Regulation of sand transport in the Colorado River by changes in the surface grain size of eddy sandbars over multi-year timescales

David J. Topping (USGS)
David M. Rubin (USGS)
John C. Schmidt (USU)

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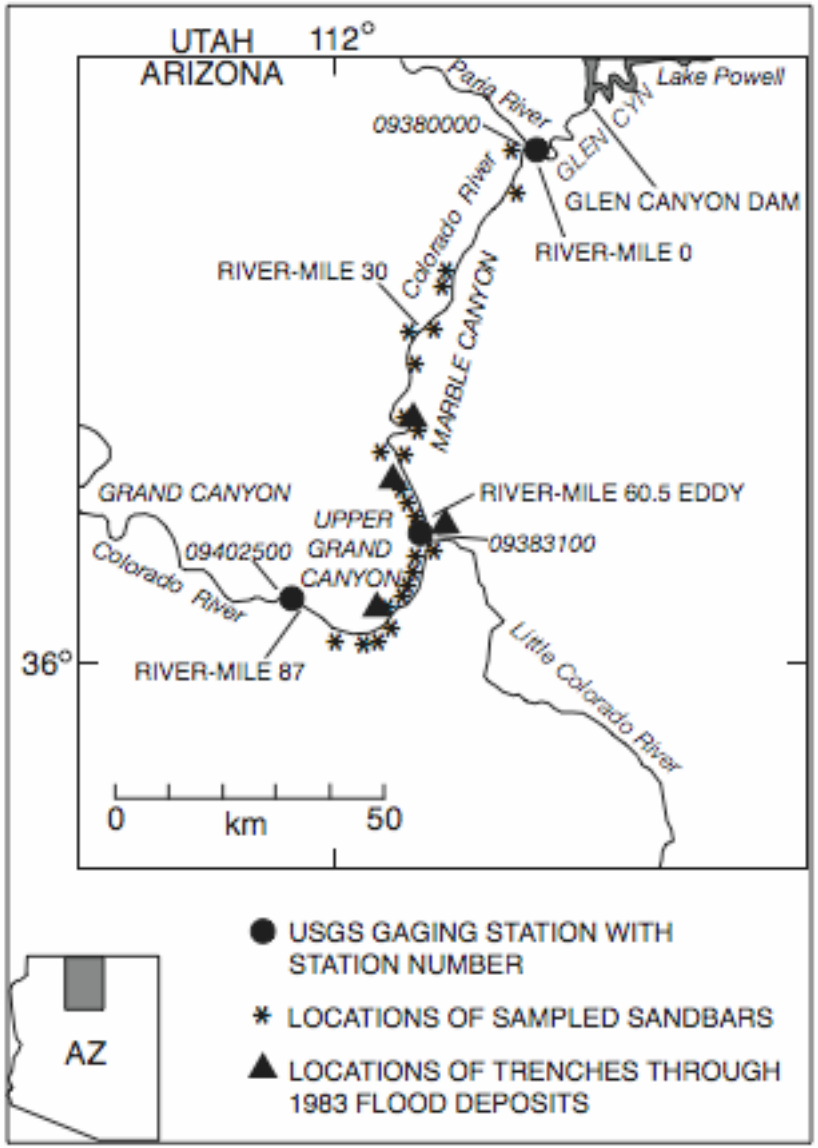
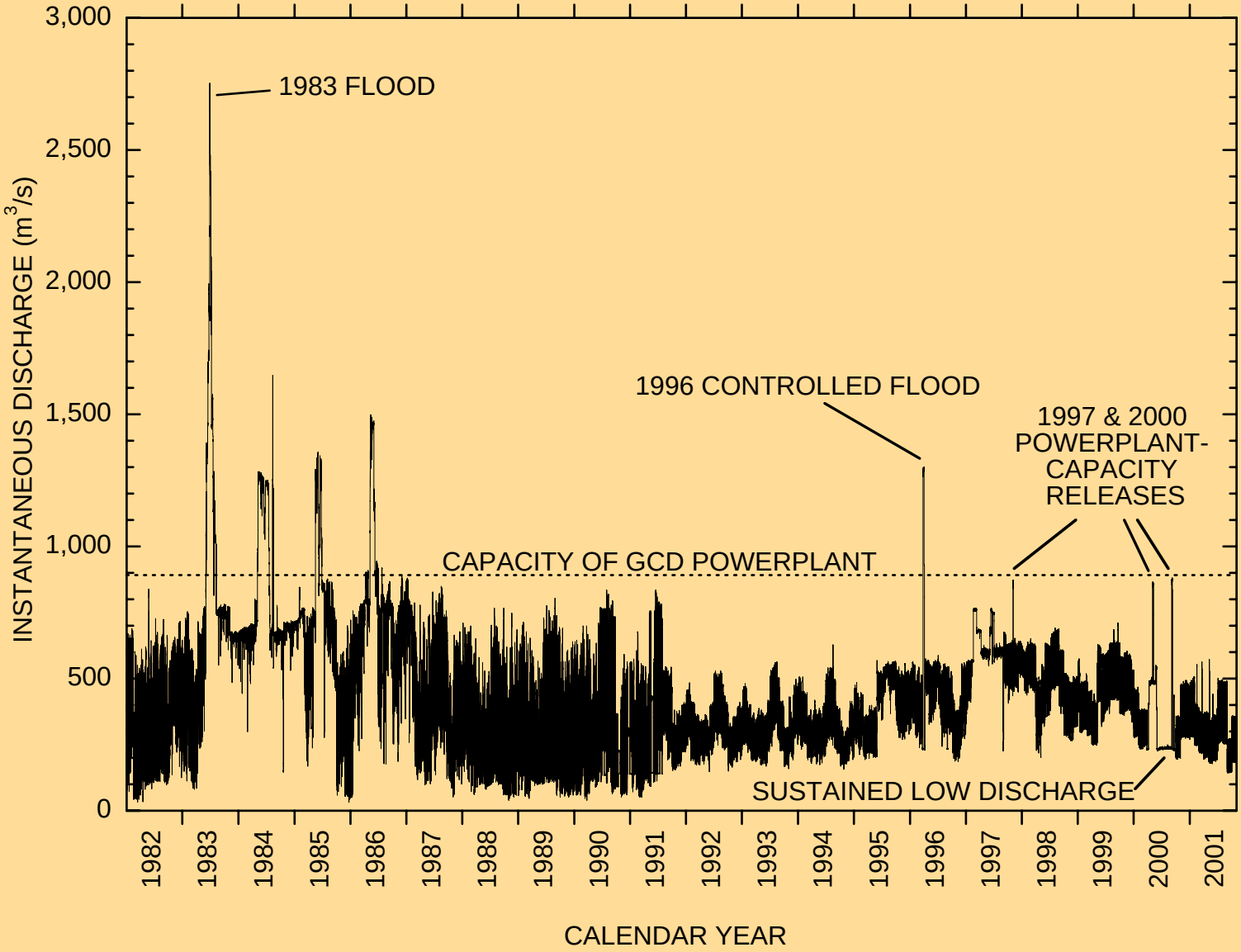

