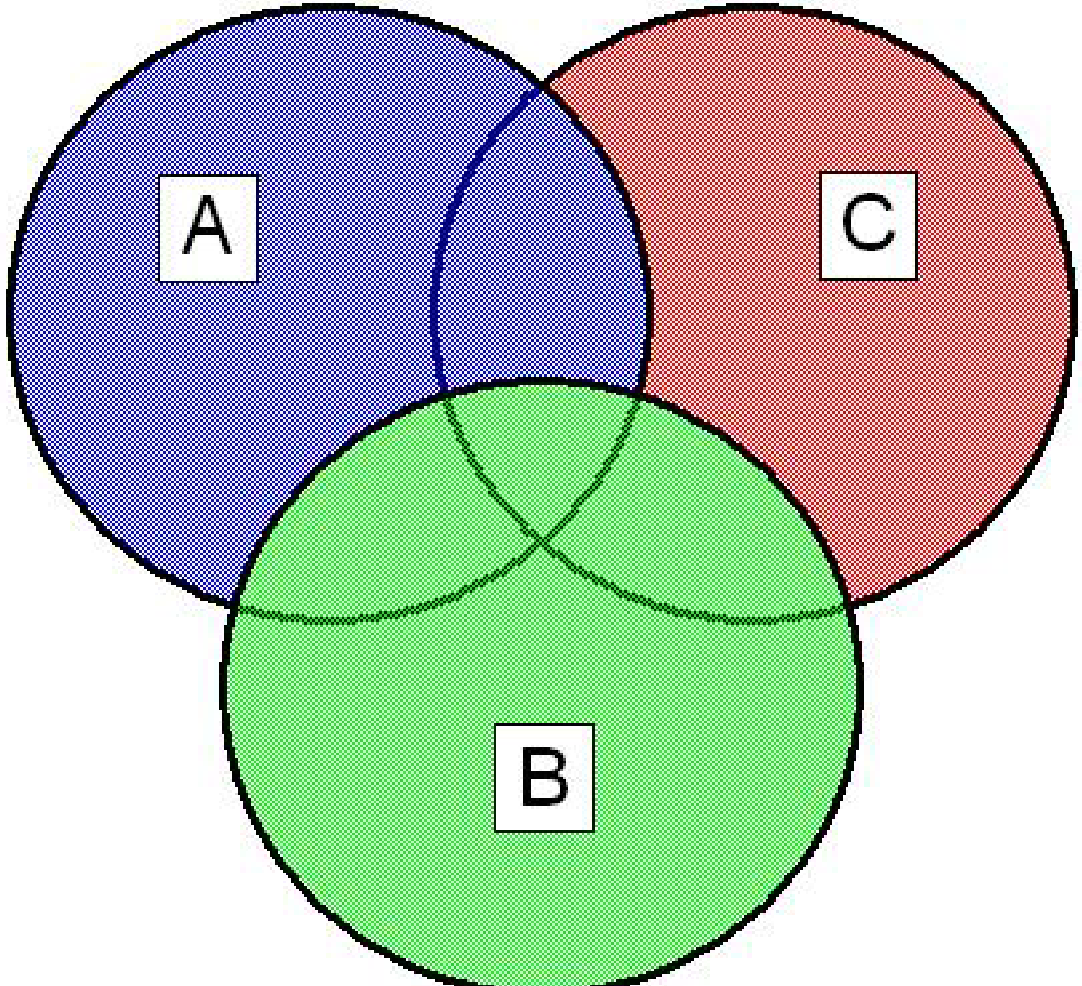
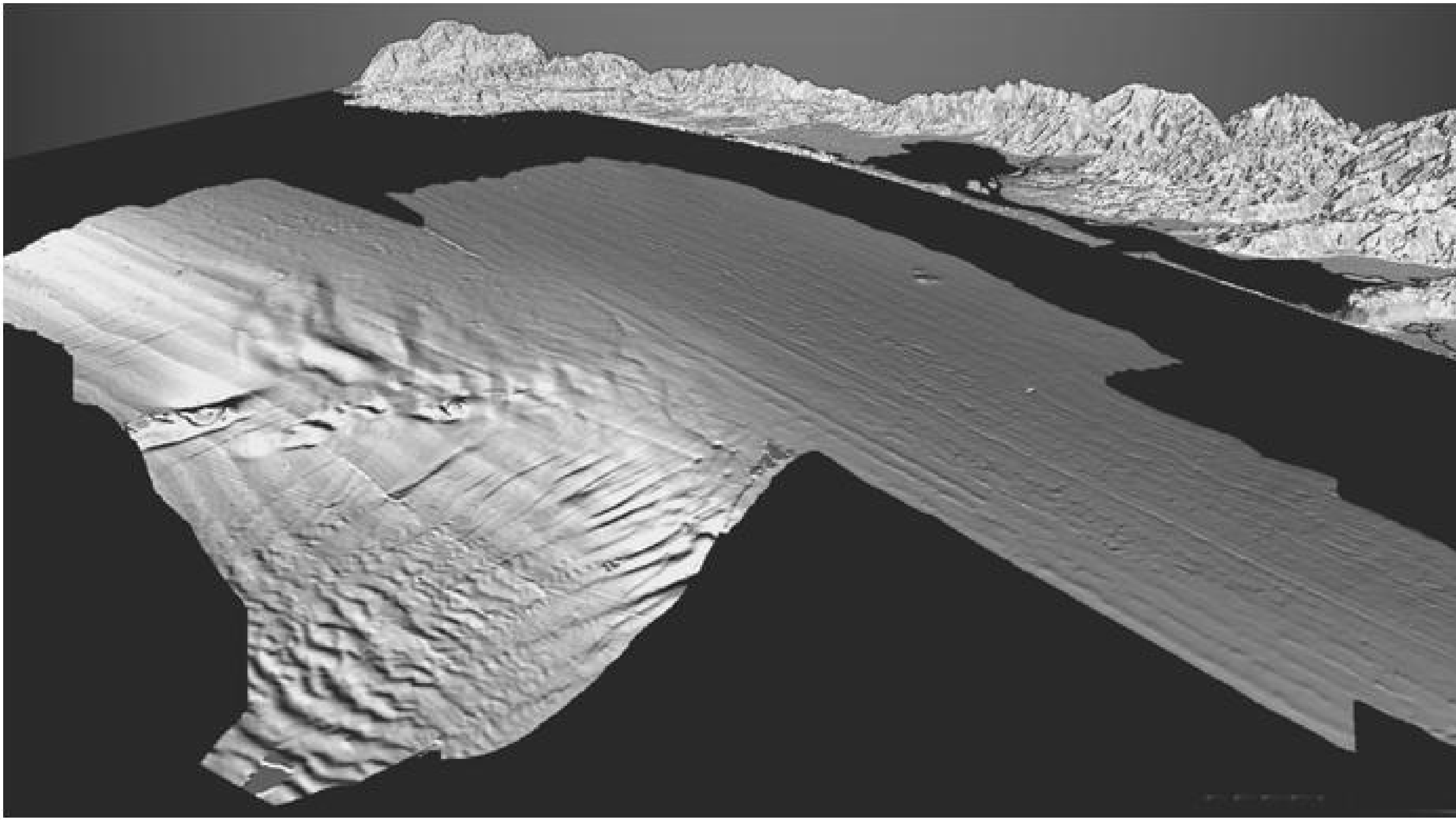
SOURCE TO SINK COMMUNITY SEDIMENT MODEL:

VENN DIAGRAM



SOURCE TO SINK COMMUNITY SEDIMENT MODEL:
RIVER MODELING



Eel River Margin, Northern California

SOURCE TO SINK COMMUNITY SEDIMENT MODEL
OVERARCHING CONCEPT NO. 1:

McDonald's

Don't just watch what goes across a bridge that's already there!!

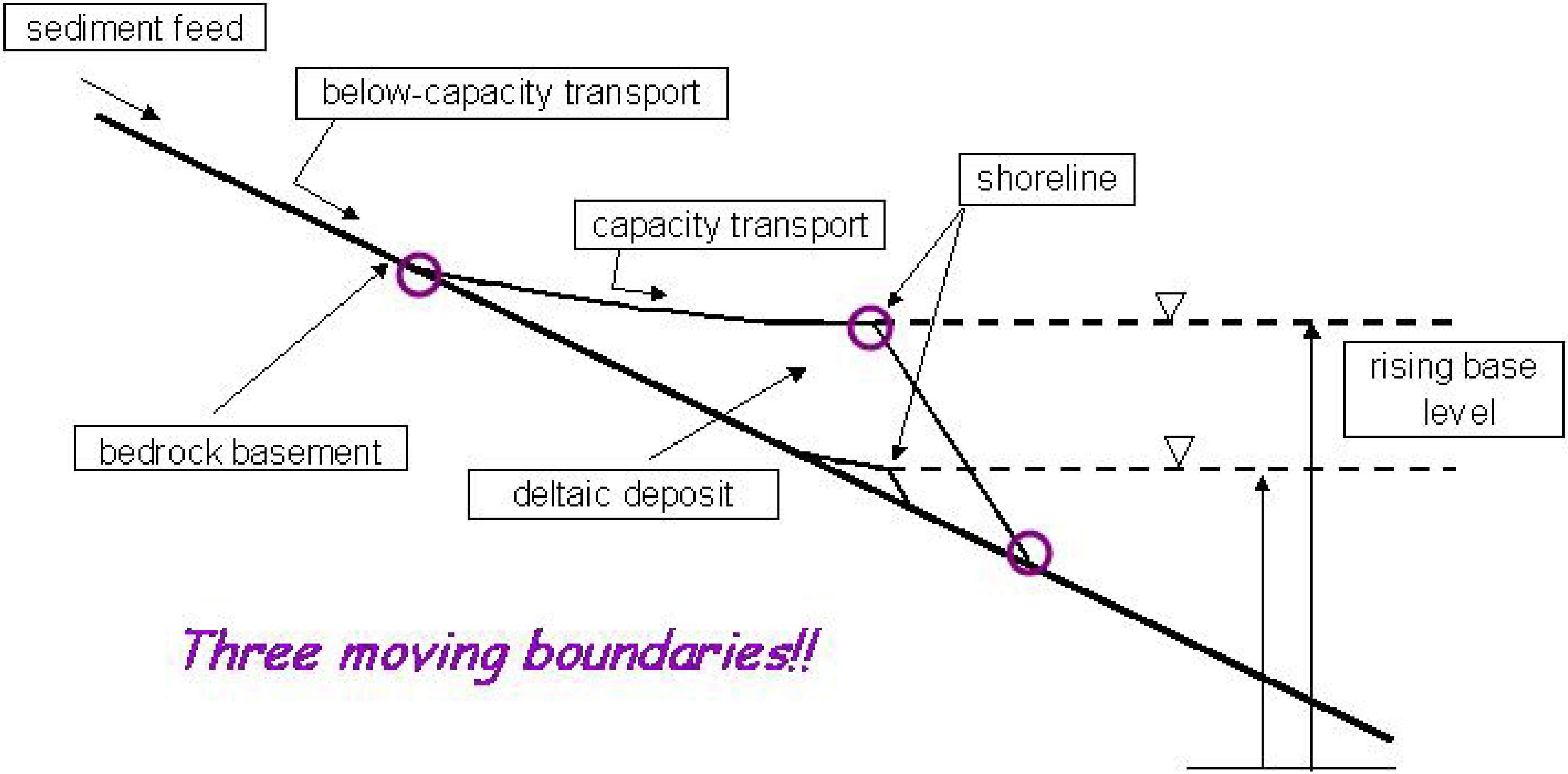
BUILD IT!!

