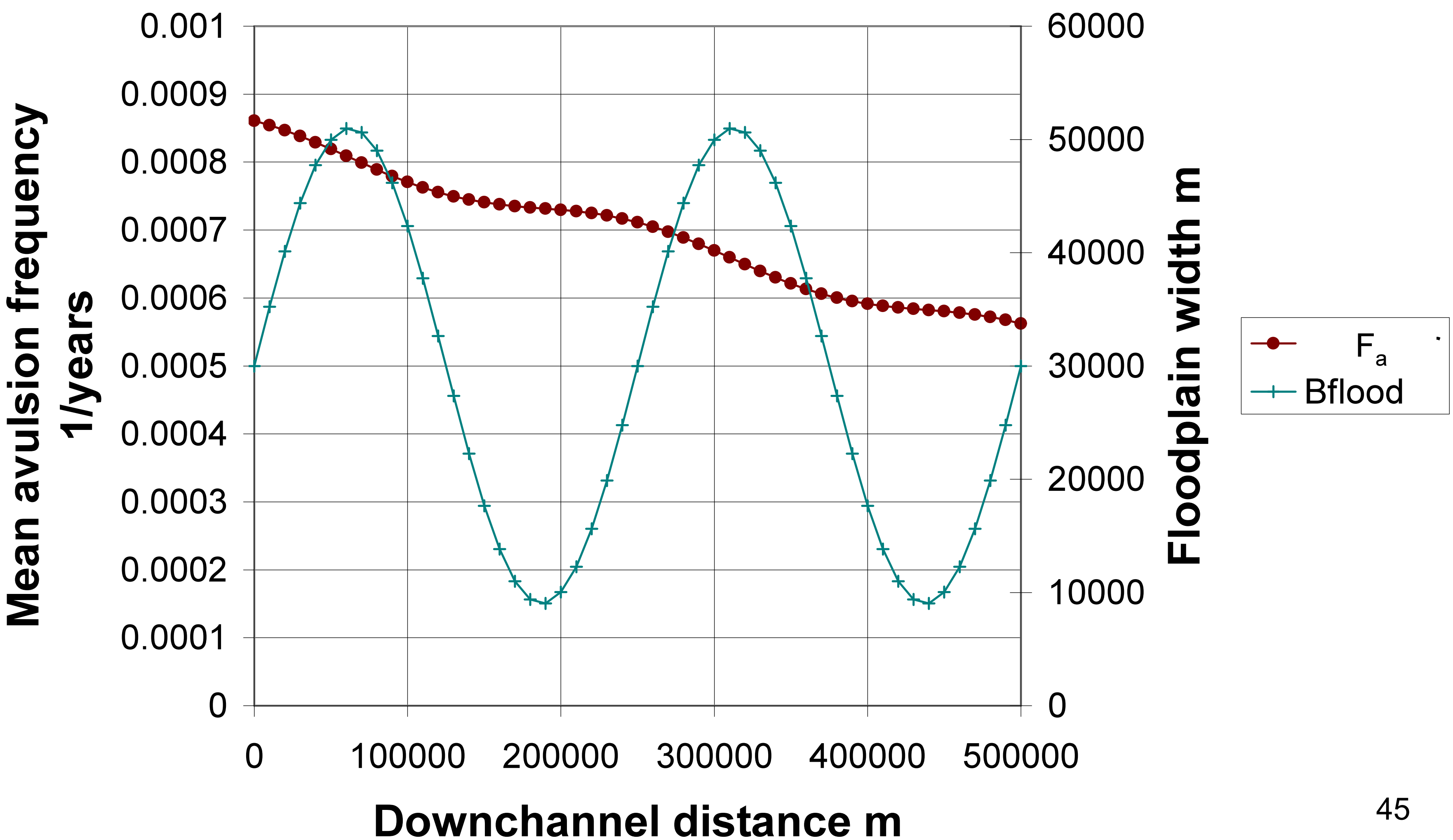


A MODERN ANALOG ??? TO MISSISSIPPI RIVER 10,000 TO 4,000 BP:
Kosi River, India (recently avulsed)



CASE:
10,000 to 4,000 BP with 3.5 mm/year of imposed sea level rise, varied floodplain width, n = 2, ε_{BF} = 0.7