UTAH
ARIZONA
112°
Paria River
Lake Powell
09380000
GLEN CYN
GLEN CANYON DAM
RIVER-MILE 0
Colorado River
RIVER-MILE 30
MARBLE CANYON
GRAND CANYON
RIVER-MILE 60.5 EDDY
UPPER GRAND CANYON
09383100
09402500
Colorado River
36°
RIVER-MILE 87
Little Colorado River
0
km
50
AZ
USGS GAGING STATION WITH STATION NUMBER
LOCATIONS OF SAMPLED SANDBARS
LOCATIONS OF TRENCHES THROUGH 1983 FLOOD DEPOSITS

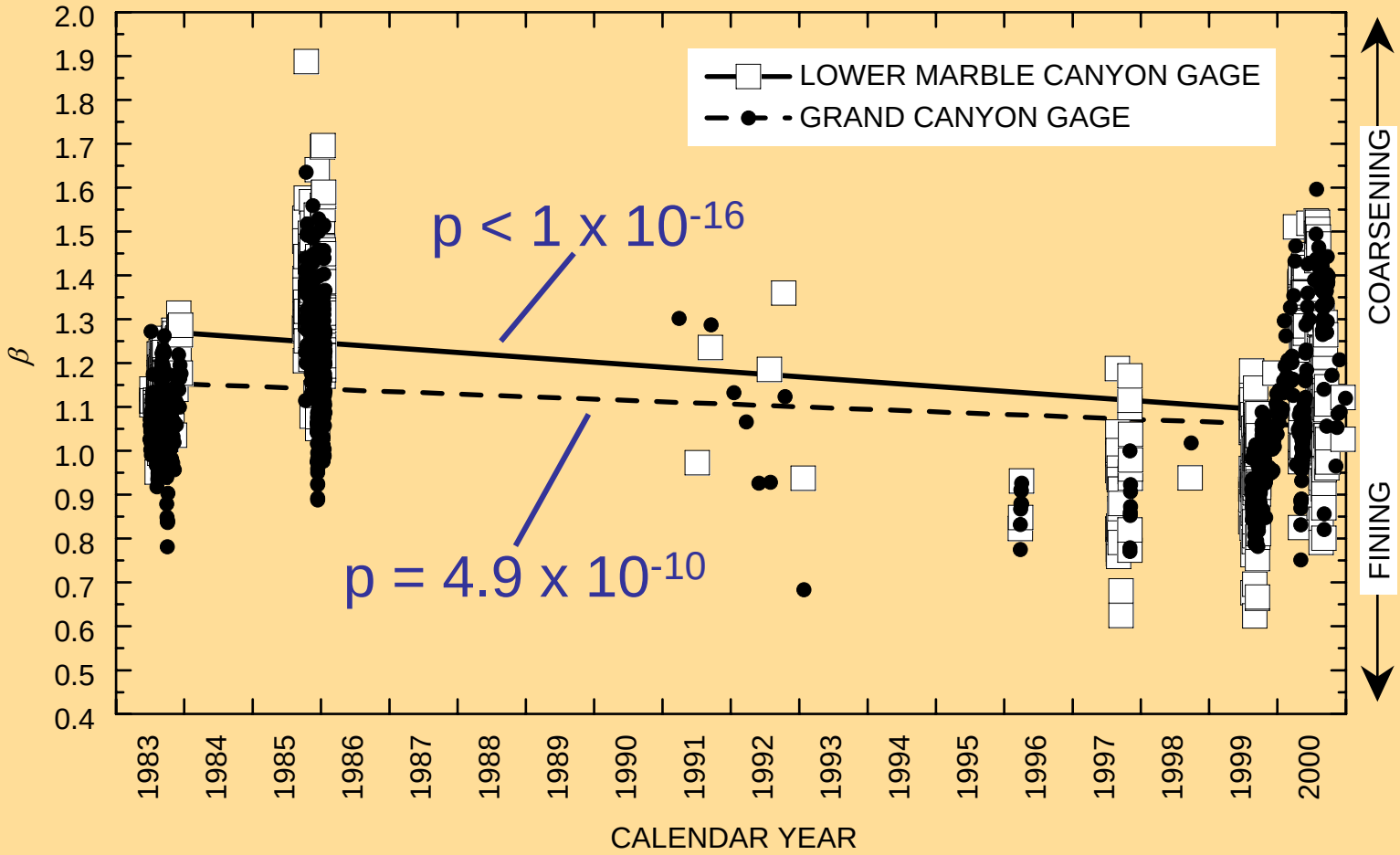
Figure 1


3,000
2,500
2,000
1,500
1,000
500
0
INSTANTANEOUS DISCHARGE (m3/s)
1983 FLOOD
1996 CONTROLLED FLOOD
1997 & 2000
POWERPLANT-
CAPACITY
RELEASES
CAPACITY OF GCD POWERPLANT
SUSTAINED LOW DISCHARGE
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
CALENDAR YEAR

Use β of Rubin and Topping (2001) in conjunction with field observations of surface grain size to evaluate which riverbed environment, main channel or eddy (~20% of area), is more important in regulating suspended-sand transport over multi-year timescales...

$$\beta = \frac{D_b}{D_{bm}}$$

$$\beta = \left(\frac{C}{C_m}\right)^{-0.1}\left(\frac{D_s}{D_{sm}}\right)^{0.2}$$


LOWER MARBLE CANYON GAGE
GRAND CANYON GAGE
p < 1 x 10-16
p = 4.9 x 10-10
β
CALENDAR YEAR
COARSENING
FINING
2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000