SOURCE TO SINK COMMUNITY SEDIMENT MODEL
OVERARCHING CONCEPT NO. 2:

***Catch Willy!!
And Make Him Do
Tricks!!***

EXAMPLE: RESPONSE OF A DELTA TO RISING BASE LEVEL

(Experiments: Mutou)



Make Willy run away from rising base level!

Numerical model "MutouDelta" demonstrated here

ALLUVIAL AND INCISIONAL MORPHODYNAMICS

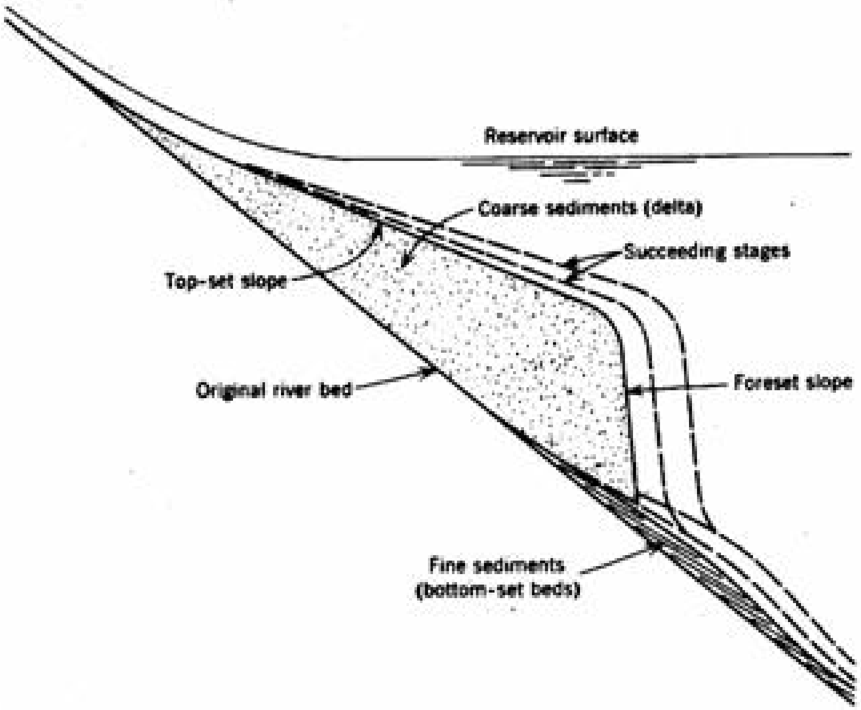
Old River Control Structure,
Mississippi River

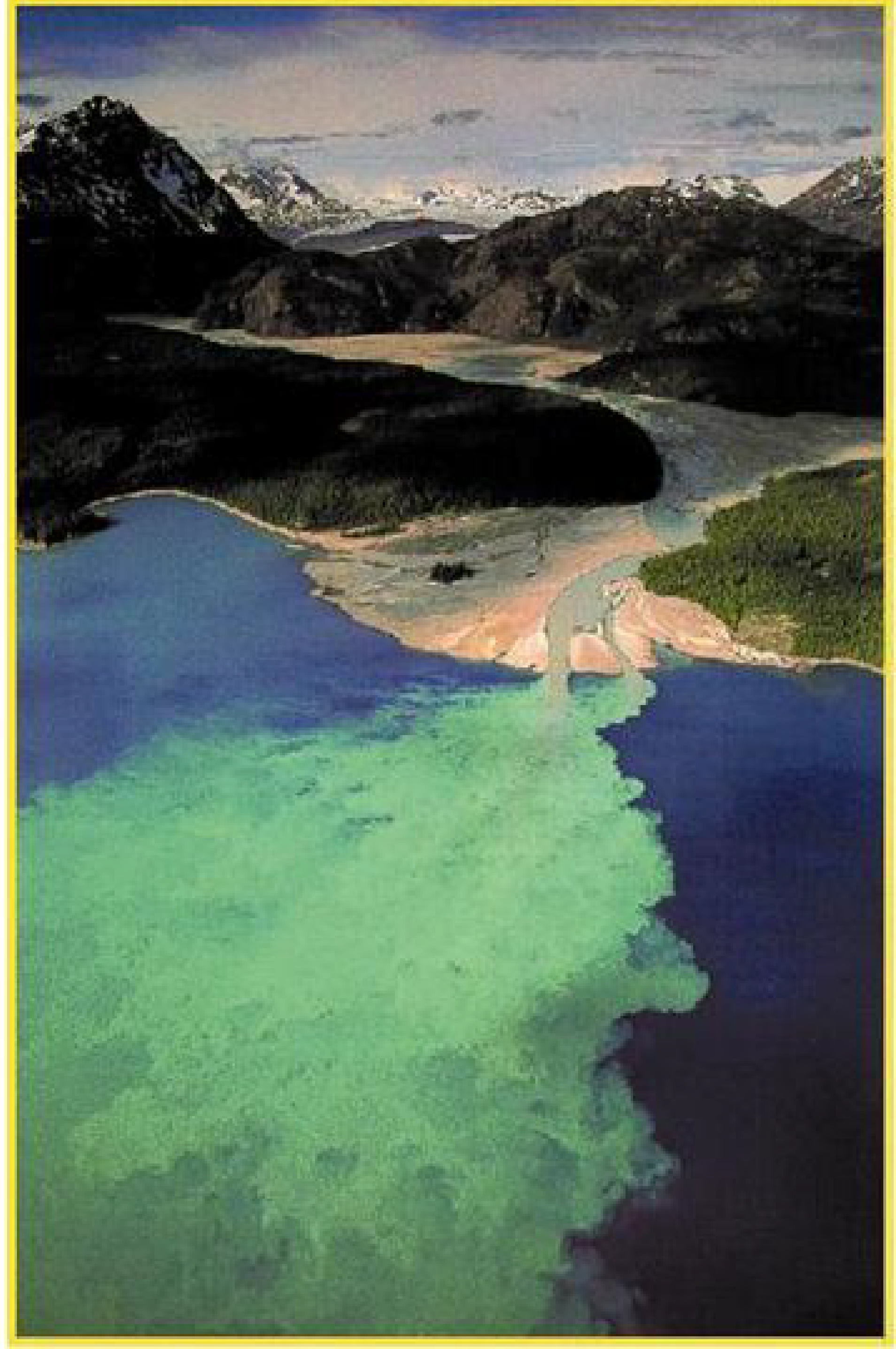
Bedrock channel,
Sierra Nevada
Mountains

INCISIONAL CANYONS

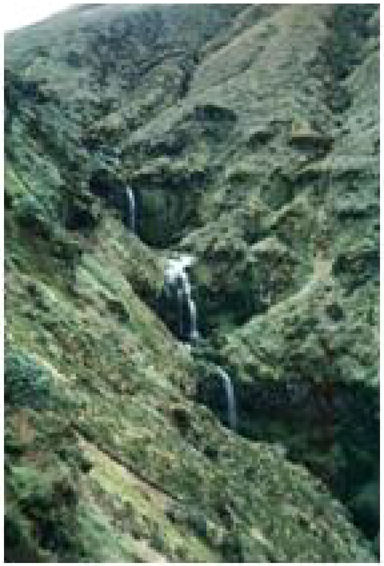
Grand Canyon

DEPOSITIONAL FAN-DELTAS: Yukon





DOWNSTREAM VARIATION IN MORPHOLOGY



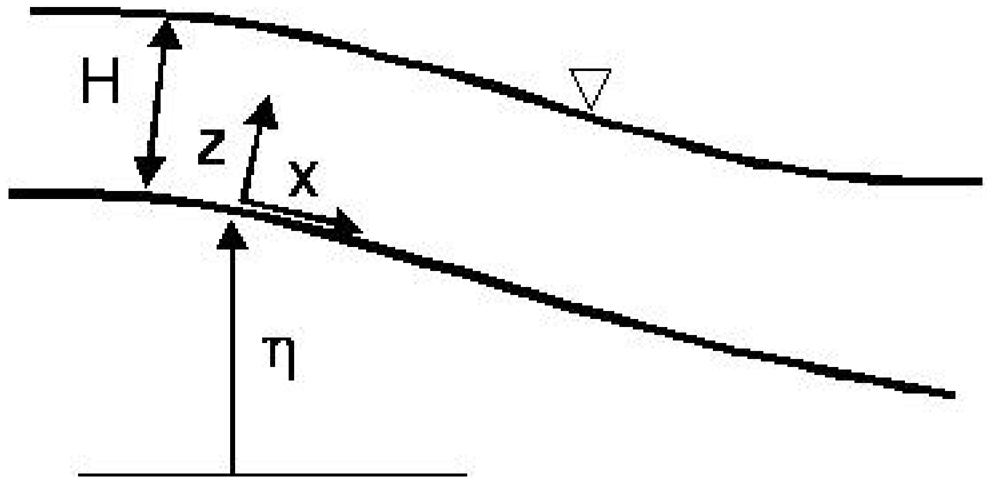
Incisional: Gough Island

Step-Pool: Oregon

Alluvial Gravel-Bed: Idaho

Alluvial Sand-Bed: PNG

RELATIONS FOR CONSERVATION OF BED SEDIMENT:
THE GUTS OF MORPHODYNAMICS



PARAMETERS

x = streamwise coordinate (boundary-attached) [L]
z = upward normal coordinate (normal to boundary) [L]
η = bed elevation [L]

In most but not all applications x is nearly horizontal and z is nearly vertical.