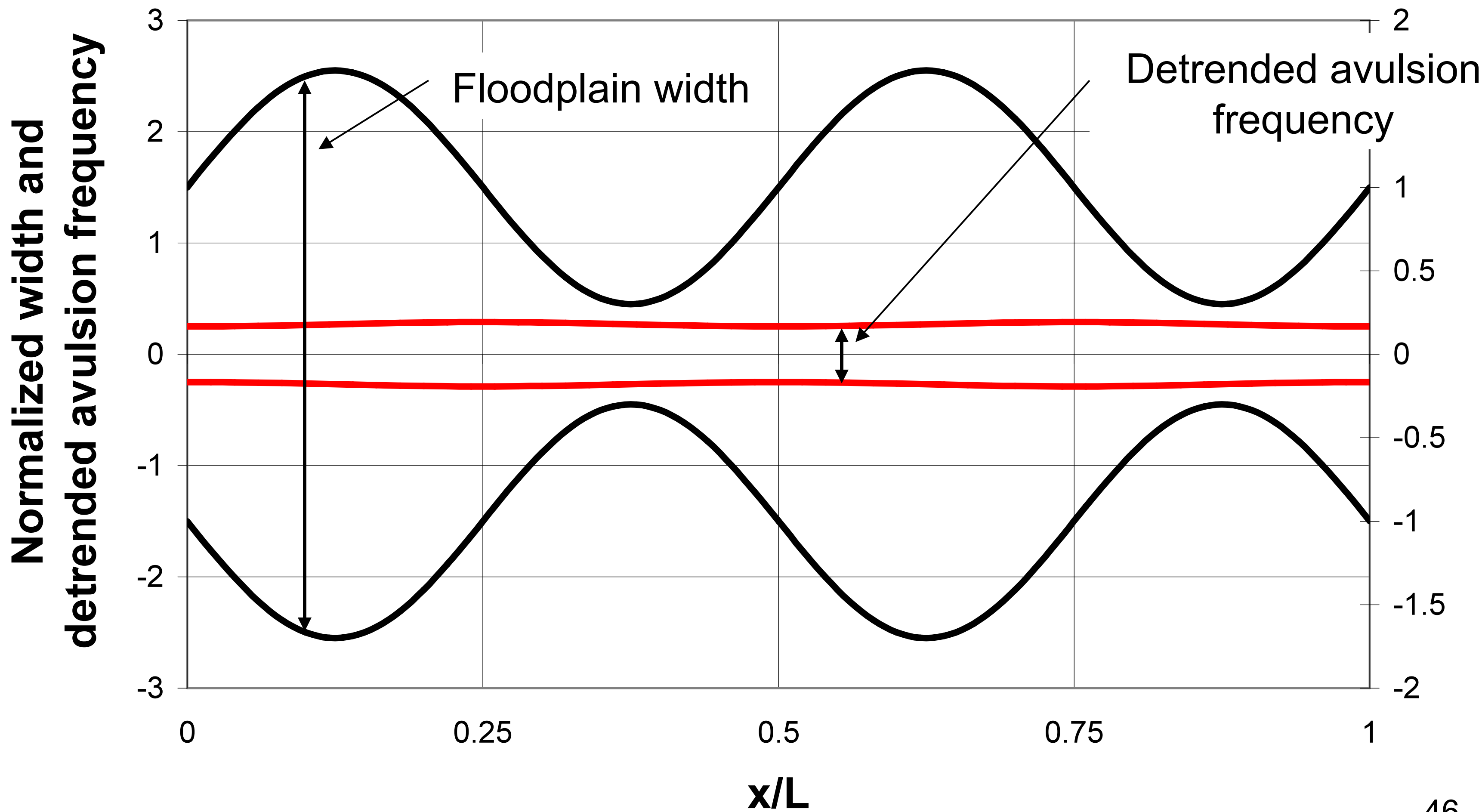
Mean Avulsion Frequency



CASE:

10,000 to 4,000 BP with 3.5 mm/year of imposed sea level rise, varied floodplain width, n = 2, ε_{BF} = 0.7: *BACKDIRT CURVE?*

Planform View of Floodplain Width and Detrended Avulsion Frequency



Higher avulsion rate upstream of contraction: lower rate downstream!

THANK YOU, JAMES SYVITSKI, RUDY SLINGERLAND, CHRIS PAOLA FOR CONCEIVING AND IMPLEMENTING CSDMS