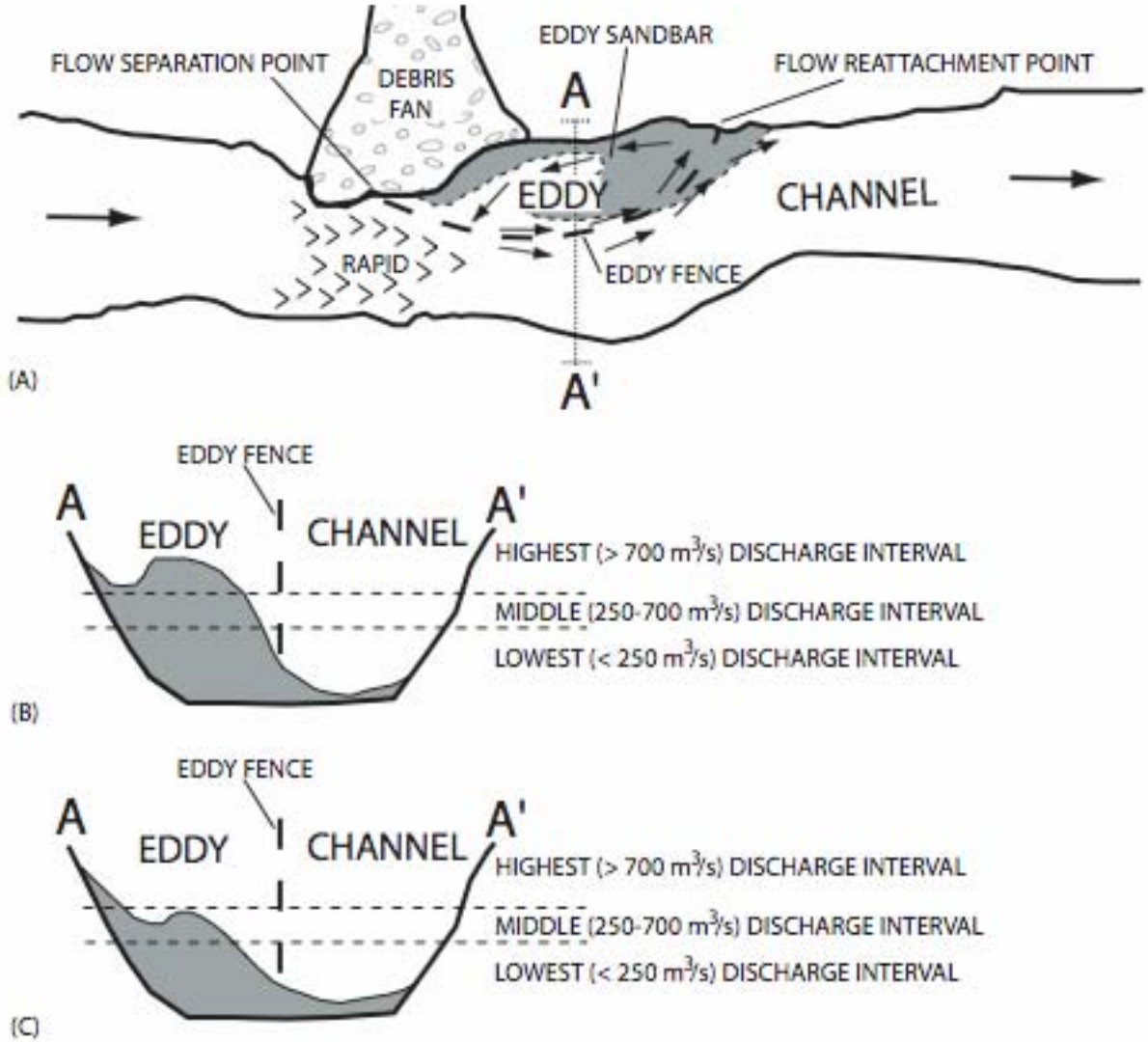
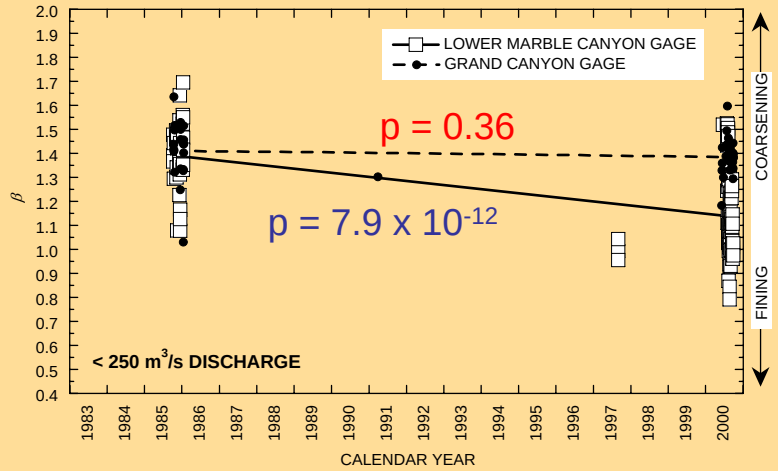
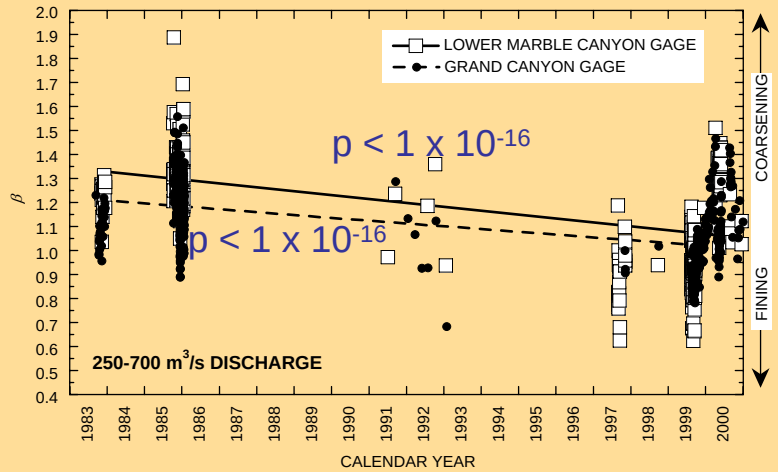