1D CONSERVATION OF BED SEDIMENT: BEDLOAD ONLY

Photo 1 – *The inlet channel of the Rio Cordon instrumented station during the October 1998 flood*

Photo 2 – *The bedload deposited in the storage area after the October 1998 flood*

$$(1-\lambda_p)\frac{\partial \eta}{\partial t} = -\frac{\partial q_b}{\partial x}$$

Make Willy wiggle up and down!!

Rio Cordon, Italy

D'Agostino et al

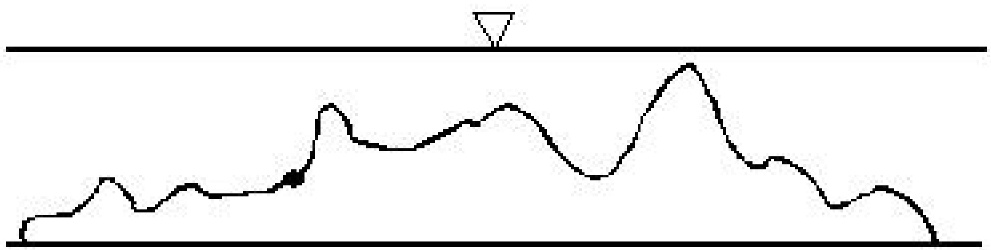
1D CONSERVATION OF BED SEDIMENT: ADD SUSPENDED LOAD

Gilgal Abay, Ethiopia

Make Willy build deltas!!

E_s = volume rate of entrainment of bed material into suspension per unit bed area per unit time [L/T]

D_s = volume rate of deposition of bed material into suspension per unit bed area per unit time [L/T]

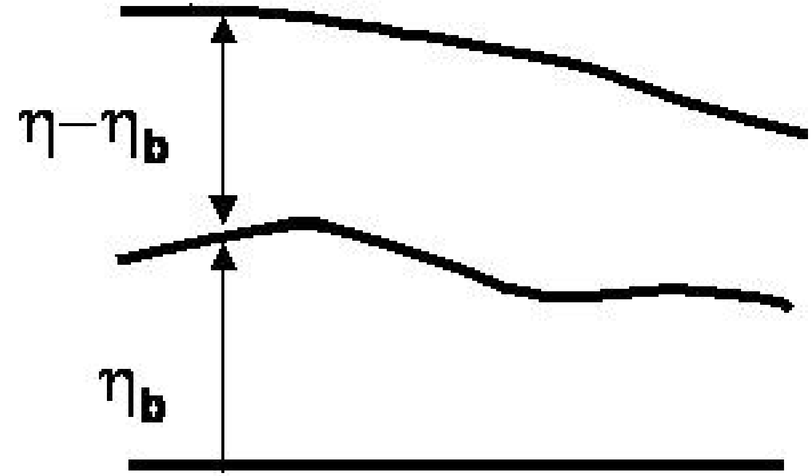


$$(1-\lambda_p)\frac{\partial \eta}{\partial t} = -\frac{\partial q_b}{\partial x} + D_s - E_s$$

CONSERVATION OF BED SEDIMENT: ADD TECTONISM

σ_s = vertical subsidence rate [L/T]

υ_s = - σ_s = vertical uplift rate [L/T]



$$\frac{\partial \eta}{\partial t} \rightarrow \frac{\partial}{\partial t}(\eta - \eta_b)$$

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

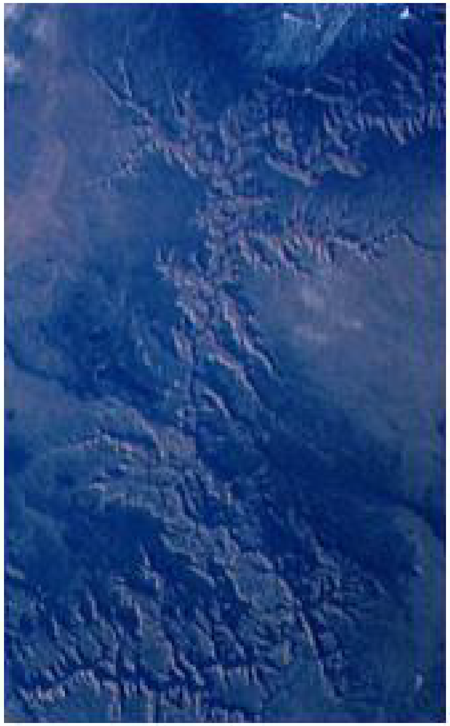
$$\frac{\partial}{\partial t}(\eta - \eta_b) = \frac{\partial \eta}{\partial t} + \sigma_b = \frac{\partial \eta}{\partial t} - \upsilon_b$$

$$(1 - \lambda_p)\left(\frac{\partial \eta}{\partial t} + \sigma_b\right) = -\frac{\partial q_b}{\partial x} + D_s - E_s$$

Or

$$(1 - \lambda_p)\left(\frac{\partial \eta}{\partial t} - \upsilon_b\right) = -\frac{\partial q_b}{\partial x} + D_s - E_s$$

Grand Canyon, USA



Make Willy cut canyons!!

CONSERVATION OF BED SEDIMENT: ADD TRANSVERSE AS WELL AS STREAMWISE BEDLOAD TRANSPORT (2D)

y = transverse coordinate [L]

$q_b \rightarrow q_{bx}$

q_{by} = transverse volume bedload transport rate per unit normal distance [L^2/T]

$$(1-\lambda_p)\left(\frac{\partial \eta}{\partial t} + \sigma_b\right) = -\frac{\partial q_{bx}}{\partial x} - \frac{\partial q_{by}}{\partial y} + D_s - E_s$$

Jamuna River, Bangladesh

Make Willy braid his dreadlocks!!

CONSERVATION OF BED SEDIMENT: PURELY INCISIONAL CASE

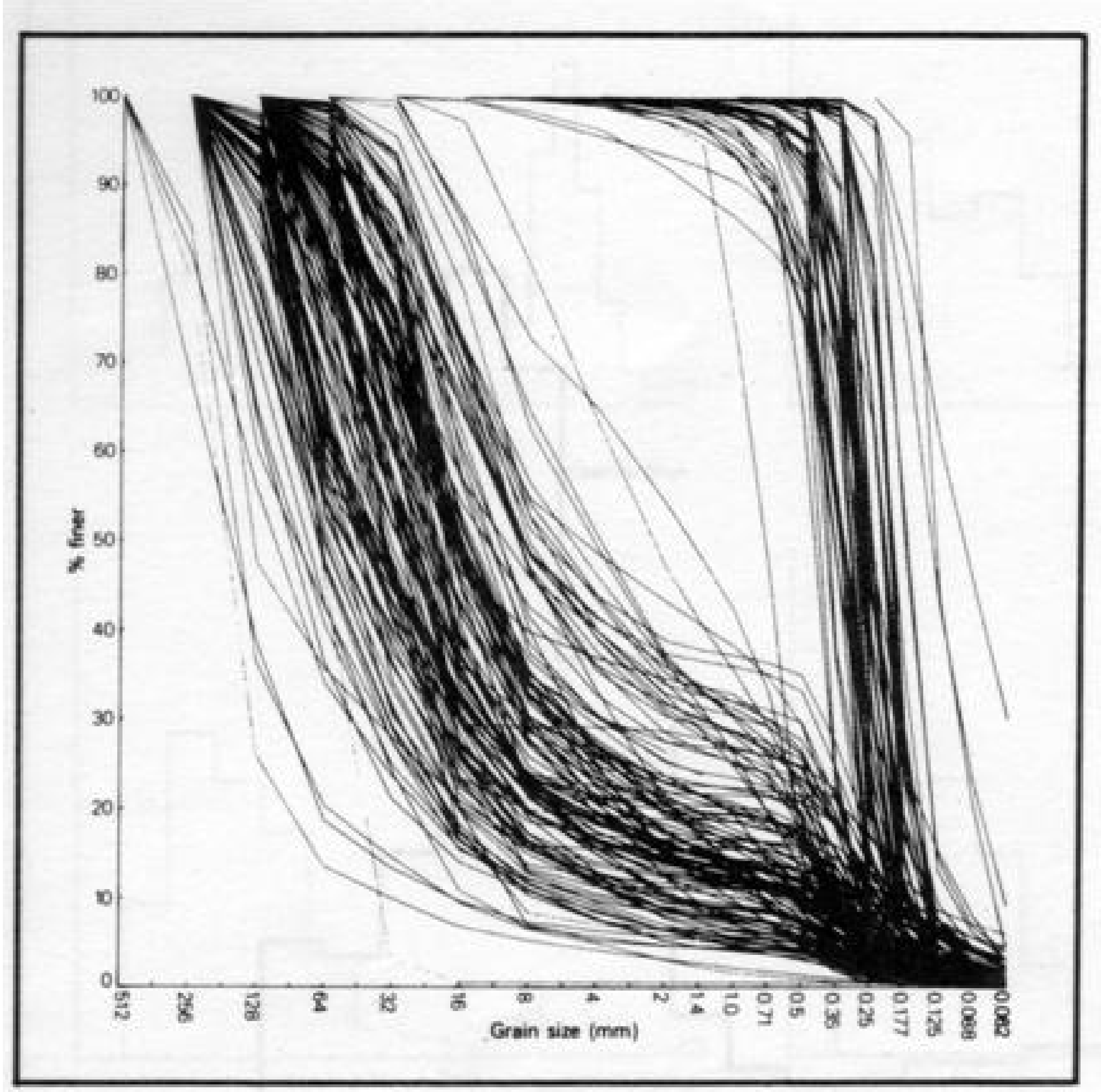
E_I = volume rate of removal of bedrock (pores or vugs not included) per unit area per unit time [L/T]

Dry Meadow Creek, California

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

Make Willy eat rock!!

