Effects of Low Summer Steady Flows (LSSF) and Habitat Maintenance Flows in 2000 on Sediment Transport and Storage in Marble and Upper Grand Canyons

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Study Team

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Sandbar Studies Group,

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Grand Canyon Monitoring and Research Center (Melis)

Sediment Budget

- Fundamental conceptual tool in organizing knowledge, identifying future research needs, and developing river management plans

Study design

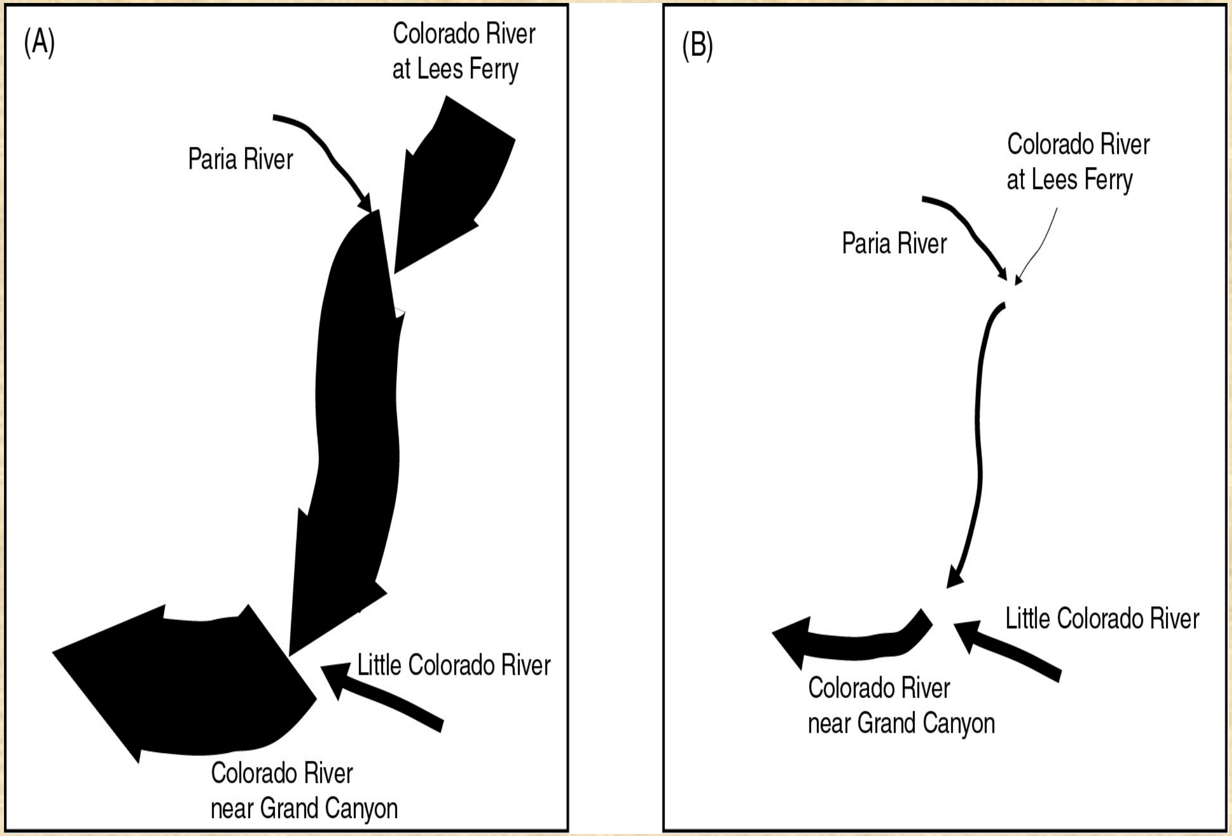
- Inflow - outflow = change in storage (bed and banks)

- Budget for Marble Canyon

  $I_{\text{(Lake Powell, Paria,, other tributaries)}} - O_{\text{(lower MC gage)}} = \Delta_{\text{(bed, banks)}}$