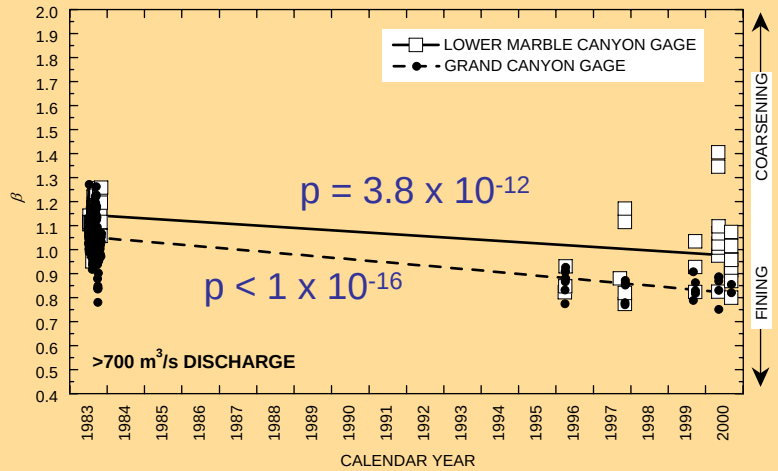
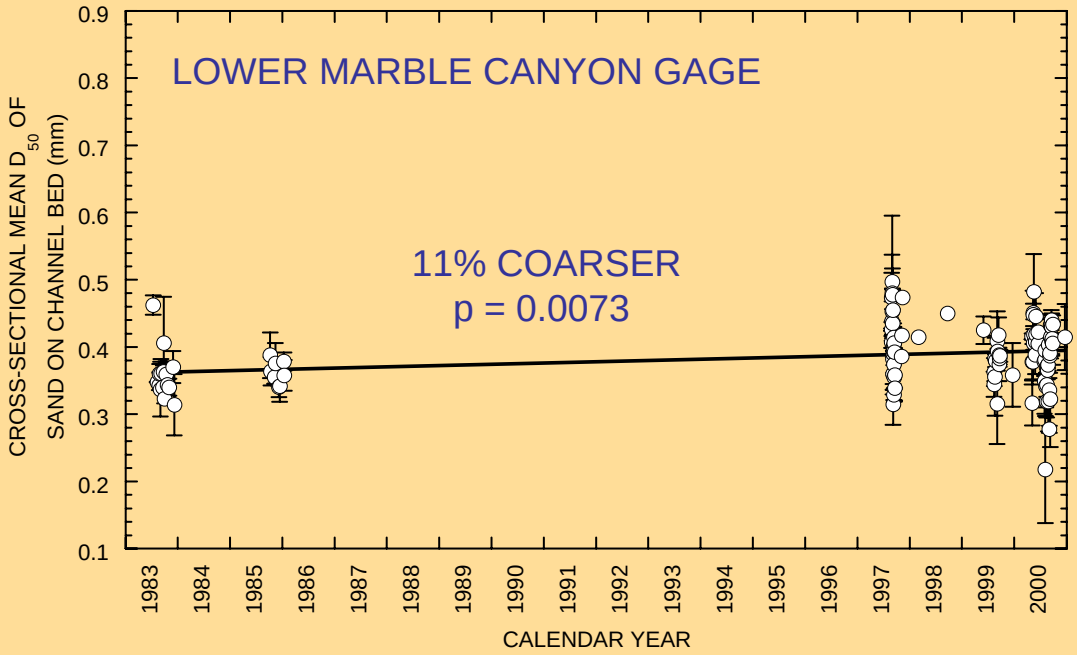

