Bed-Sediment Grain Size and Influence on Sediment Transport

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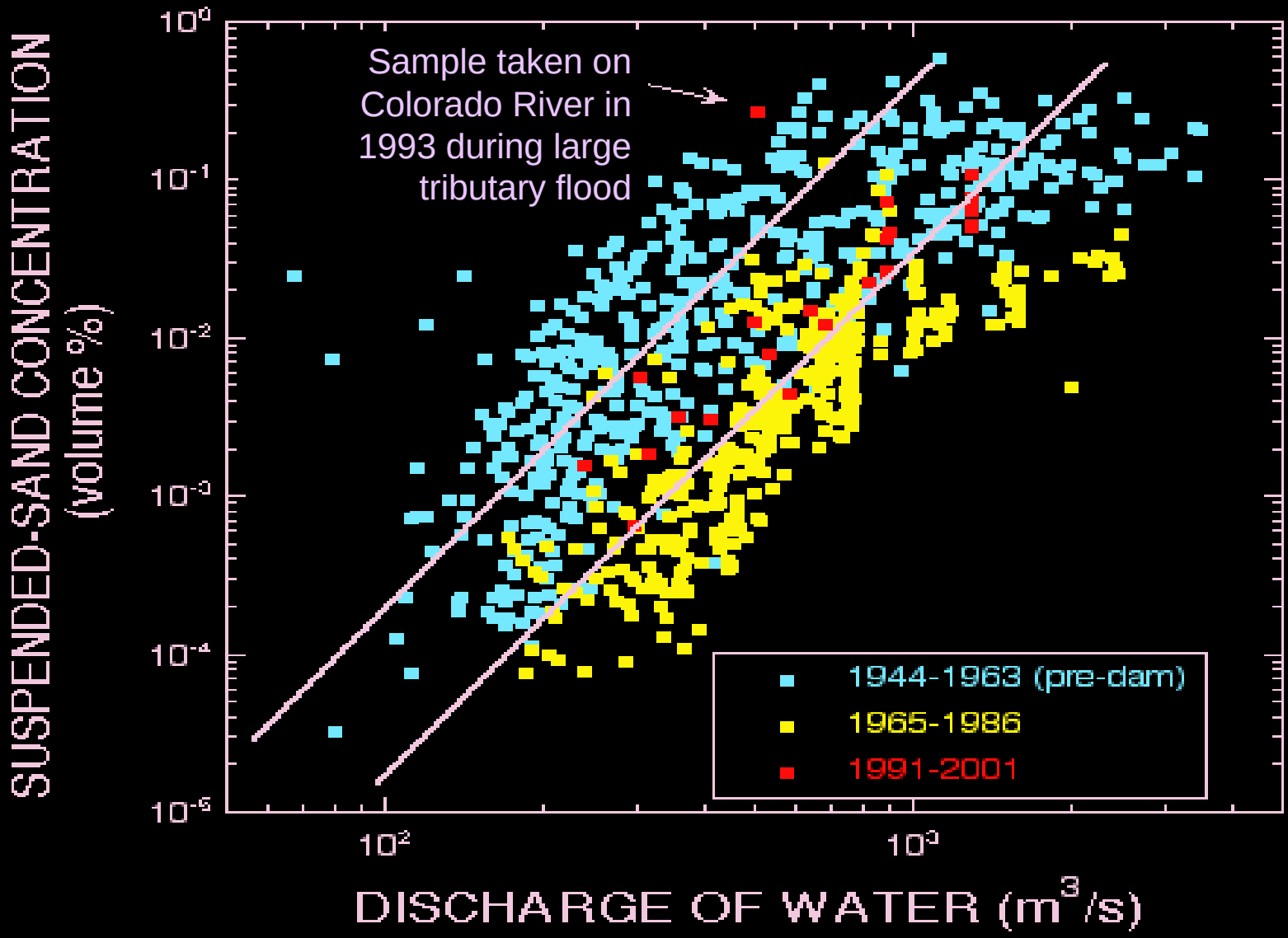
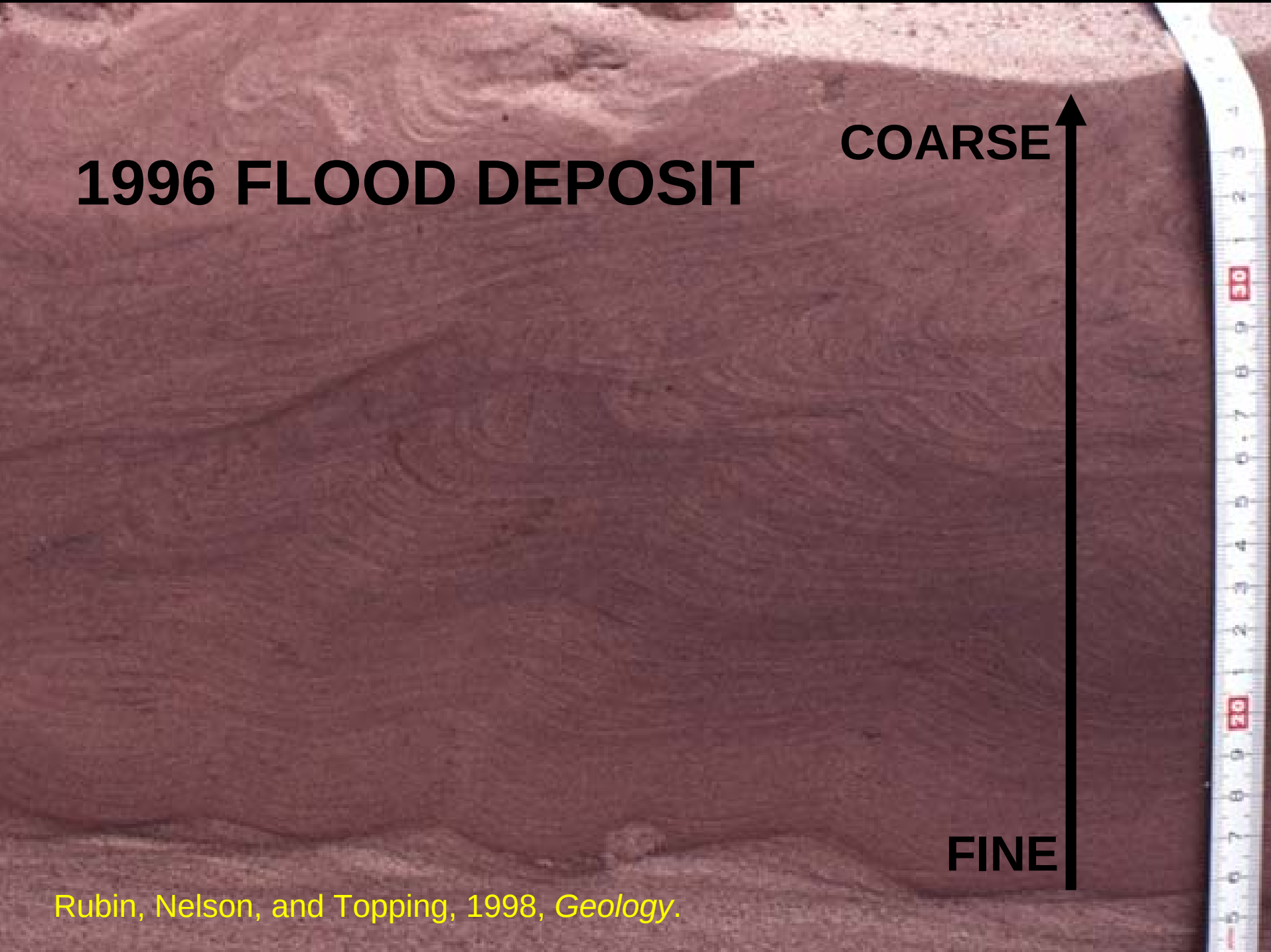
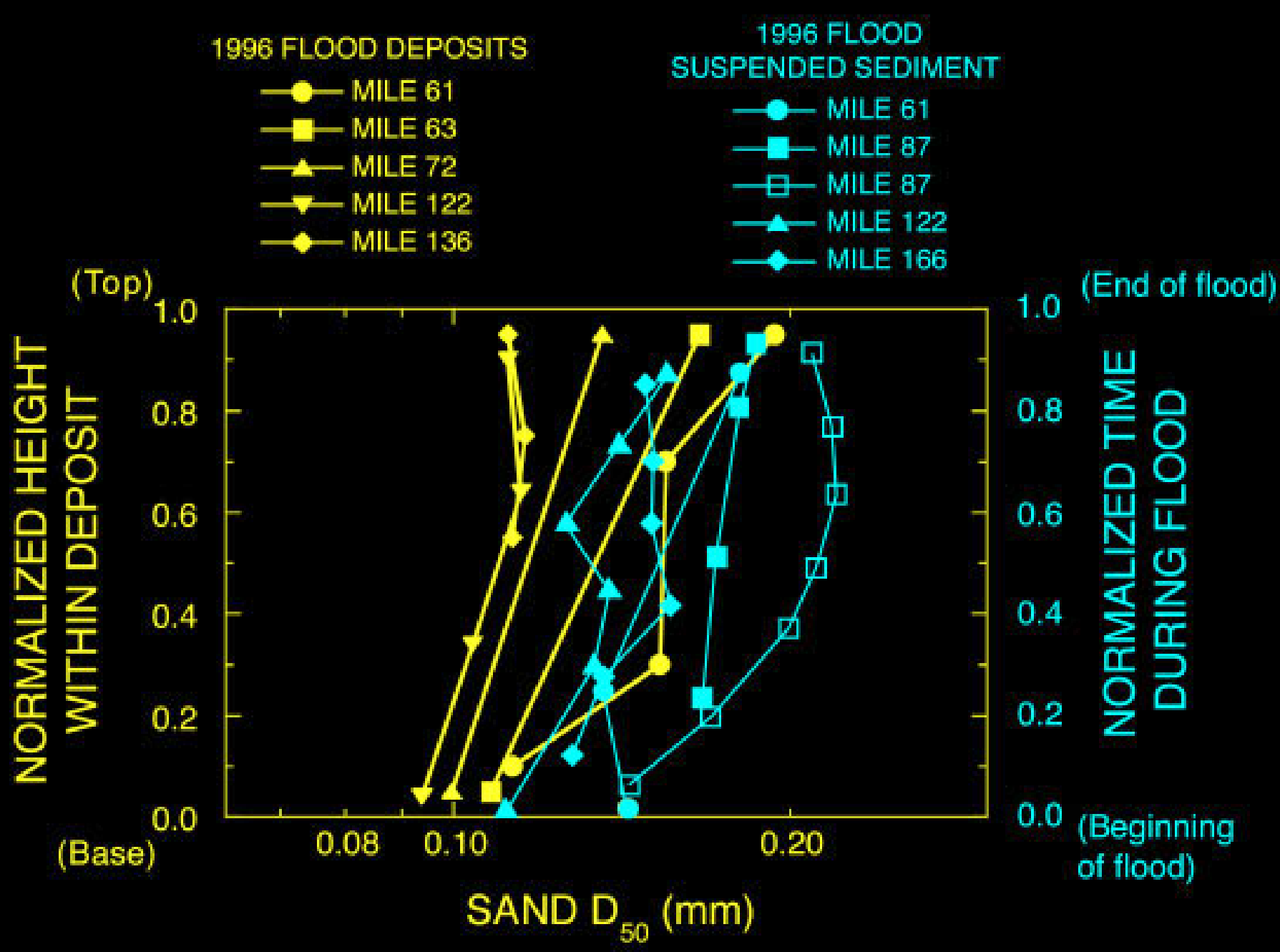
- Importance of changing bed sediment
- How to monitor