CONSERVATION OF BED SEDIMENT: SIZE MIXTURES



Shaw and Kellerhals

Grain size distributions of streams, Alberta, Canada

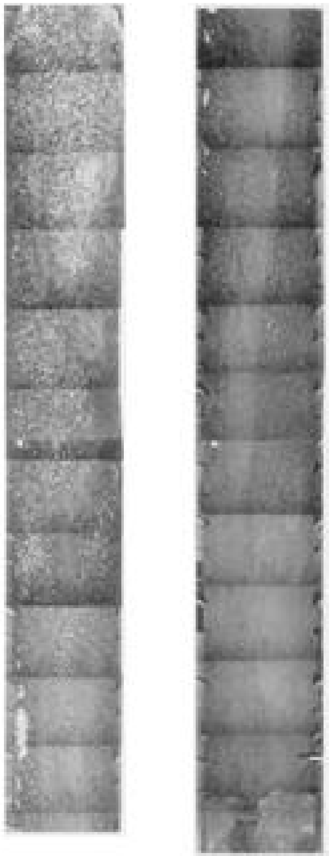
1D CONSERVATION OF BED SEDIMENT MIXTURES

q_{bT} = total volume bedload transport rate per unit width $[L^2/T]$
p_i = fractions in bedload
F_i = fractions in active layer
L_a = active layer thickness
B_c = channel width
A_i = loss rate to abrasion

$$q_{bT} = \sum_{i=1}^{N} p_i \qquad p_i = \frac{q_{bi}}{\sum_{i=1}^{N} q_{bi}}$$

Make Willy sort pebbles!!

upstream



downstream

1D form with width variation

$$(1-\lambda_p)B_c\left[f_{li}\frac{\partial}{\partial t}(\eta - L_a) + \frac{\partial}{\partial t}(F_i L_a)\right] = -\frac{\partial B_c q_{bT} p_i}{\partial x} - B_c A_i$$

1D CONSERVATION OF BED SEDIMENT MIXTURES: ADD TECTONISM

$$(1-\lambda_p)B_c\left[f_{Ii}\frac{\partial}{\partial t}(\eta - L_a) + \frac{\partial}{\partial t}(F_i L_a) + f_{Ii}\sigma_b\right] = -\frac{\partial B_c q_{bT} p_i}{\partial x} - B_c A_i$$

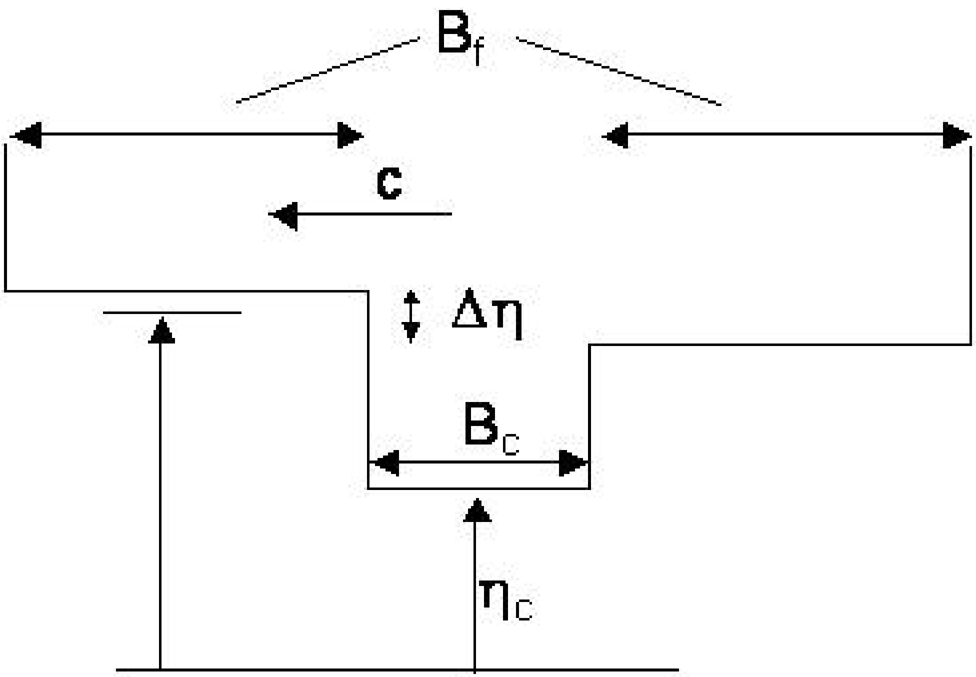
Make Willy stack stratigraphy!!

Paola, Heller et al.

GRAVEL-SAND TRANSITION: Ok Tedi, PNG

Make Willy change form abruptly!!

SEDIMENT CONSERVATION FOR FLOODPLAINS

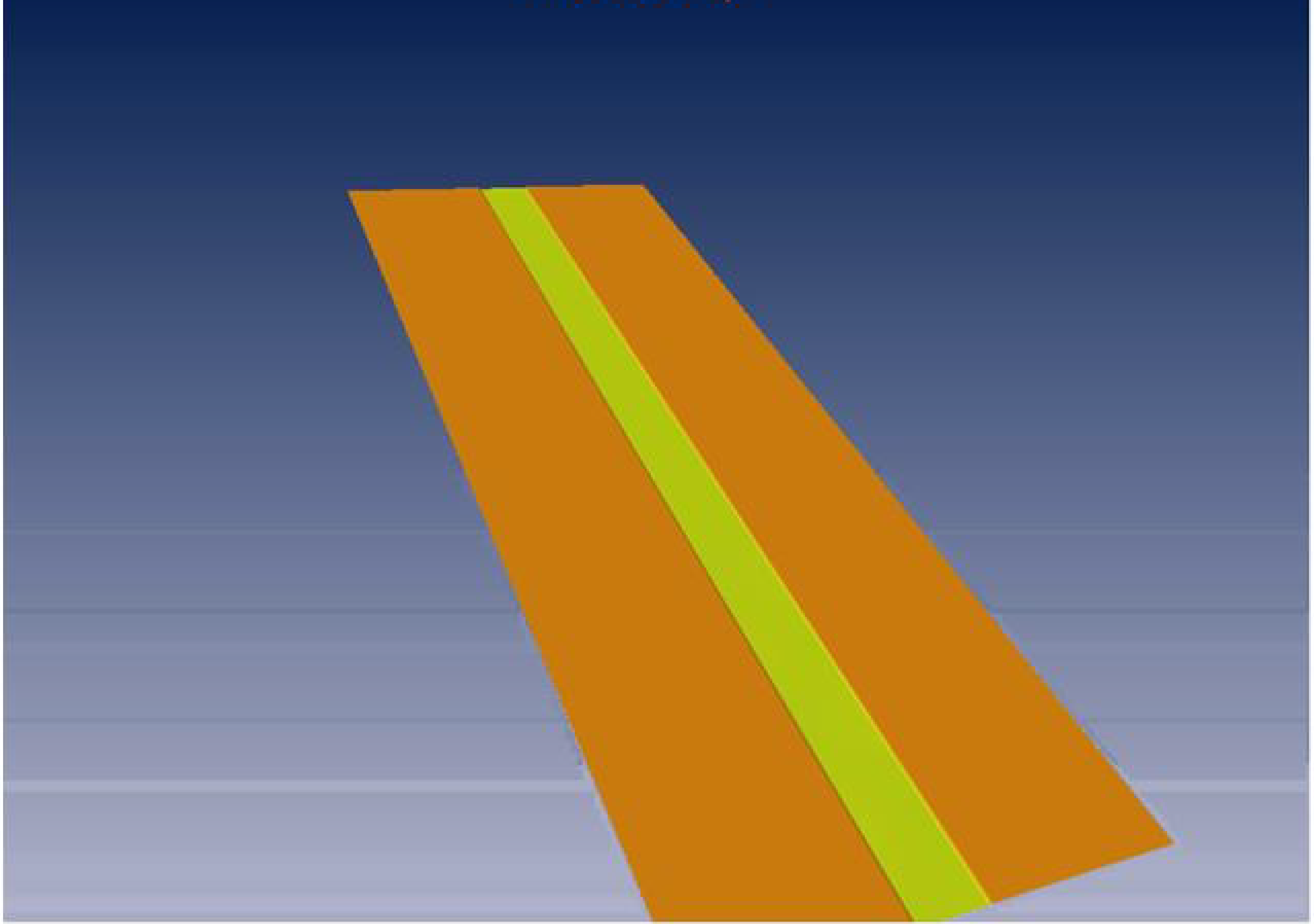


B_f = floodplain width
B_c = channel width
η_f = mean floodplain elev.
η_c = mean channel bed elev.
c = mean channel migration speed
$\Delta\eta$ = elev. diff. due to channel migration
F_{fi} = floodplain fractions
f_{ci}, f_{fi} = exchange fractions
q_{oi} = mean normal overbank sediment export rate
e_i = efficiency coefficient

Make Willy build floodplains!!

$$(1-\lambda_{pf})B_f\left[f_{fi}\left(\frac{\partial\eta_c}{\partial t}+\sigma_b\right)+\frac{\partial}{\partial t}F_{fi}(\eta_f-\eta_b)\right]=e_i q_{oi}-c\,\Delta\eta f_{ci}$$

Tao Sun (see also Howard)



SOME SEMINAL SOURCE-TO-SINK RIVER PROBLEMS THAT REQUIRE **MODELING** AS PART OF THE SOLUTION

Source to Sink

SEMINAL PROBLEM:

HOW SHOULD THE PROBLEM OF BEDROCK INCISION BE FORMULATED?

Source to Sink

SEMINAL PROBLEM:

HOW SHOULD THE PROBLEM OF BEDROCK INCISION BE FORMULATED?

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

Traditional, Brand X Formulation

$$E_I = aS^m A^n$$

S = slope
A = drainage area

Sklar and Dietrich

Alternative Formulation

$$E_I = \beta q_e\left(1-\frac{q_e}{q_{ec}}\right)$$

q_e = vol. load/width that is effective to incise bed
q_{ec} = capacity of effective vol. load/width to cover bed
β = coefficient with dimensions of 1/length (like abrasion coefficient)

Source to Sink

SEMINAL PROBLEM:

HOW IMPORTANT IS THE ROLE OF KNICKPOINT MIGRATION IN PRODUCING INCISION BY "UNZIPPING" ?