FLOW SEPARATION POINT
DEBRIS FAN
EDDY SANDBAR
A
FLOW REATTACHMENT POINT
EDDY
CHANNEL
RAPID
EDDY FENCE
(A)
A'
EDDY FENCE
A
EDDY
CHANNEL
A'
HIGHEST (> 700 m3/s) DISCHARGE INTERVAL
MIDDLE (250-700 m3/s) DISCHARGE INTERVAL
LOWEST (< 250 m3/s) DISCHARGE INTERVAL
(B)
EDDY FENCE
A
EDDY
CHANNEL
A'
HIGHEST (> 700 m3/s) DISCHARGE INTERVAL
MIDDLE (250-700 m3/s) DISCHARGE INTERVAL
LOWEST (< 250 m3/s) DISCHARGE INTERVAL
(C)

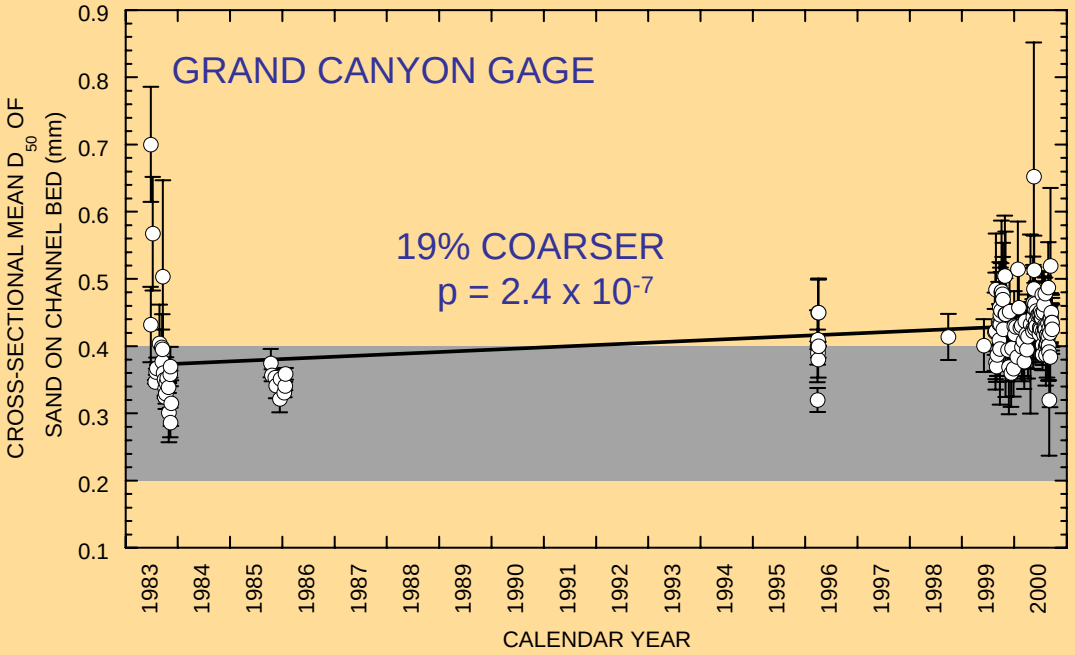
Figure 6

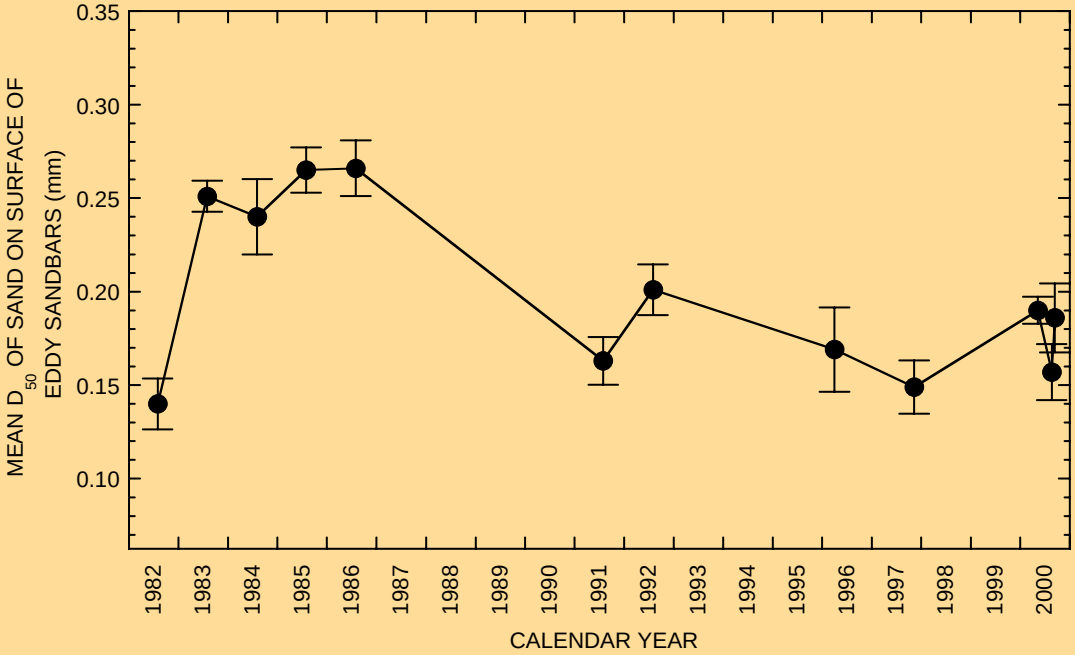

LOWER MARBLE CANYON GAGE
GRAND CANYON GAGE
p = 0.36
p = 7.9 x 10-12
< 250 m3/s DISCHARGE
β
COARSENING
FINING
CALENDAR YEAR

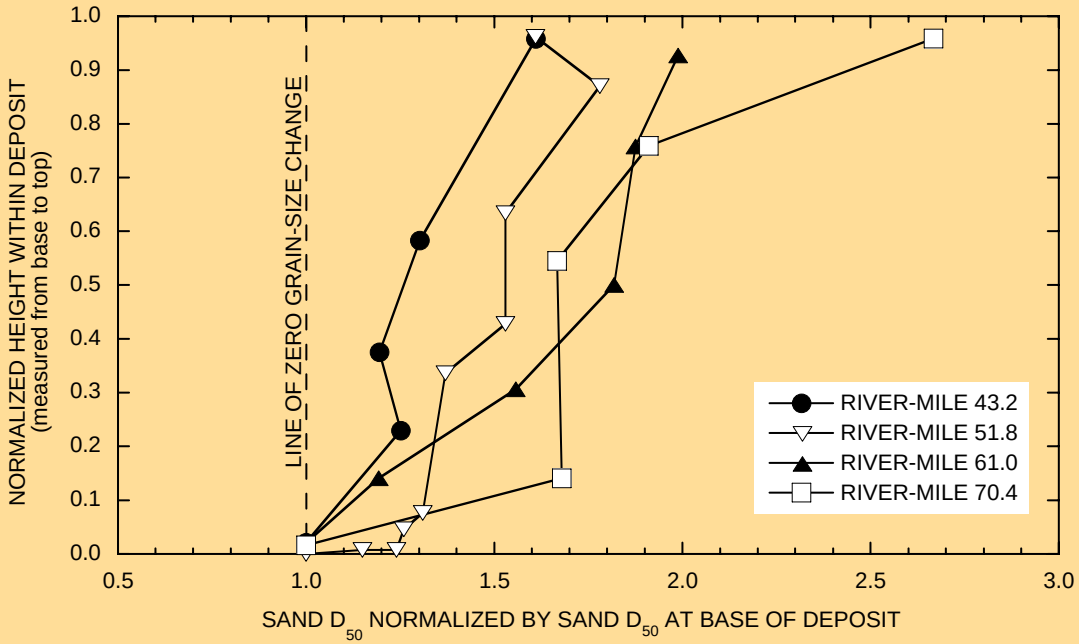

LOWER MARBLE CANYON GAGE
GRAND CANYON GAGE
p < 1 x 10-16
p < 1 x 10-16
250-700 m3/s DISCHARGE
β
COARSENING
FINING
CALENDAR YEAR


LOWER MARBLE CANYON GAGE
GRAND CANYON GAGE
p = 3.8 x 10-12
p < 1 x 10-16
>700 m3/s DISCHARGE
β
COARSENING
FINING
CALENDAR YEAR


LOWER MARBLE CANYON GAGE
11% COARSER
p = 0.0073
CROSS-SECTIONAL MEAN D_{50} OF SAND ON CHANNEL BED (mm)
CALENDAR YEAR
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000


GRAND CANYON GAGE
19% COARSER
p = 2.4 x 10^{-7}
CROSS-SECTIONAL MEAN D_{50} OF SAND ON CHANNEL BED (mm)
CALENDAR YEAR
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000


MEAN D_{50} OF SAND ON SURFACE OF EDDY SANDBARS (mm)
0.35
0.30
0.25
0.20
0.15
0.10
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
CALENDAR YEAR