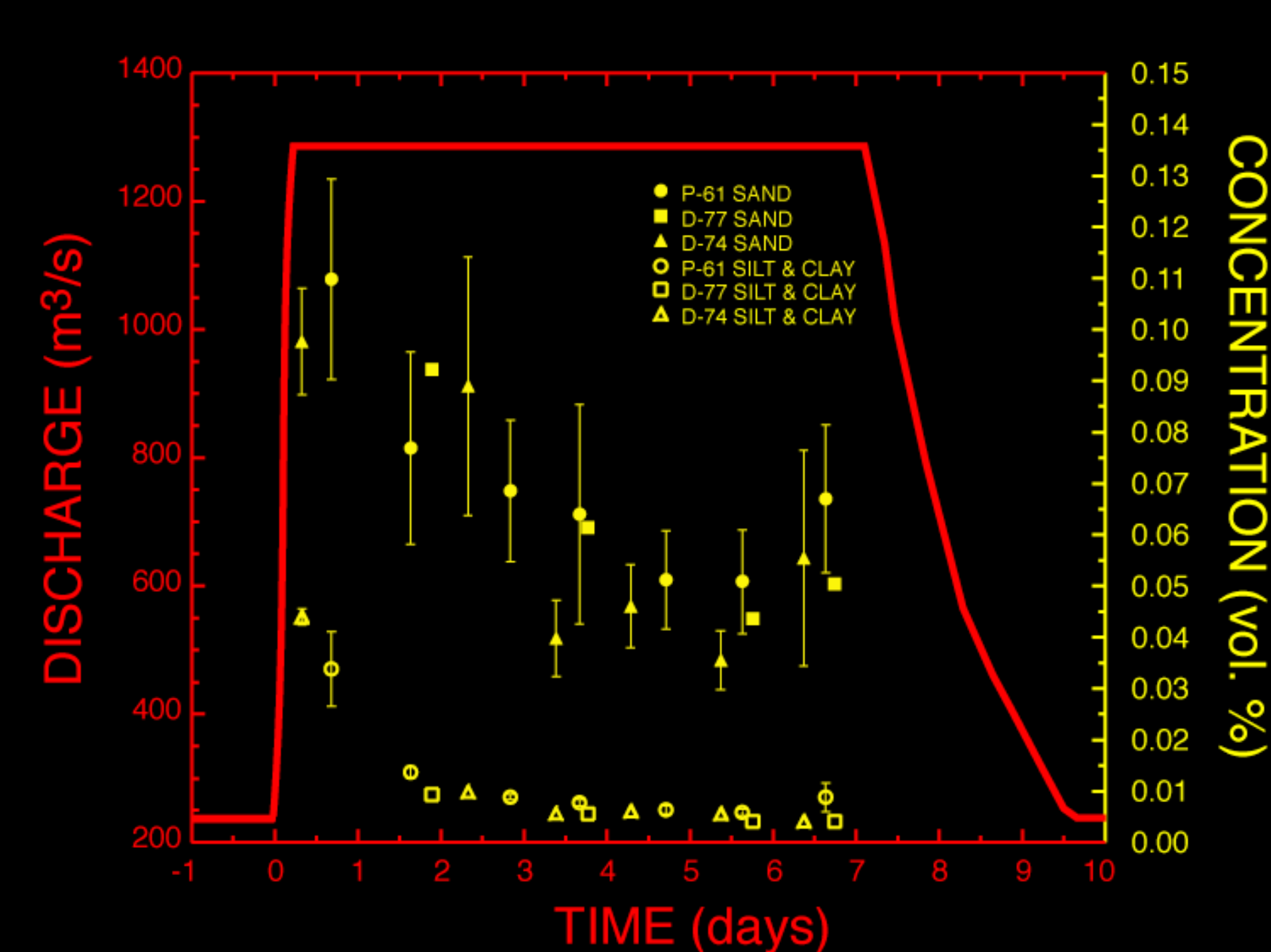
    Calculate from suspended sediment
    Observe the bed


SUSPENDED-SAND CONCENTRATION (volume %)
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{2}
10^{3}
DISCHARGE OF WATER (m^3/s)
Sample taken on Colorado River in 1993 during large tributary flood
1944-1963 (pre-dam)
1965-1986
1991-2001