Hasbargen and Paola

How does incision respond to base level variation?
Do bedrock streams obey "Playfoul's Rule"

Kirby and Whipple

Source to Sink

SEMINAL PROBLEM:

HOW DO BEDROCK-ALLUVIAL AND GRAVEL-SAND TRANSITIONS RESPOND TO VARYING TECTONIC AND SEDIMENT PRODUCTION REGIMES?

Yatsu

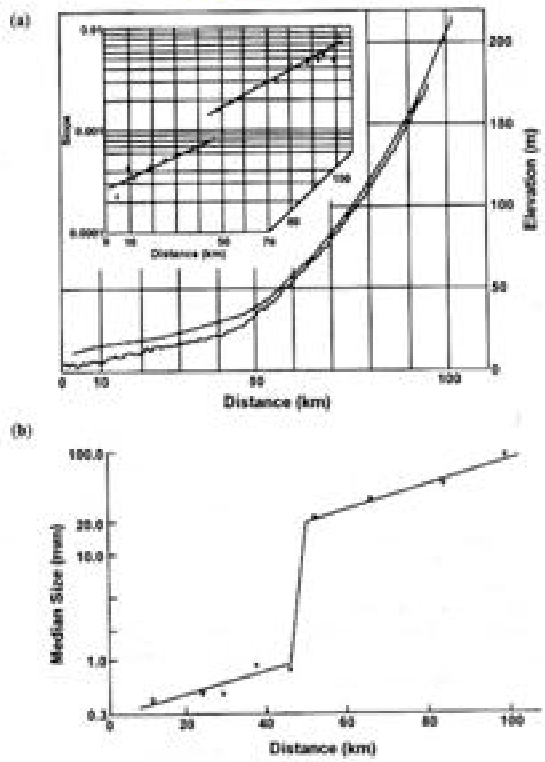
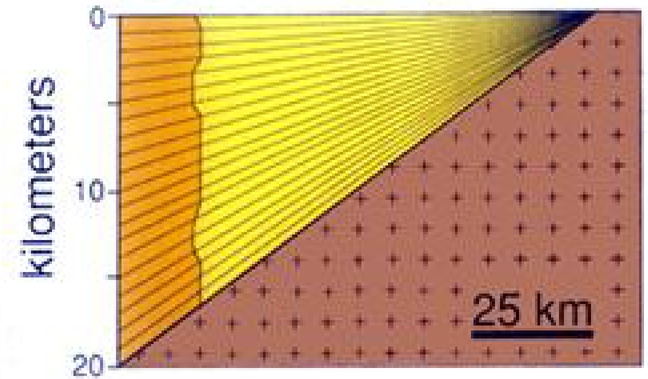


Fig. 1. (a). Long profile of the Kinu River, Japan, showing a discontinuity in bed slope. Based on an original from Yatsu (1955).

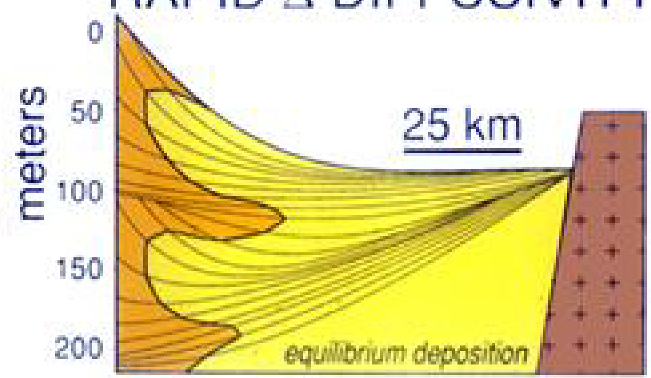
(b). Downstream grain size variation of Kinu River, Japan, showing a discontinuity at the gravel-sand transition. Based on an original from Yatsu (1955).

Paola et al.

SLOW Δ DIFFUSIVITY



RAPID Δ DIFFUSIVITY



Source to Sink

SEMINAL PROBLEM:

HOW DO FLOODPLAIN AND CHANNEL PROCESSES INTERACT?

How does floodplain construction keep up with channel

SHEYENNE RIVER, NORTH DAKOTA

WHY IS THE FLOODPLAIN OF THE PARANÁ RIVER FULL OF "HOLES"

Incomplete construction?

We must come to grips with "wash load"

HOW DOES CHANNEL MIGRATION INTERACT WITH OVERBANK DEPOSITION TO SET FLOODPLAIN HEIGHT ABOVE THE RIVER BED?

FLY RIVER, PNG

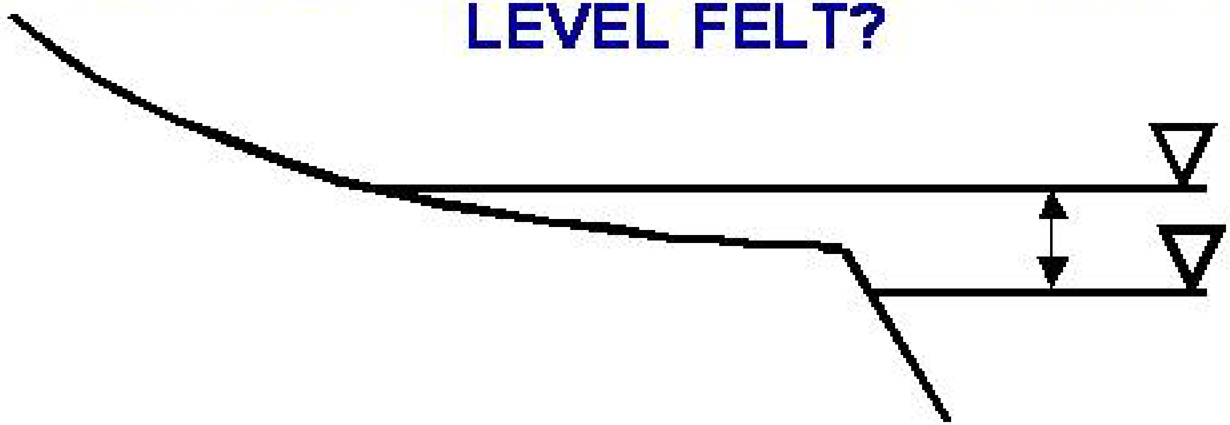
OKAVANGO RIVER, BOTSWANA

N. Smith

Source to Sink

SEMINAL PROBLEM:

IN LARGE RIVER SYSTEMS, HOW FAR UPSTREAM ARE THE EFFECTS OF GLACIAL CYCLIC VARIATION IN SEA LEVEL FELT?



Thousands of km??? (Fisk)

Or at best hundreds of km??? (Blum)

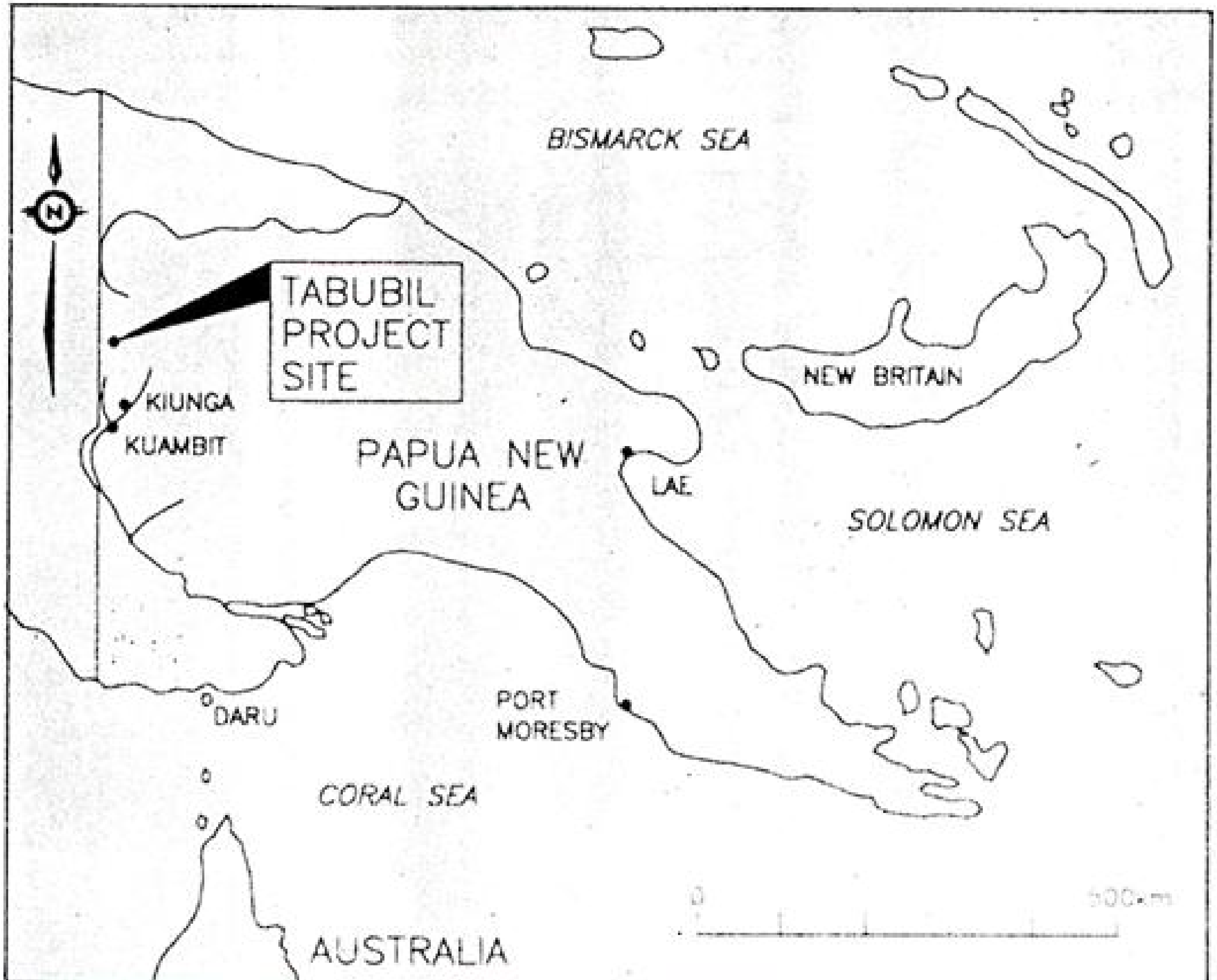
Influence confined to the deltaic zone?