NORMALIZED HEIGHT WITHIN DEPOSIT (measured from base to top)
LINE OF ZERO GRAIN-SIZE CHANGE
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0.5
1.0
1.5
2.0
2.5
3.0
SAND D_{50} NORMALIZED BY SAND D_{50} AT BASE OF DEPOSIT
RIVER-MILE 43.2
RIVER-MILE 51.8
RIVER-MILE 61.0
RIVER-MILE 70.4

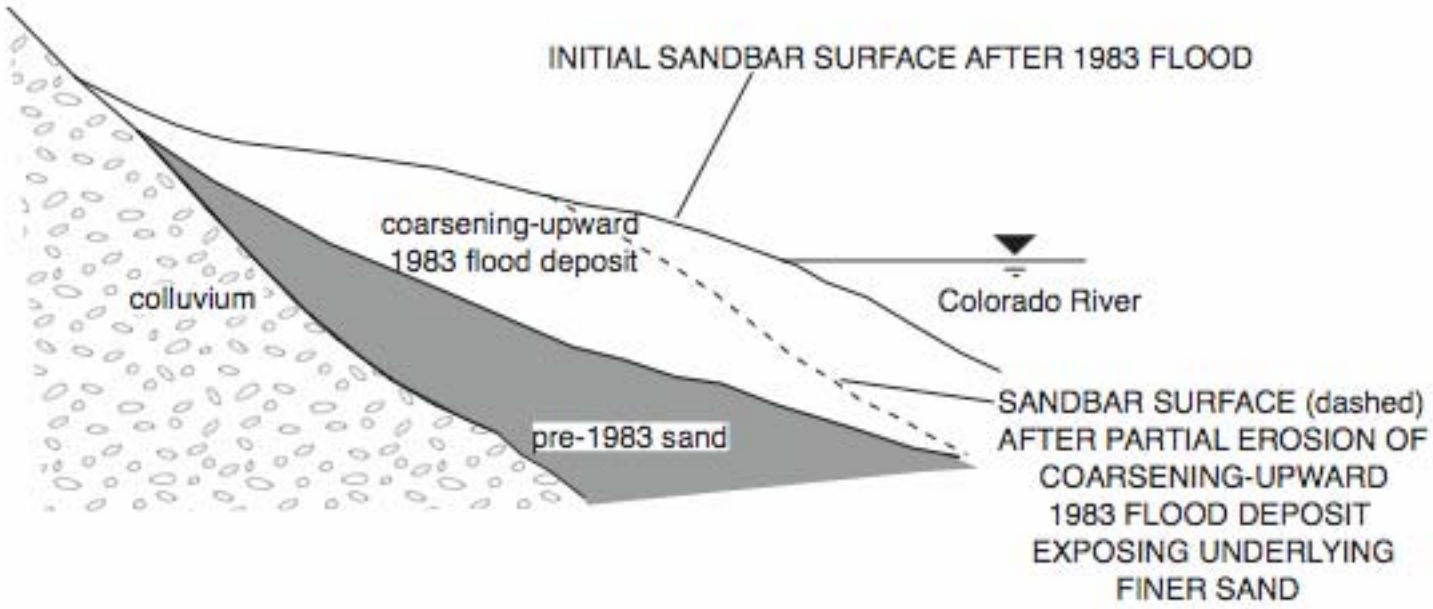


Figure 13

Idealized from Rubin *et al.* (1994) and Barnhardt *et al.* (2001)

Conclusions

- β-analyses of suspended-sediment data can be used in conjunction with analyses of surface grain-size data to deduce which environments in a complicated setting are the most important environments for regulating sediment transport, regardless of whether these environments comprise a relatively large or small part of the total environment

- In the case of the sand-supply-limited Colorado River in Marble and upper Grand Canyons, the bed environment that is the dominant regulator of sand transport in the river over multi-year timescales, the eddy environment, comprises only a small percentage (~20%) of the total area of the river [NOTE eddies also dominant storage environment in post-dam river (Hazel *et al.*, 2006)]

- 30-40% fining in eddy sandbar surfaces between 1986 and early 1990s corresponds to a factor of two increase in the concentration of suspended sand over these sandbars (Topping *et al.*, 2000)

- Increase in flux over the eddy-sandbar surfaces as the bar surfaces fined can lead to greater deposition and erosion rates in the eddies depending on the details of the flow fields in the eddies (Schmidt *et al.*, 1993; Nelson *et al.*, 1994, 2003; Nelson and McDonald, 1995; Rubin *et al.*, 1998; Wiele *et al.*, 1999)