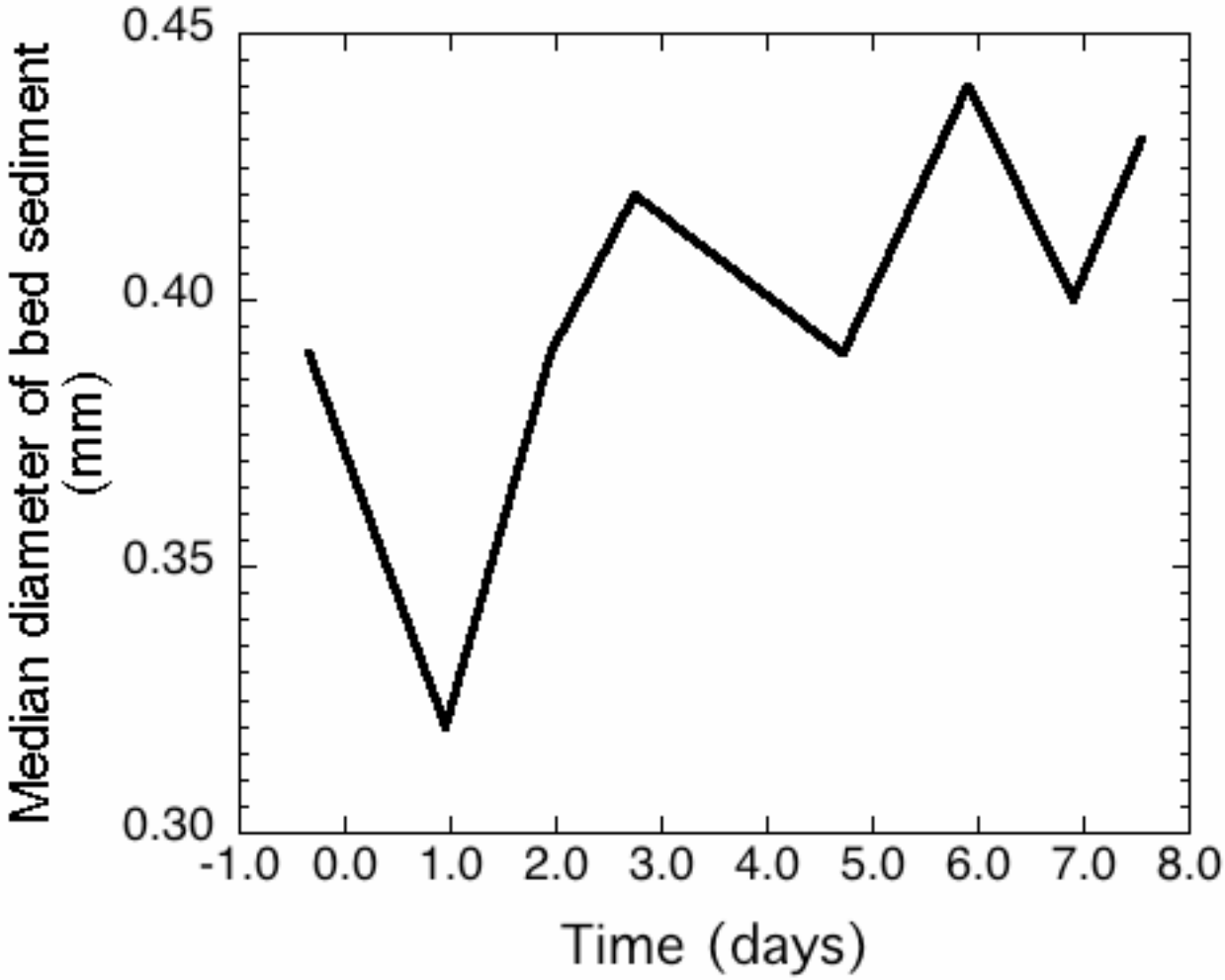


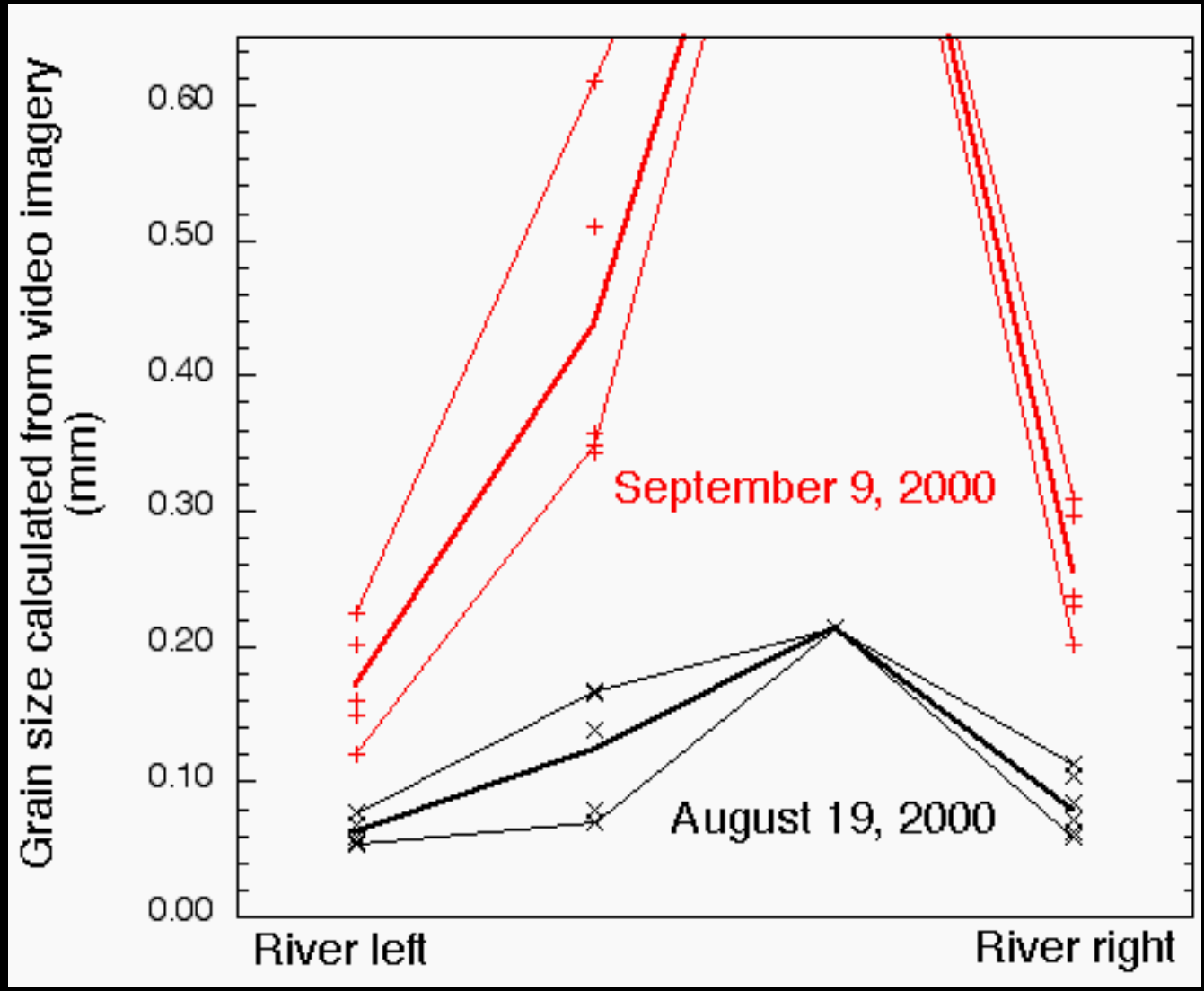
Rubin, Nelson, and Topping, 1998, *Geology*.


1996 FLOOD DEPOSITS
MILE 61
MILE 63
MILE 72
MILE 122
MILE 136
1996 FLOOD
SUSPENDED SEDIMENT
MILE 61
MILE 87
MILE 87
MILE 122
MILE 166
(Top)
(Base)
NORMALIZED HEIGHT
WITHIN DEPOSIT
1.0
0.8
0.6
0.4
0.2
0.0
0.08
0.10
0.20
SAND D_{50} (mm)
(End of flood)
(Beginning
of flood)
NORMALIZED TIME
DURING FLOOD

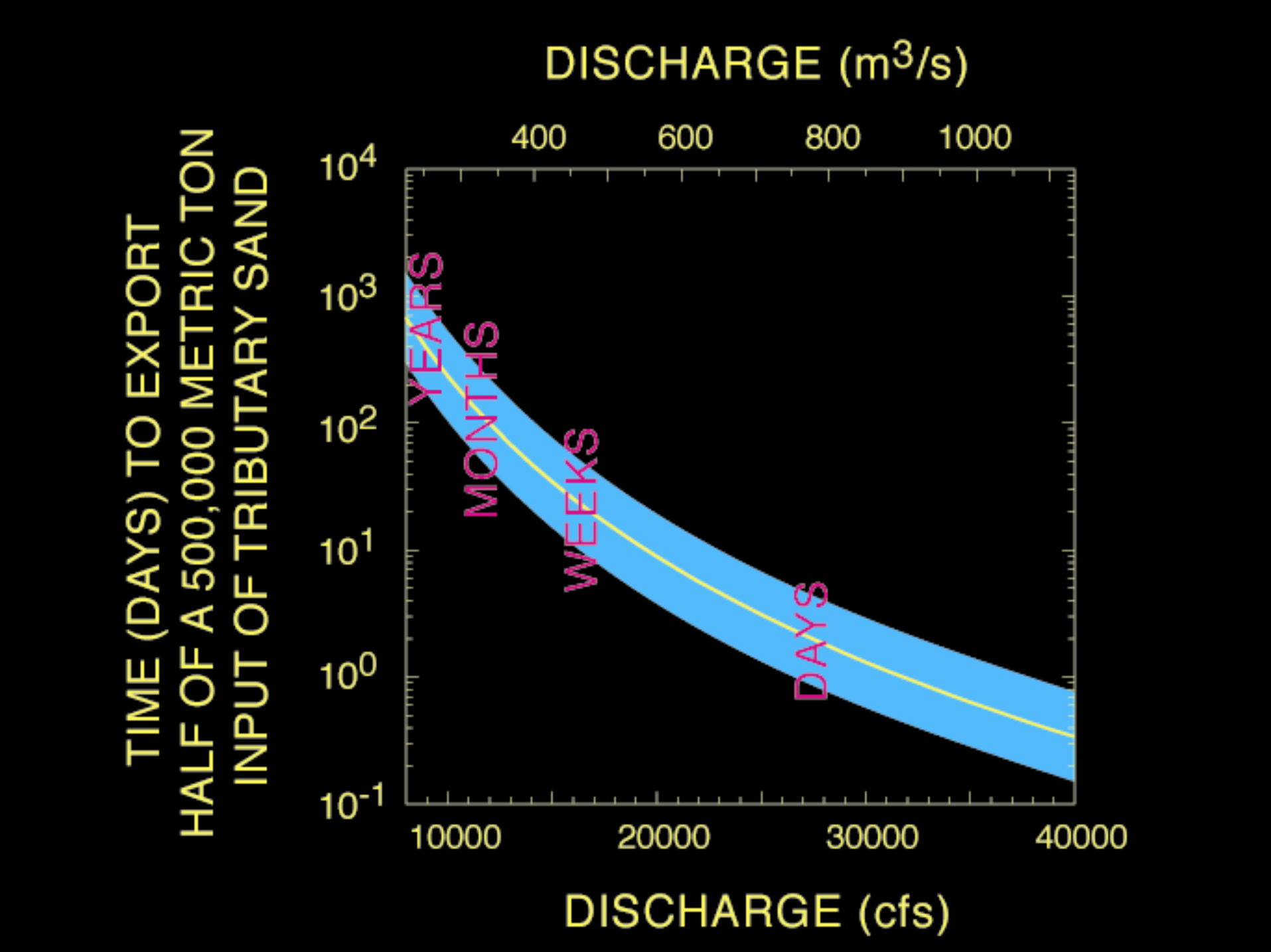

DISCHARGE (m3/s)
CONCENTRATION (vol. %)
TIME (days)
1400
1200
1000
800
600
400
200
0.15
0.14
0.13
0.12
0.11
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
-1
0
1
2
3
4
5
6
7
8
9
10
P-61 SAND
D-77 SAND
D-74 SAND
P-61 SILT & CLAY
D-77 SILT & CLAY
D-74 SILT & CLAY

1996 Flood Experiment





This observed change in grain size on the bed caused concentration to increase by several orders of magnitude (for constant water discharge).


DISCHARGE (m3/s)
400
600
800
1000
TIME (DAYS) TO EXPORT
HALF OF A 500,000 METRIC TON
INPUT OF TRIBUTARY SAND
10^4
10^3
10^2
10^1
10^0
10^-1
YEARS
MONTHS
WEEKS
DAYS
10000
20000
30000
40000
DISCHARGE (cfs)