Or can the effect propagate up to e.g gravel-sand transition?

Do hillslopes and base level talk to each other?

What about basin size?

CASE IN POINT: FLY-STRICKLAND RIVER SYSTEM, PNG



A CLOSER VIEW OF THE SYSTEM

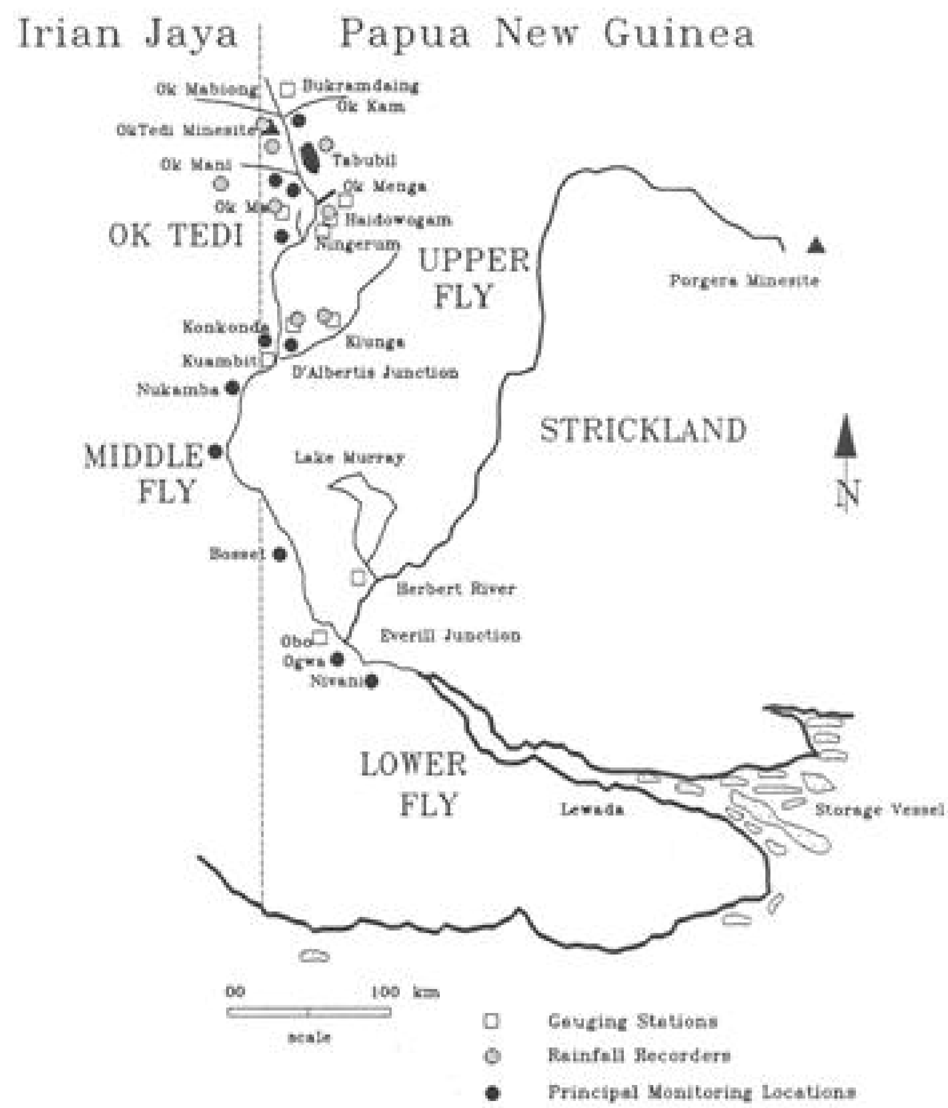
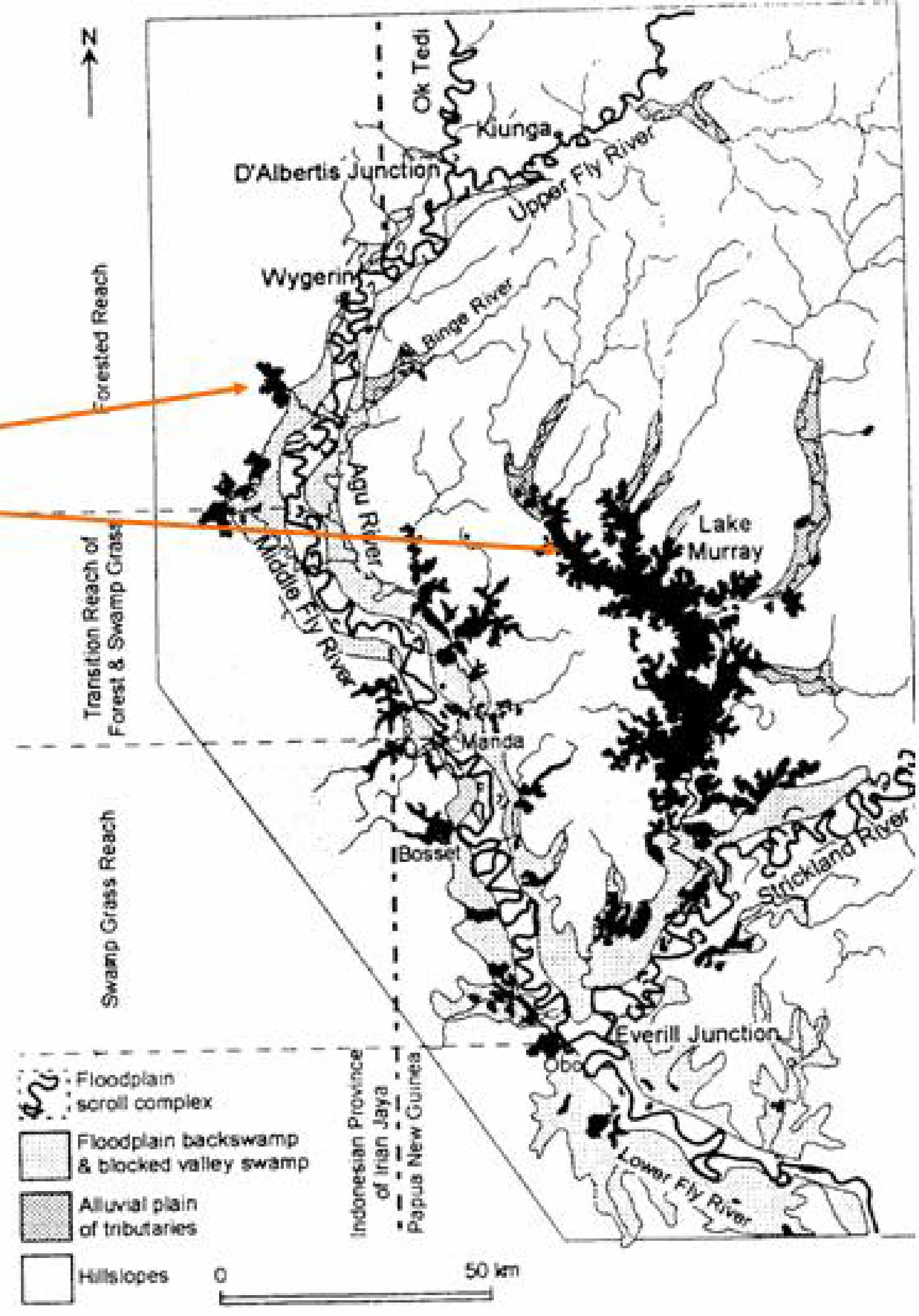


Figure 1. Location of Principal Stations

EVEN CLOSER: BLOCKED VALLEY LAKES 100'S OF KM UPSTREAM OF ESTUARY

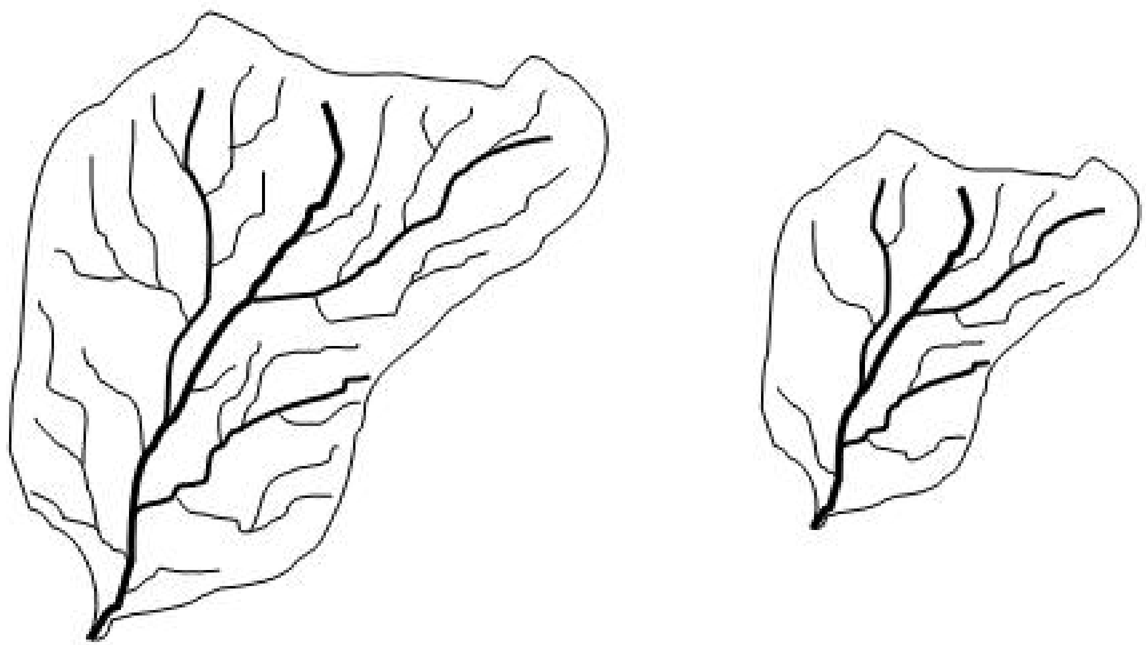
A consequence of sea level rise?