- Importance of changing bed sediment
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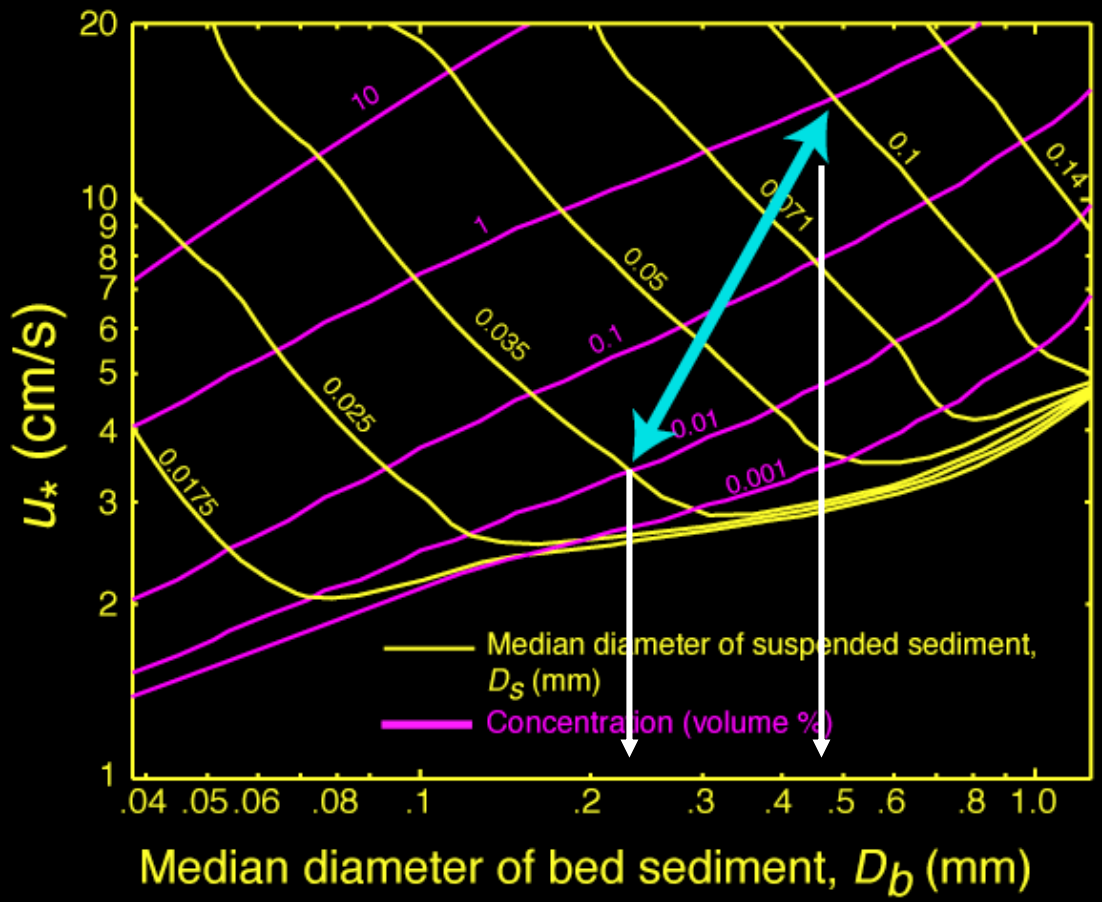
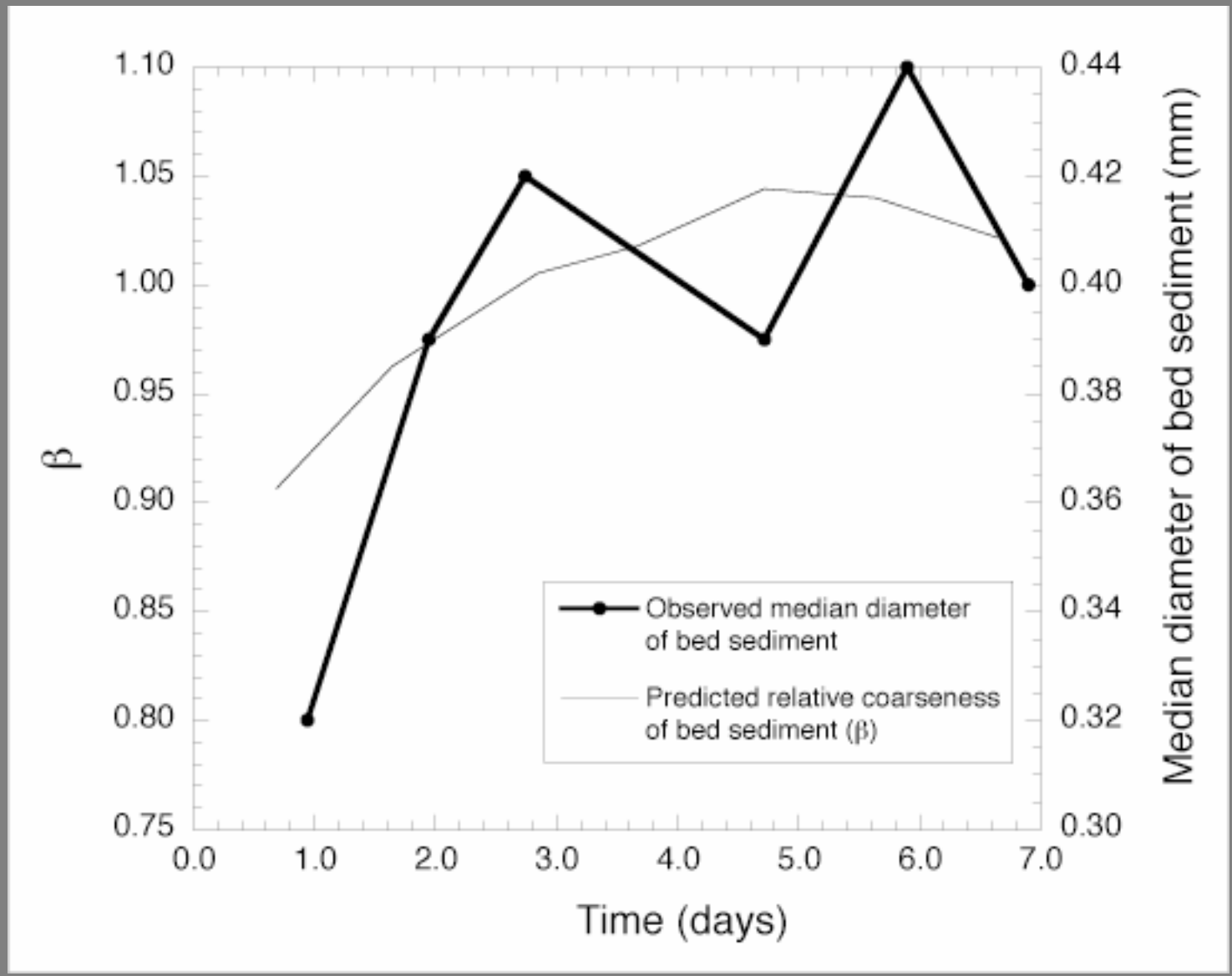
    Calculate from suspended sediment
    Observe the bed

Use observations of suspended-sediment concentration and grain size to calculate relative coarseness of bed sediment.

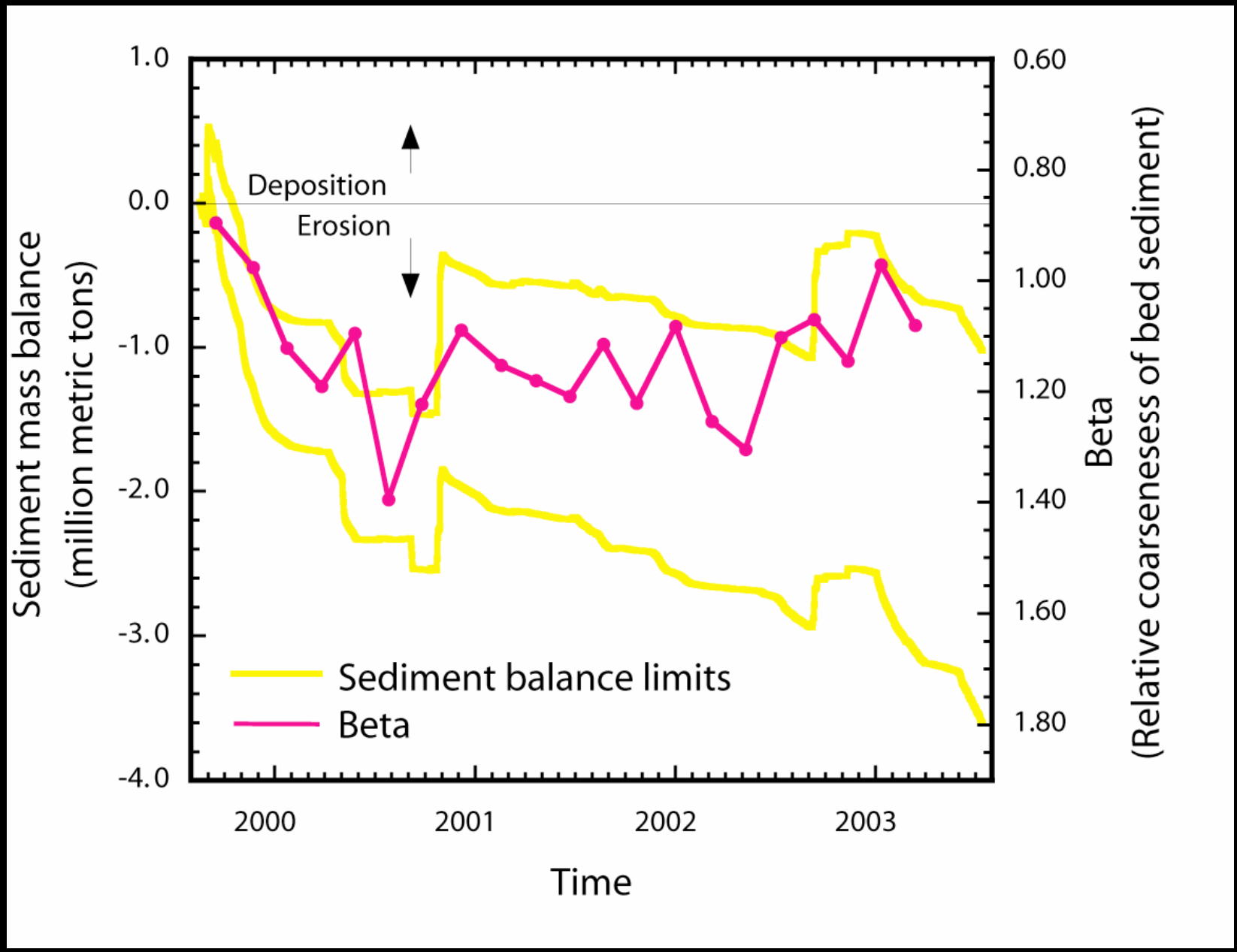


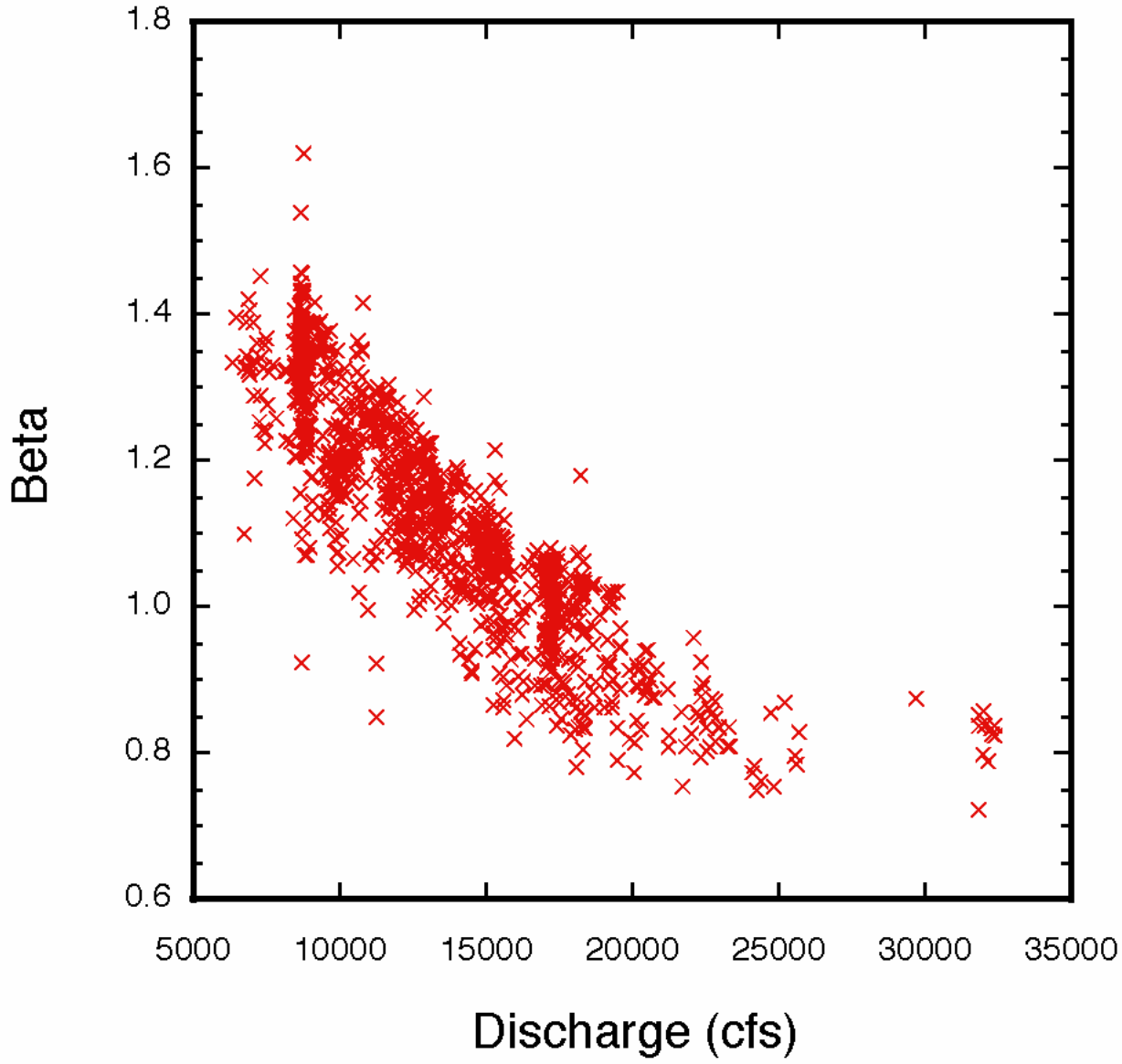
$$\beta = \frac{D_b}{\overline{D_b}}$$

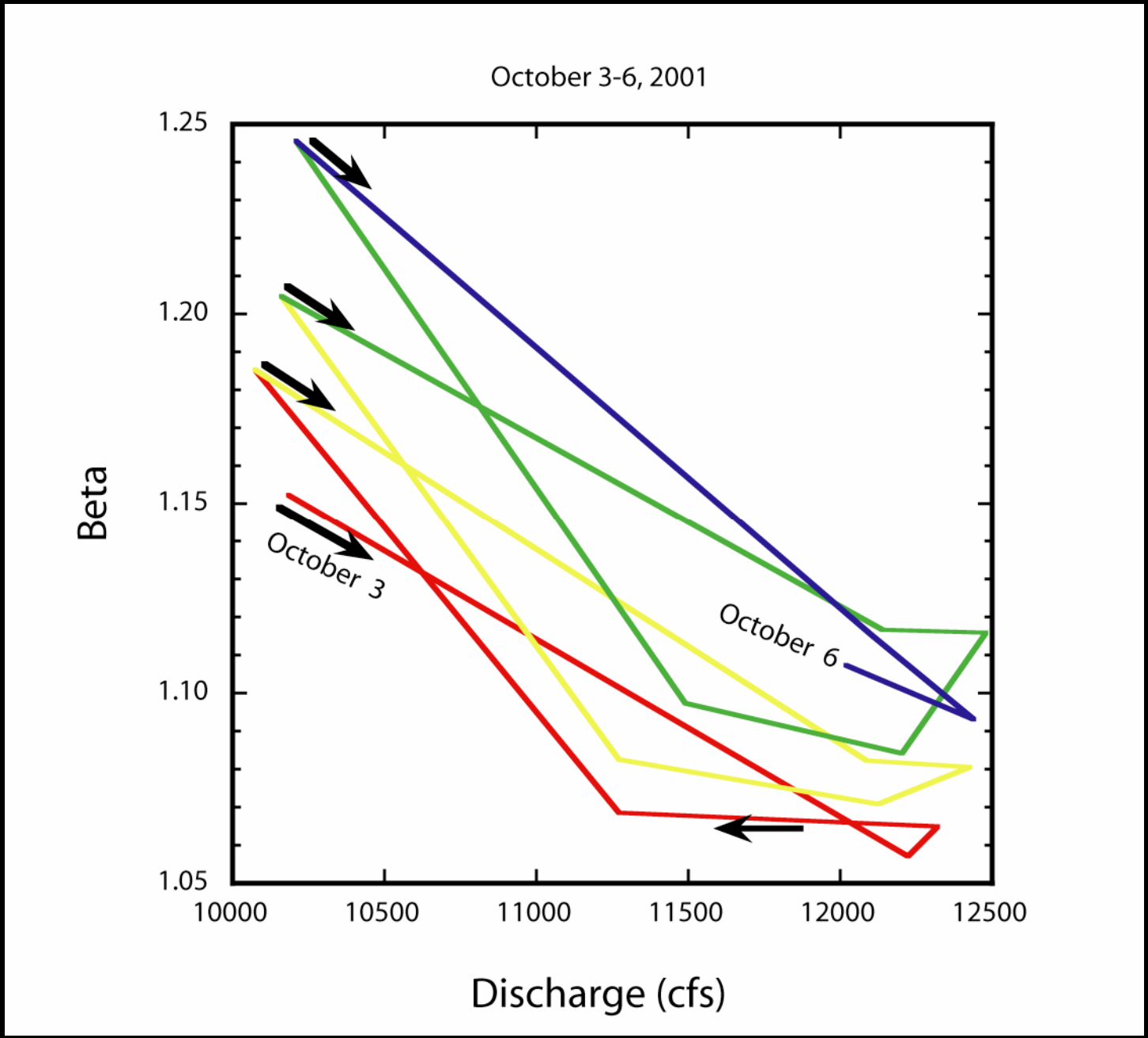
$$\frac{D_b}{\overline{D_b}} = \left(\frac{C}{\overline{C}}\right)^{-0.1} \left(\frac{D_s}{\overline{D_s}}\right)^{0.17}$$



From Rubin and Topping, 2001, Water Resources Research.


1.0
0.0
-1.0
-2.0
-3.0
-4.0
0.60
0.80
1.00
1.20
1.40
1.60
1.80
Deposition
Erosion
Sediment mass balance
(million metric tons)
Beta
(Relative coarsenesess of bed sediment)
Sediment balance limits
Beta
2000
2001
2002
2003
Time


Beta
1.8
1.6
1.4
1.2
1.0
0.8
0.6
5000
10000
15000
20000
25000
30000
35000
Discharge (cfs)


October 3-6, 2001
1.25
1.20
1.15
1.10
1.05
Beta
October 3
October 6
10000
10500
11000
11500
12000
12500
Discharge (cfs)

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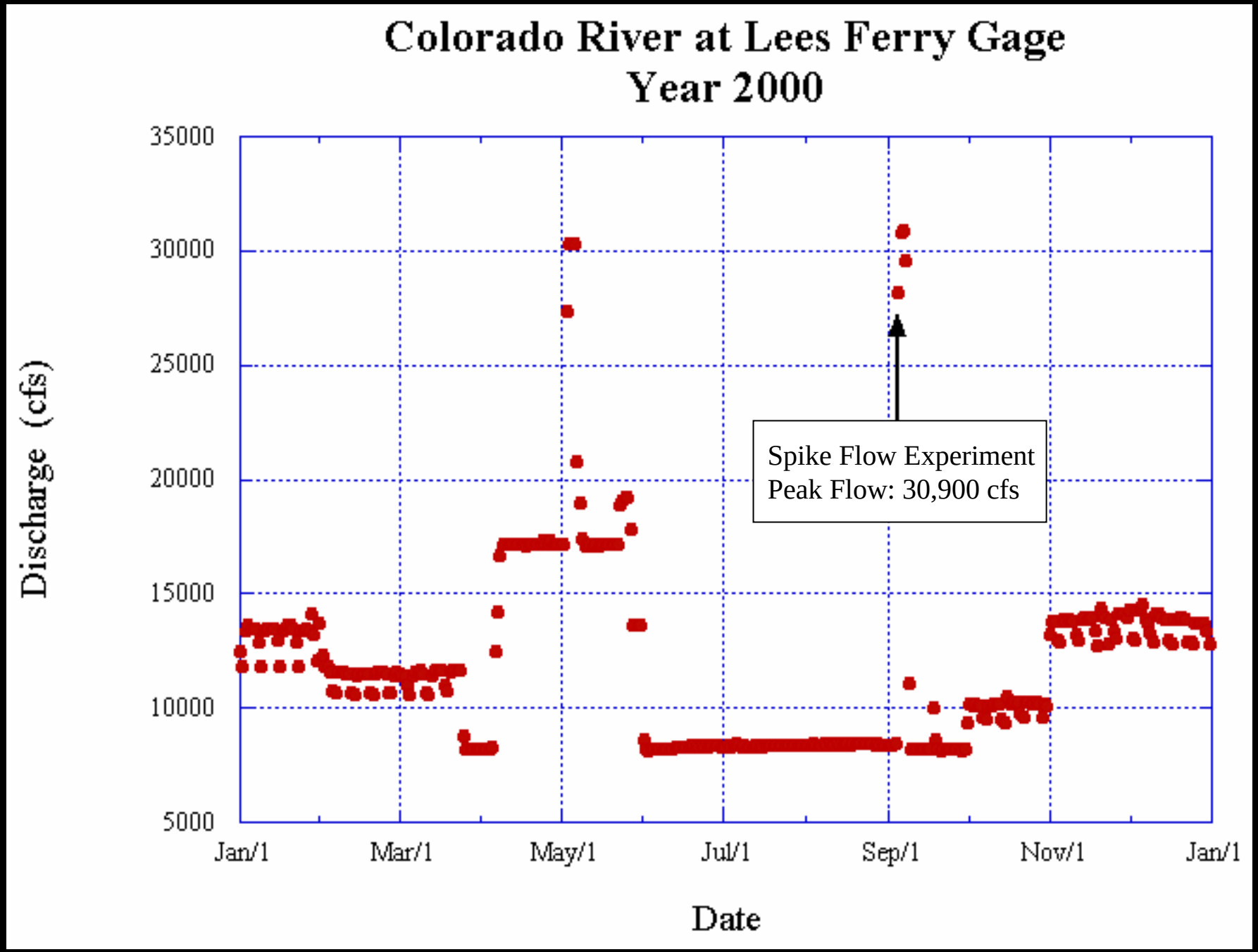
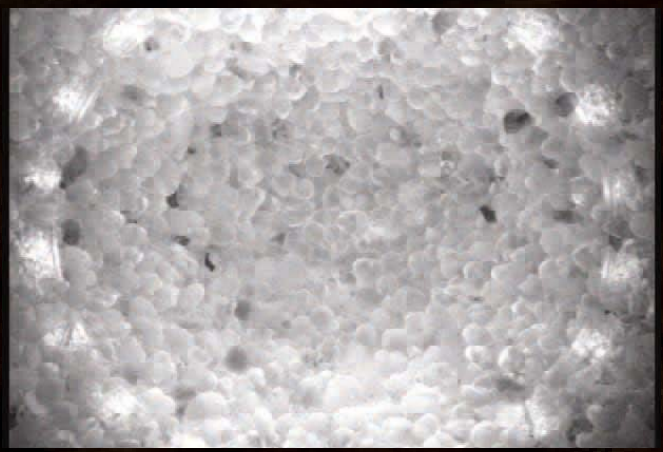