ALLOMETRY AND DIMENSIONAL ANALYSIS:

Do basins of different size respond differently to the same sea level cycle?

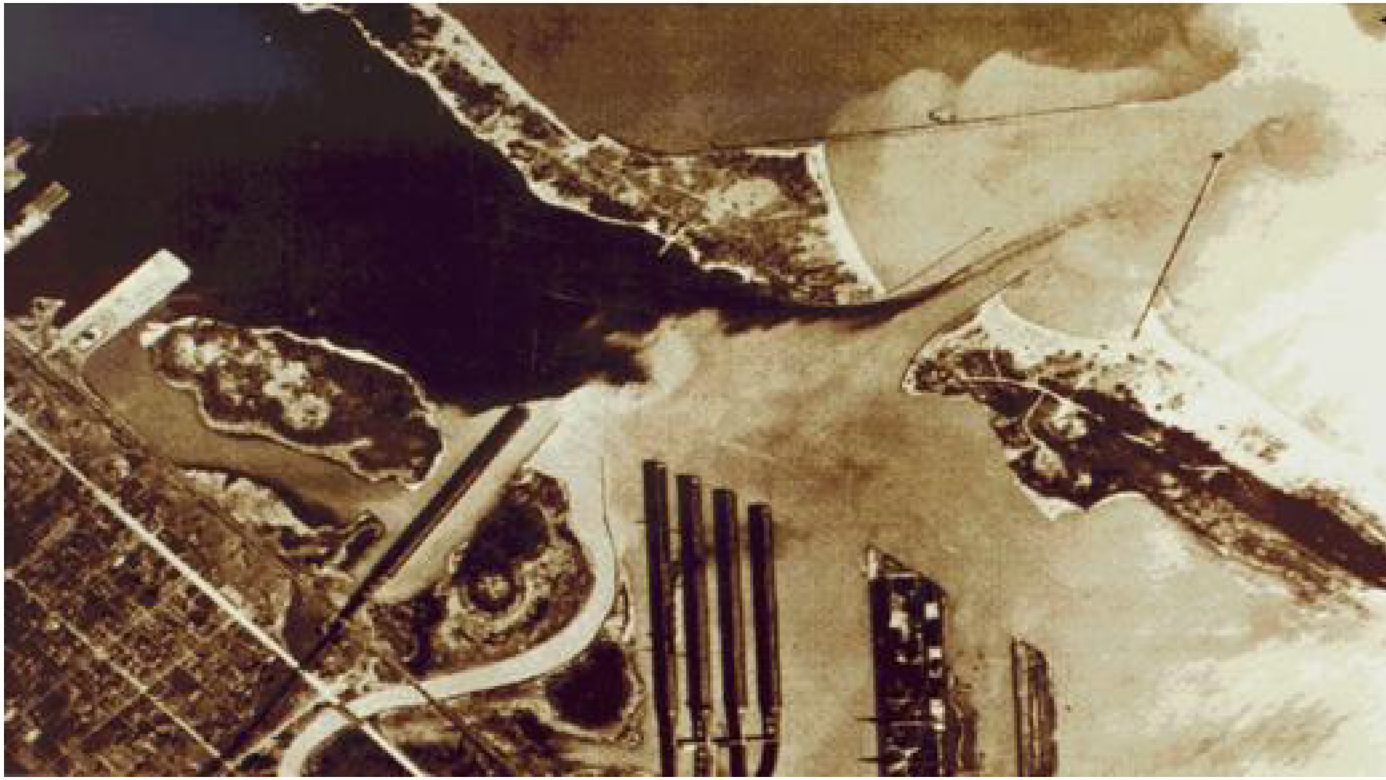
Is there a unifying dimensionless scheme that wraps the problem into a neat bundle?



Source to Sink

SEMINAL PROBLEM:

WERE HYPERPYCAL FLOWS WITH DIRECT CONVERSION TO TURBIDITY CURRENTS FAR MORE PREVALENT DURING THE LAST FALLING OR LOW STAND?



Plunge line

NEMADJI RIVER AT LAKE SUPERIOR

SUBMARINE FAN:

Signal of hyperpycnal flow?

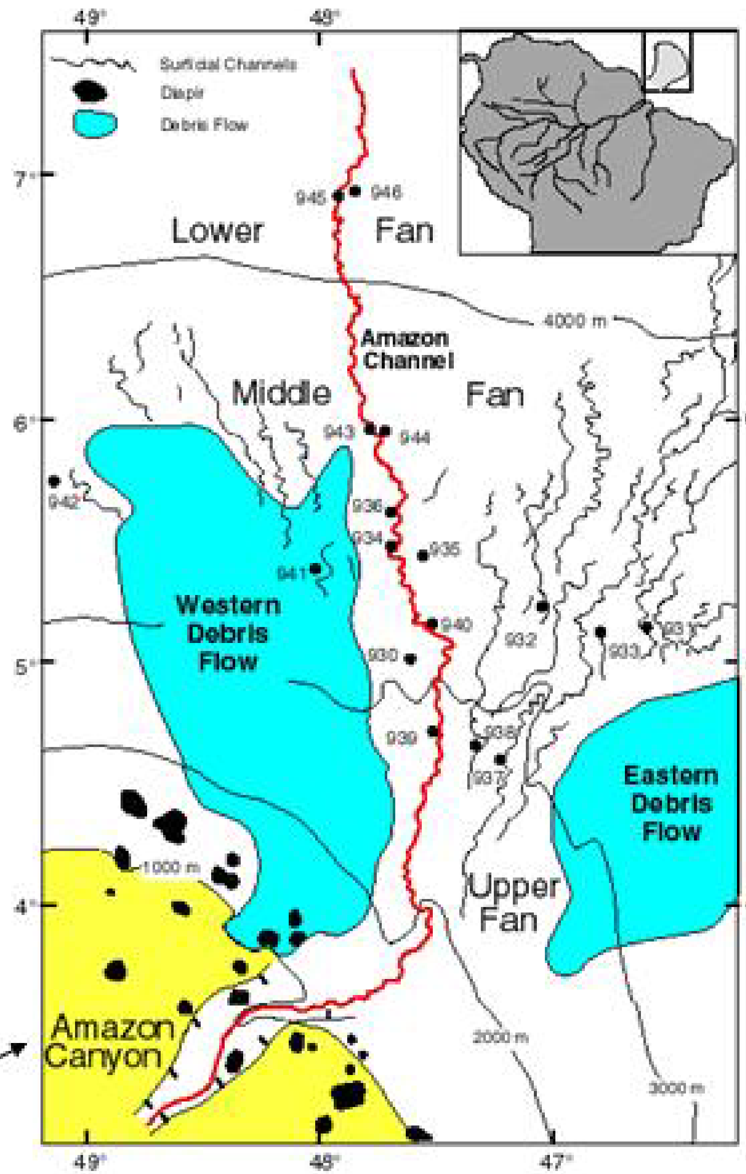
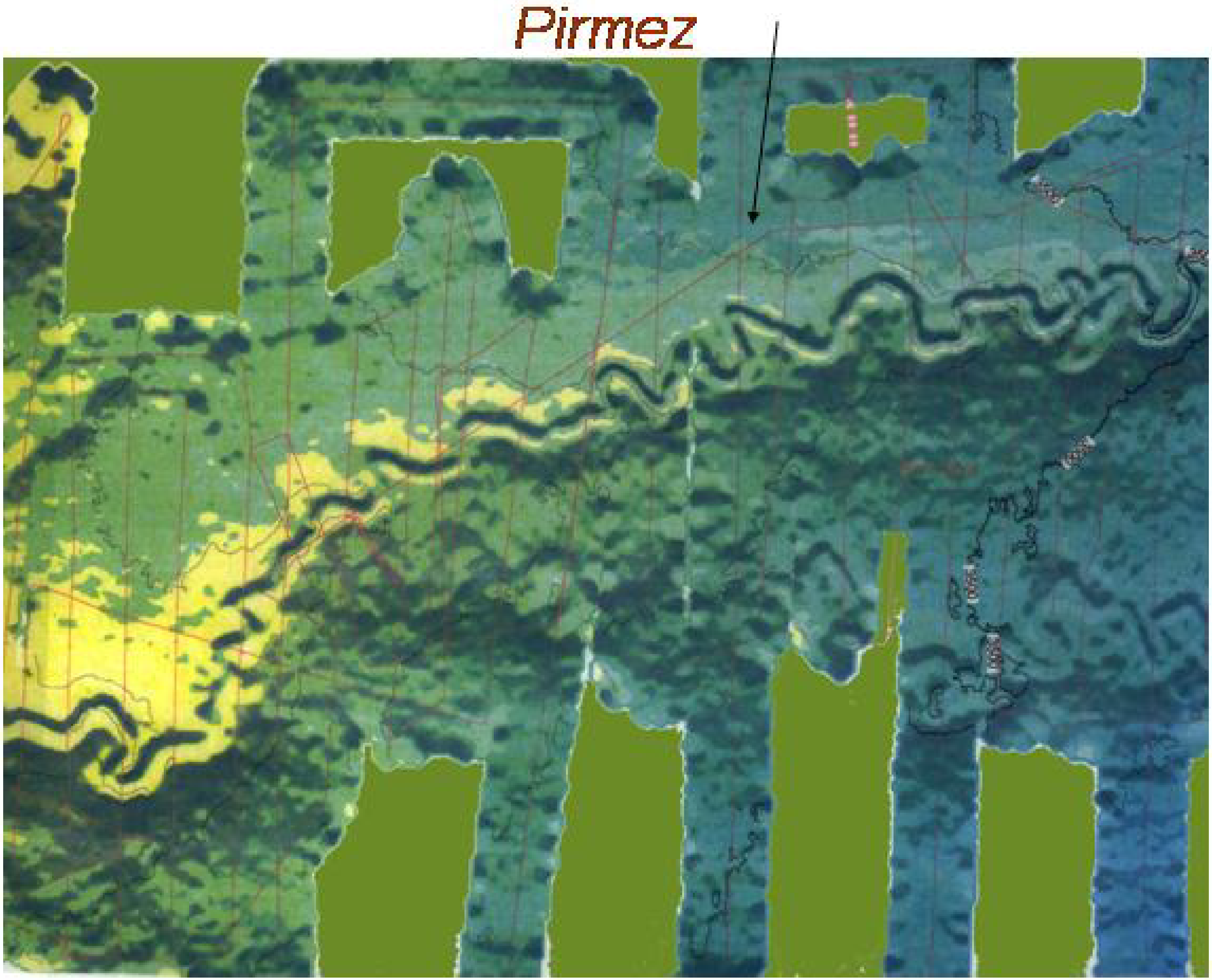


Figure 1. Surface features of Amazon Fan. Thick (red) line indicates the path of the most recently active channel system, Amazon Channel.