Colorado River at Lees Ferry Gage
Year 2000
Discharge (cfs)
35000
30000
25000
20000
15000
10000
5000
Jan/1
Mar/1
May/1
Jul/1
Sep/1
Nov/1
Jan/1
Date
Spike Flow Experiment
Peak Flow: 30,900 cfs

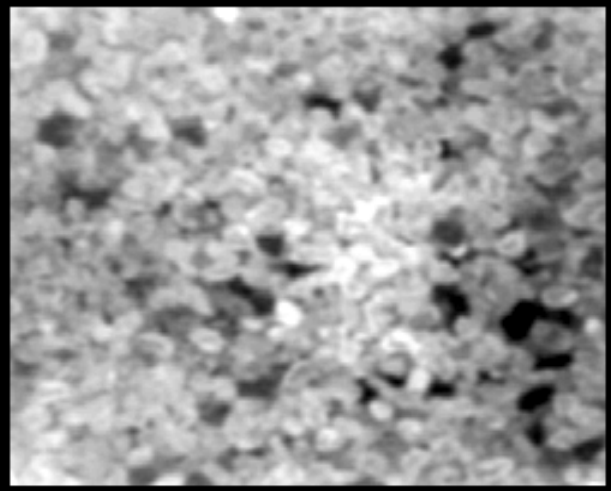
Sub-Aqueous Digital Video Microscopy: aka “The Flying Eyeball”



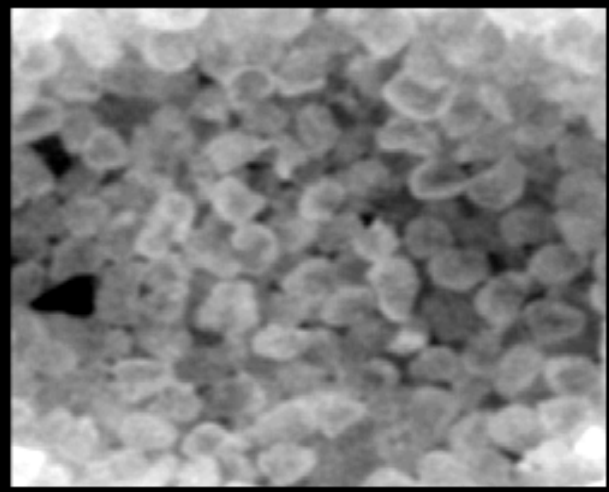
Reach 2
Eyeball Sites

Courtesy of: M. Manone - NAU

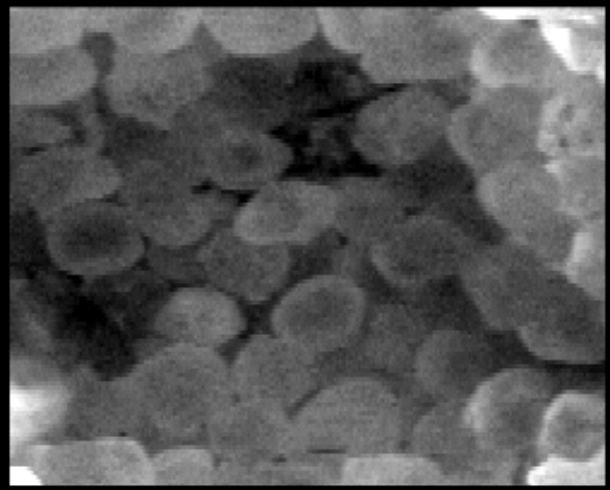
Eyeball Calibration Samples



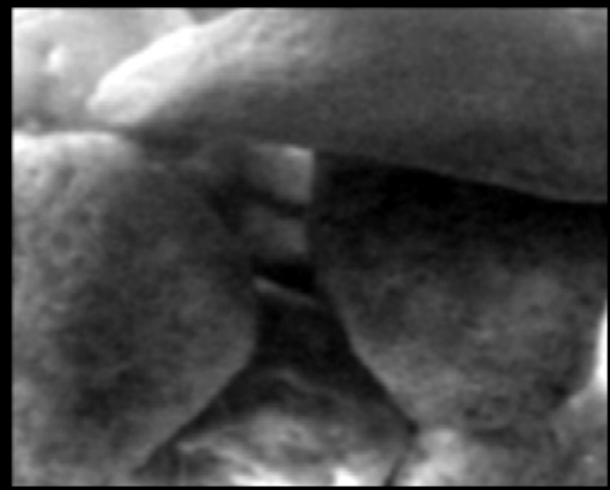
0.125 mm



0.25 mm



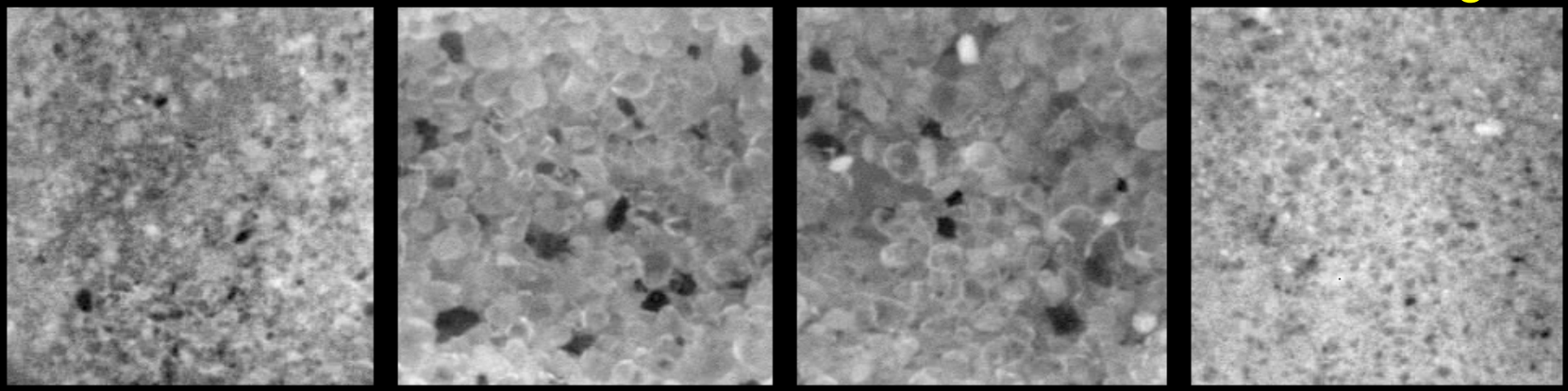
0.5 mm



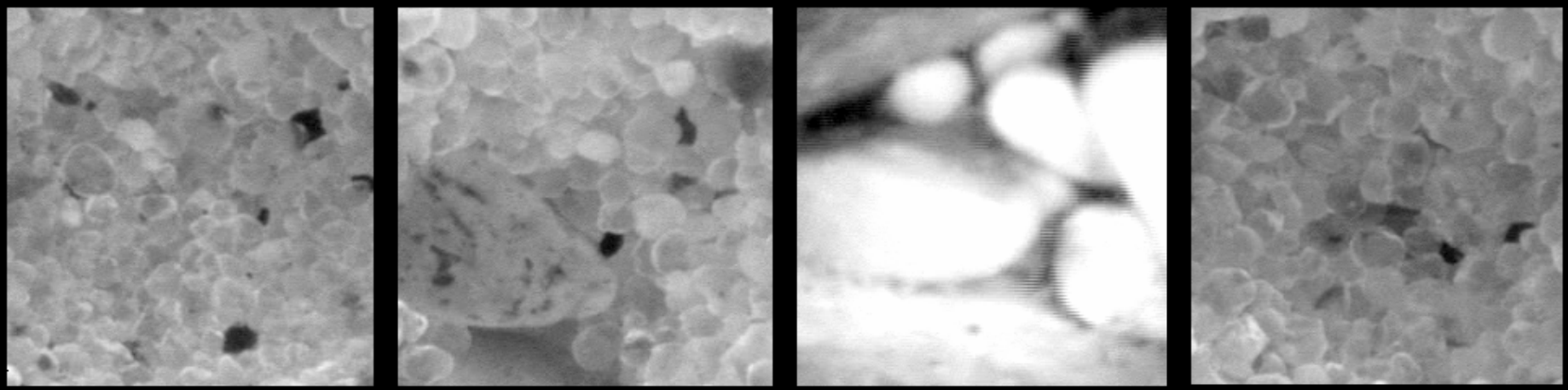
2.0 mm

River left

River right

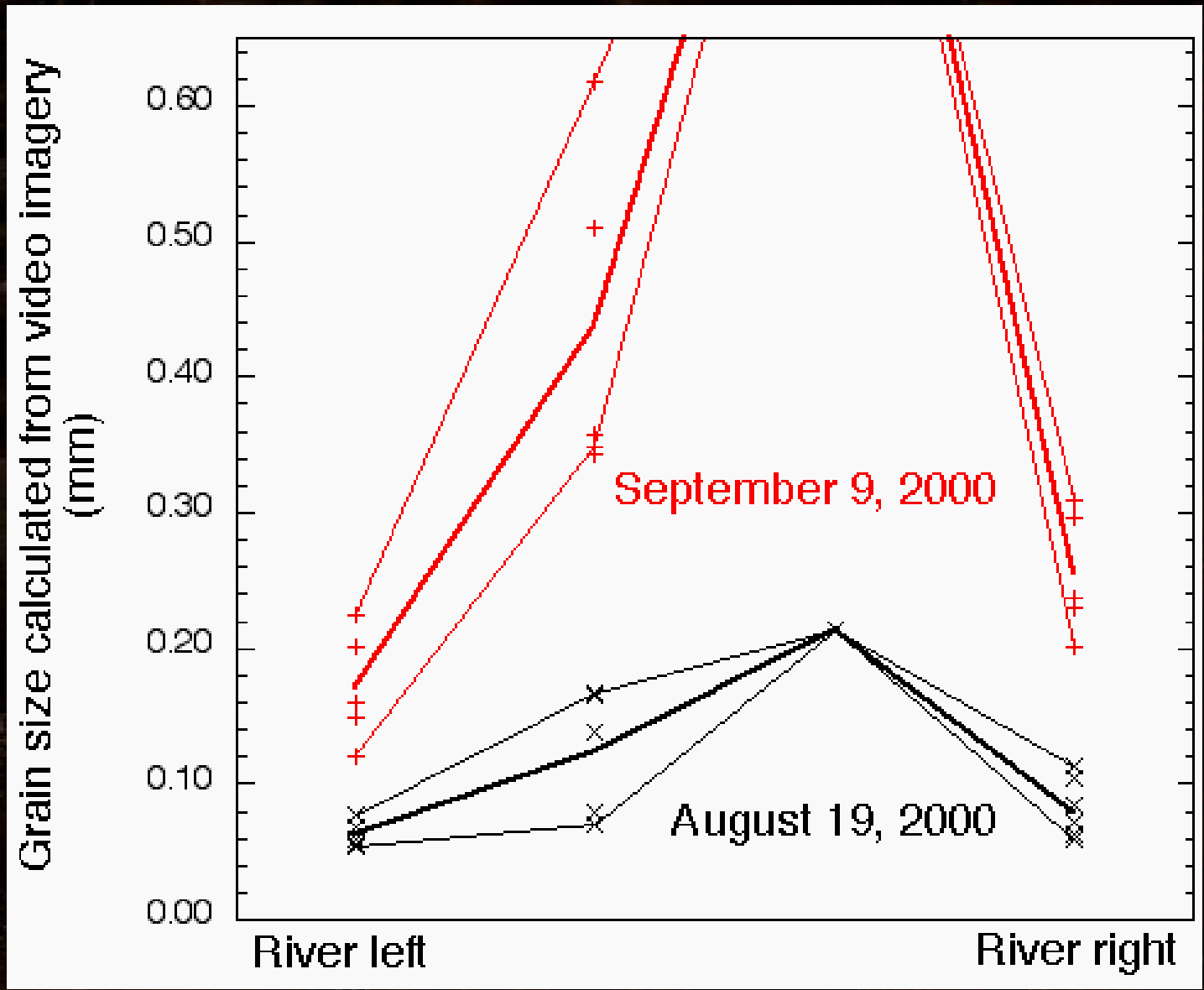


August 19, 2000

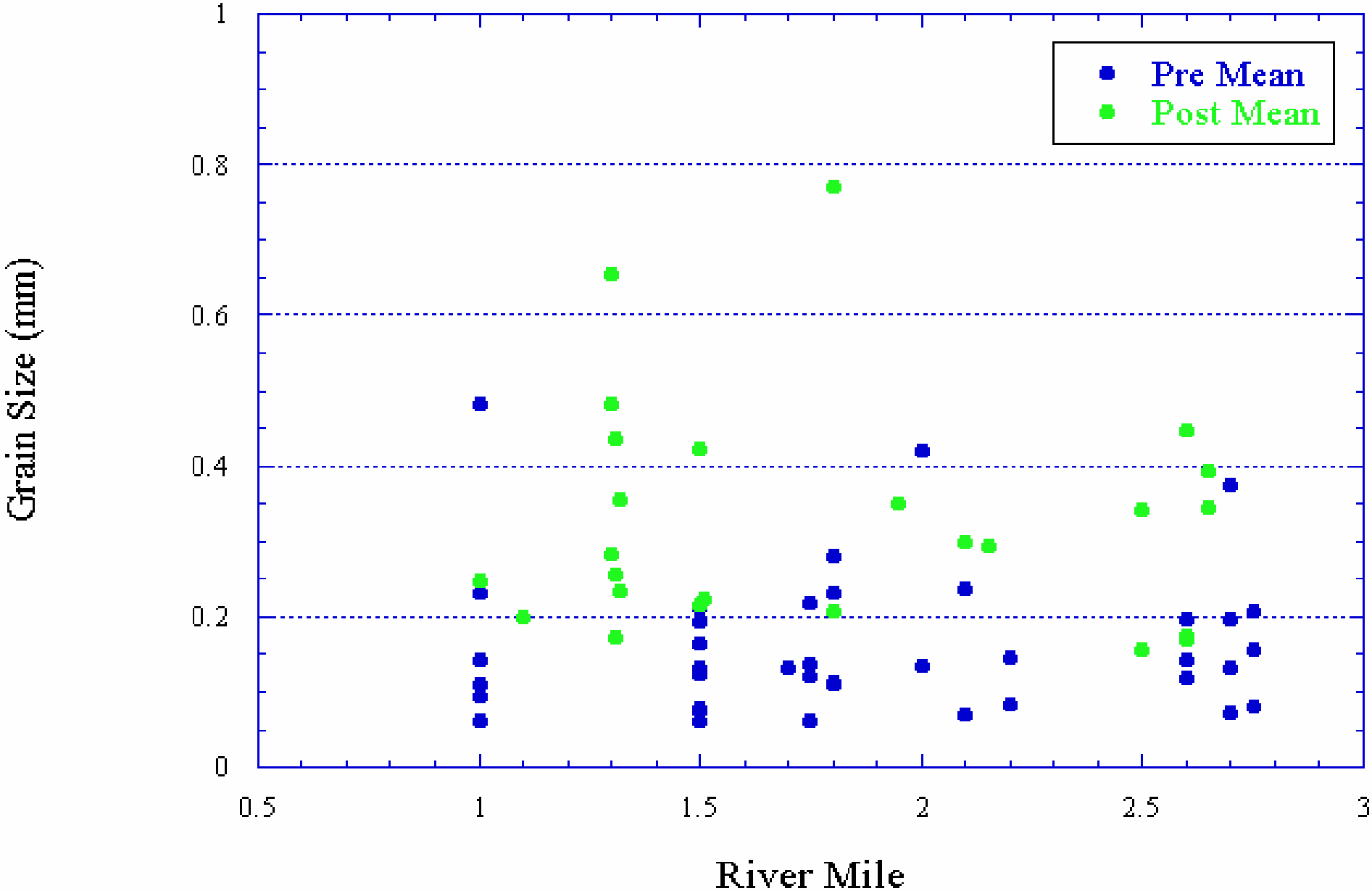


September 9, 2000

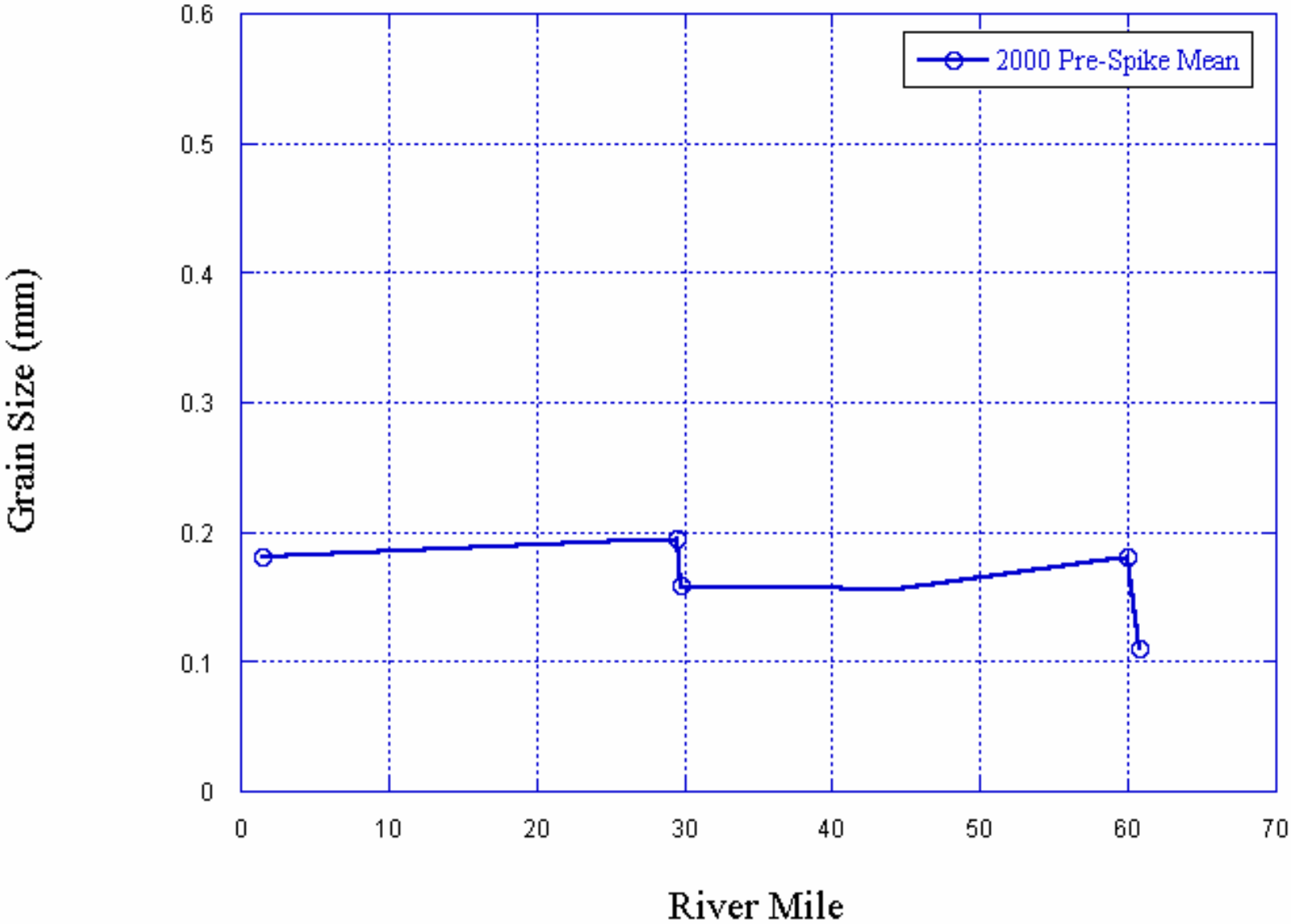
Mile 2-3:


Grain size calculated from video imagery (mm)
0.60
0.50
0.40
0.30
0.20
0.10
0.00
September 9, 2000
August 19, 2000
River left
River right

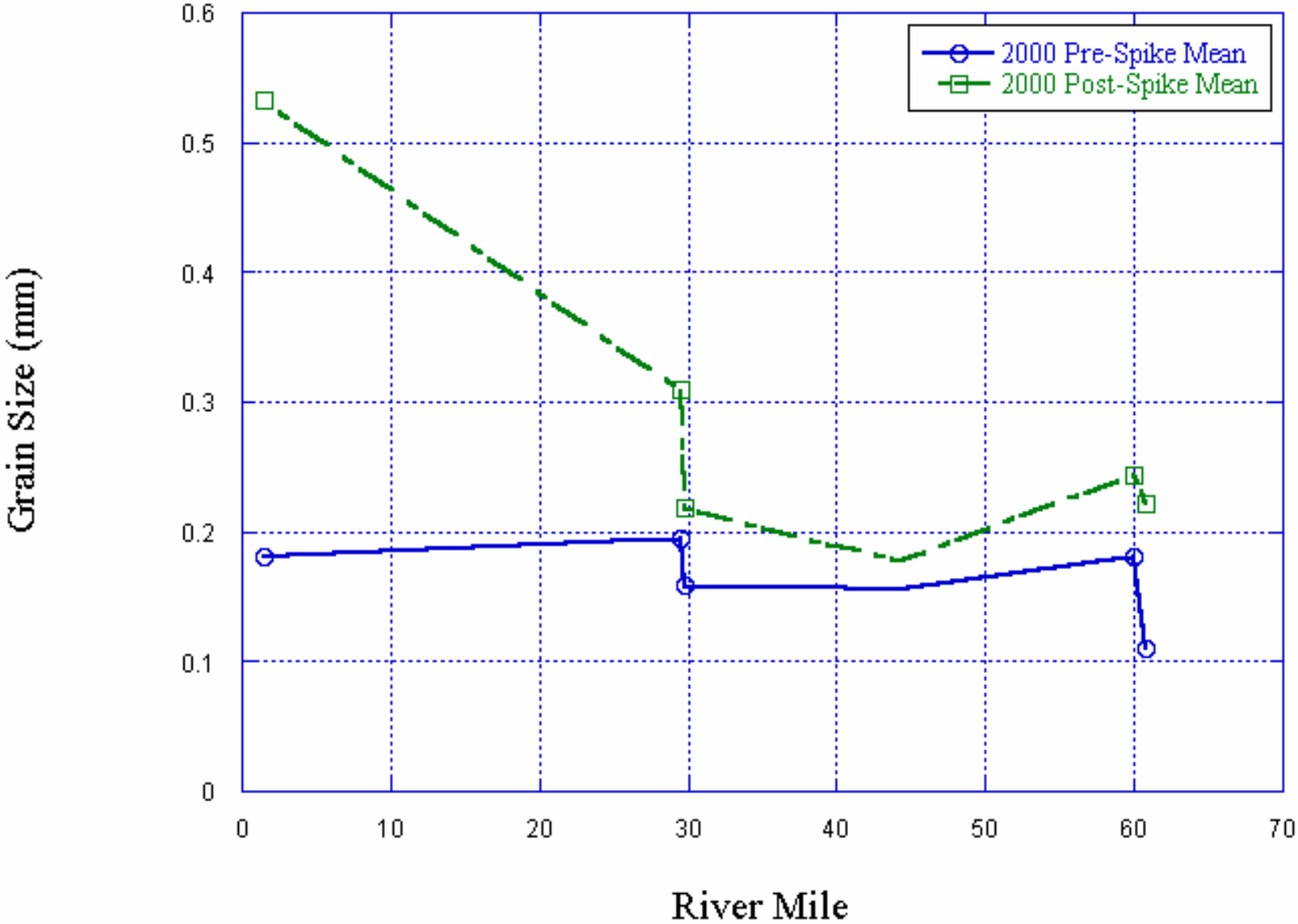
Grand Canyon Eyeball Data
Mean Grain Size Plot: Reach 2



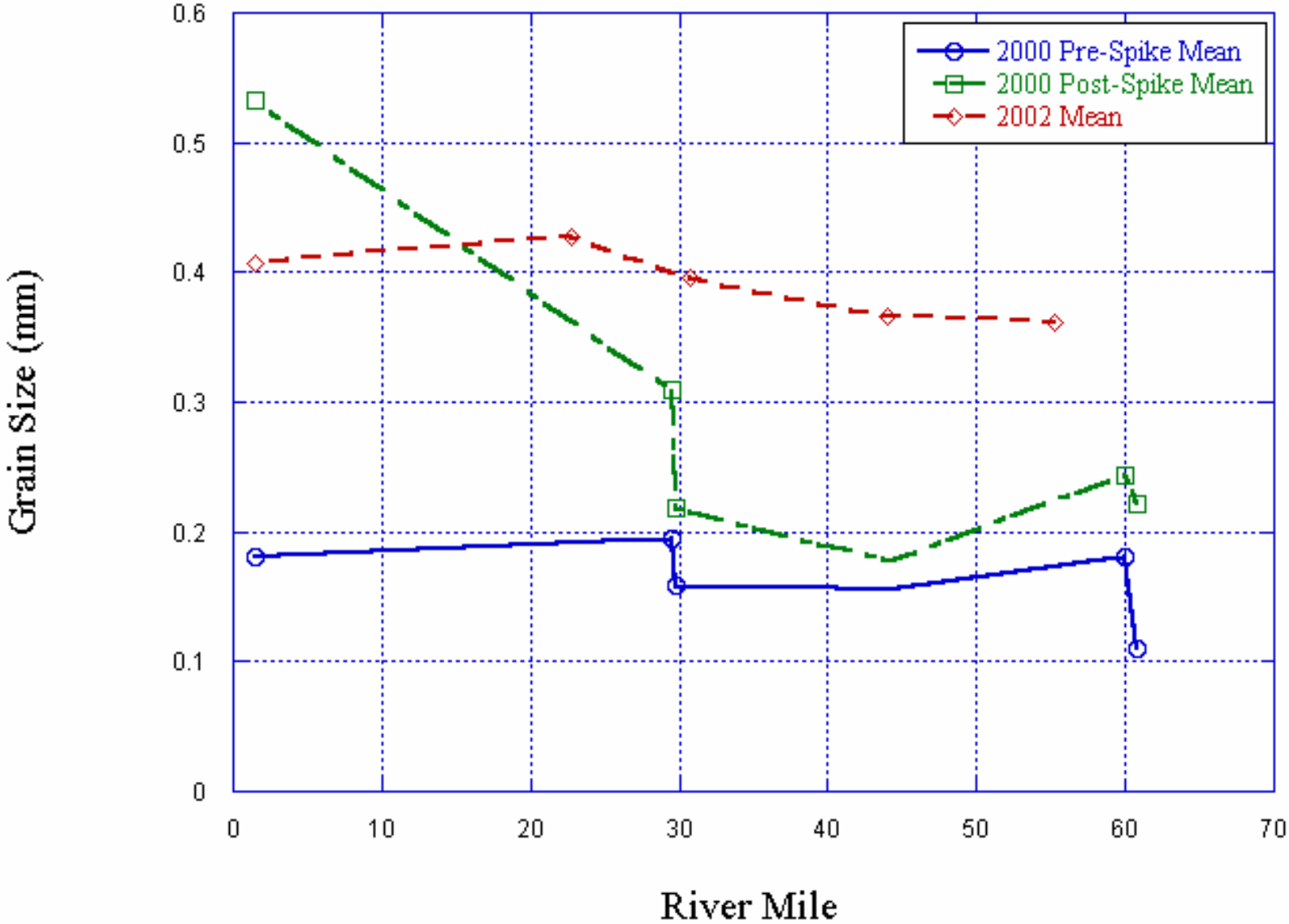
Flying Eyeball
Mean Grain Size Plot



Flying Eyeball
Mean Grain Size Plot



Flying Eyeball
Mean Grain Size Plot



Conclusions of 2000 Spike Flow: All Reaches

- Mean grain size of surficial bed sediment coarsened most dramatically between river miles 1 and 3 (from 0.17 mm to 0.58 mm)
- Mean grain size coarsened at four sites between river miles 29 and 45 (from 0.17 mm to 0.26 mm)
- Between river miles 59 and 68, three sites coarsened slightly, and one site fined (from 0.22 mm to 0.11 mm)

Field Samples Collected by the Beachball: Sub-Aerial Microscopy