Pirmez

MEANDERING SUBMARINE CHANNELS:

Signal of hyperpycnal flow?



ANALOG: DAM REMOVAL:

Upstream-migrating degradation, bank caving

(Cantelli)

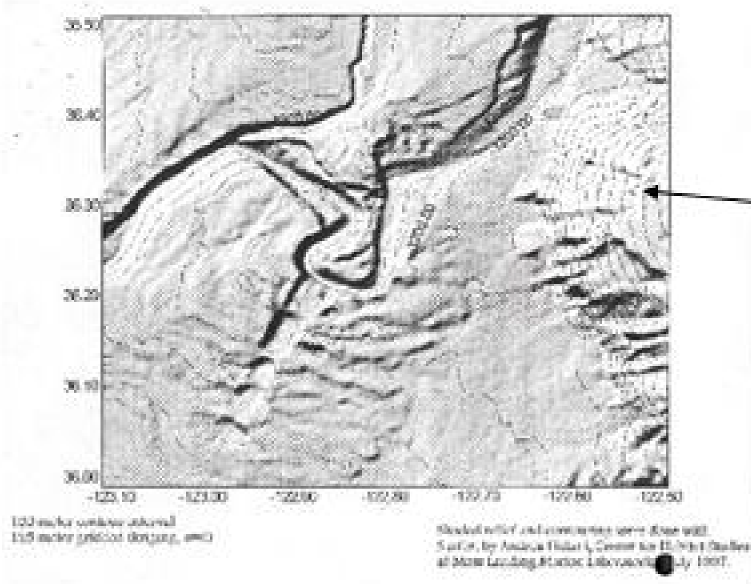
Exp. 9

Processo di erosione

Vista da valle

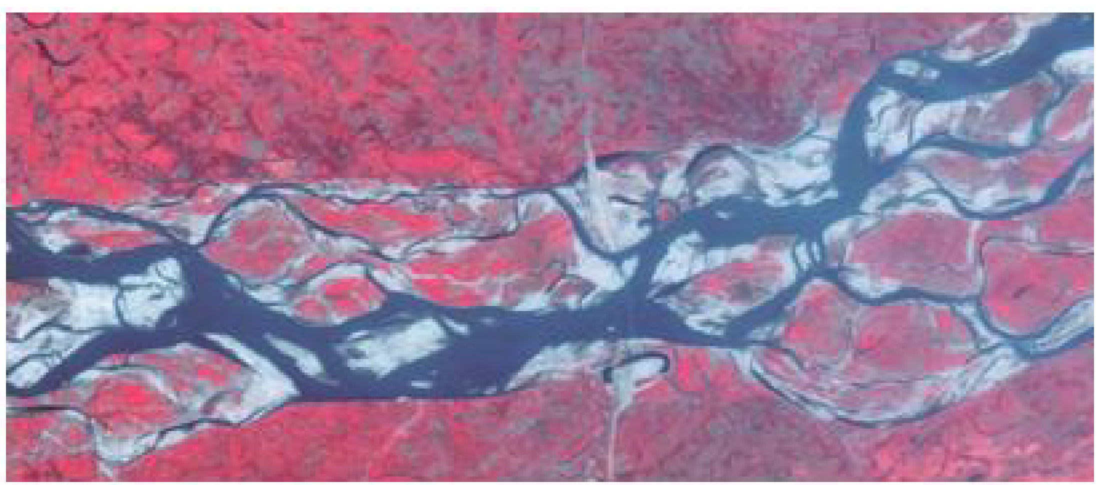
St. Anthony Falls Laboratory
University of Minnesota

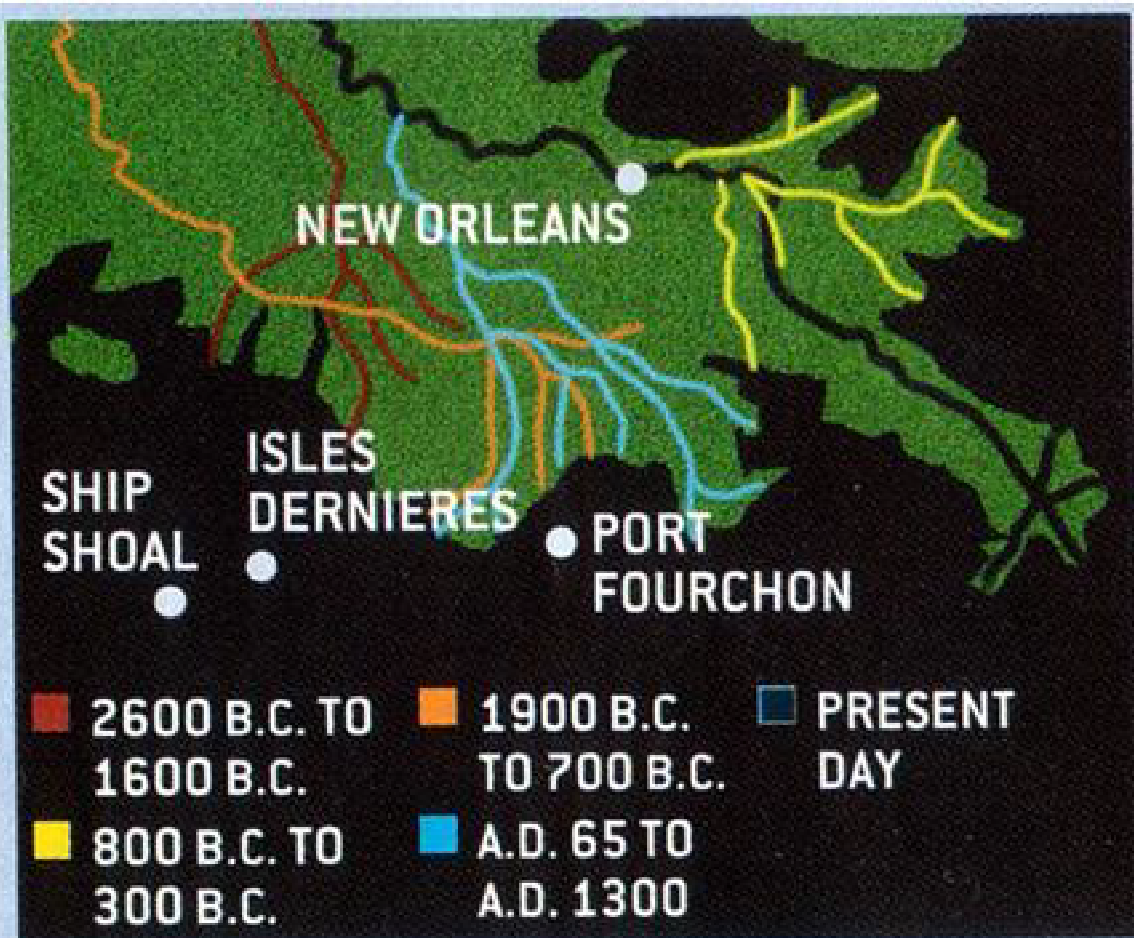
THE *QUESTION* RELATES TO THE DEEP SEA



Normark et al.

THE *ANSWER* CAN ONLY BE FOUND IN THE SUBAERIAL SETTING





LIKE ANY RIVER, the mighty Mississippi changes course over time. Over the past 4,600 years it has built four distinct deltas by depositing vast quantities of sediment each year during spring floods.

AND NOW FOR AN APPLIED PROBLEM: THE MISSISSIPPI DELTA

Scientific American

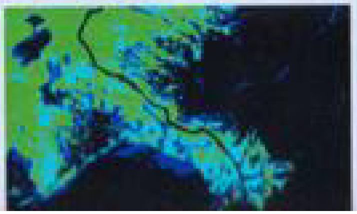
HELLLP!!!

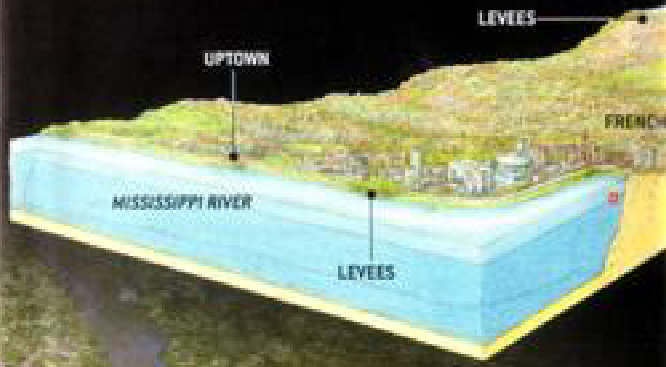
Sinking out of Sight

[H]uman beings have dramatically increased the rate of land loss in [s]outheastern Louisiana—and made themselves more vulnerable to [h]urricanes—by restricting certain natural processes and accelerating the [d]elta's natural subsidence. Even now, vast portions of the region lie only a [f]ew feet above sea level, and another 60 acres disappear every day. At this [r]ate, New Orleans will be exposed to the open sea by 2090.

SOUTHEASTERN LOUISIANA is a valuable test case for disappearing coastal wetlands around the world.

LIKE ANY RIVER, the mighty Mississippi changes course over time. Over the past 4,600 years it has built four distinct deltas by depositing vast quantities of sediment each year during spring floods.





LEVEES

inhibit the river's natural ability to sustain marshes with sediment and freshwater during spring floods. Without this supply, marshes subside and erode, and ocean water moves inland. This intrusion raises the salinity of marsh waters, killing trees and grasses that