- Examine how each of these terms changes downstream

Sediment-transport reaches



Study Plan

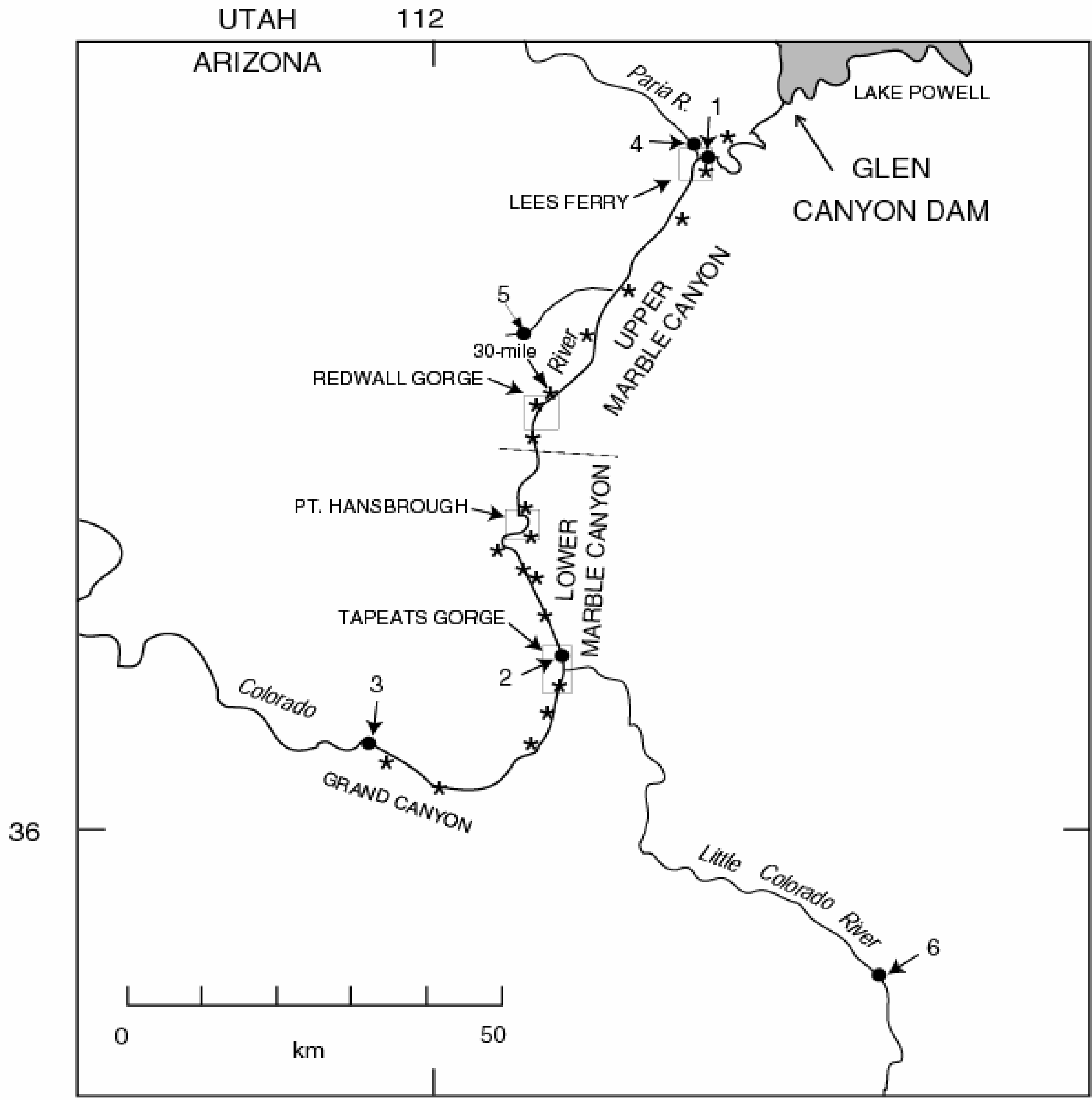
- Measure sediment inflow and outflow at gages
- Measure changes in amount of sediment on the bed
- Measure changes in sand bars at long-term study sites and in long term study reaches

Data Collection

1,2,3,4,5,6 - gages

* - detailed survey sites

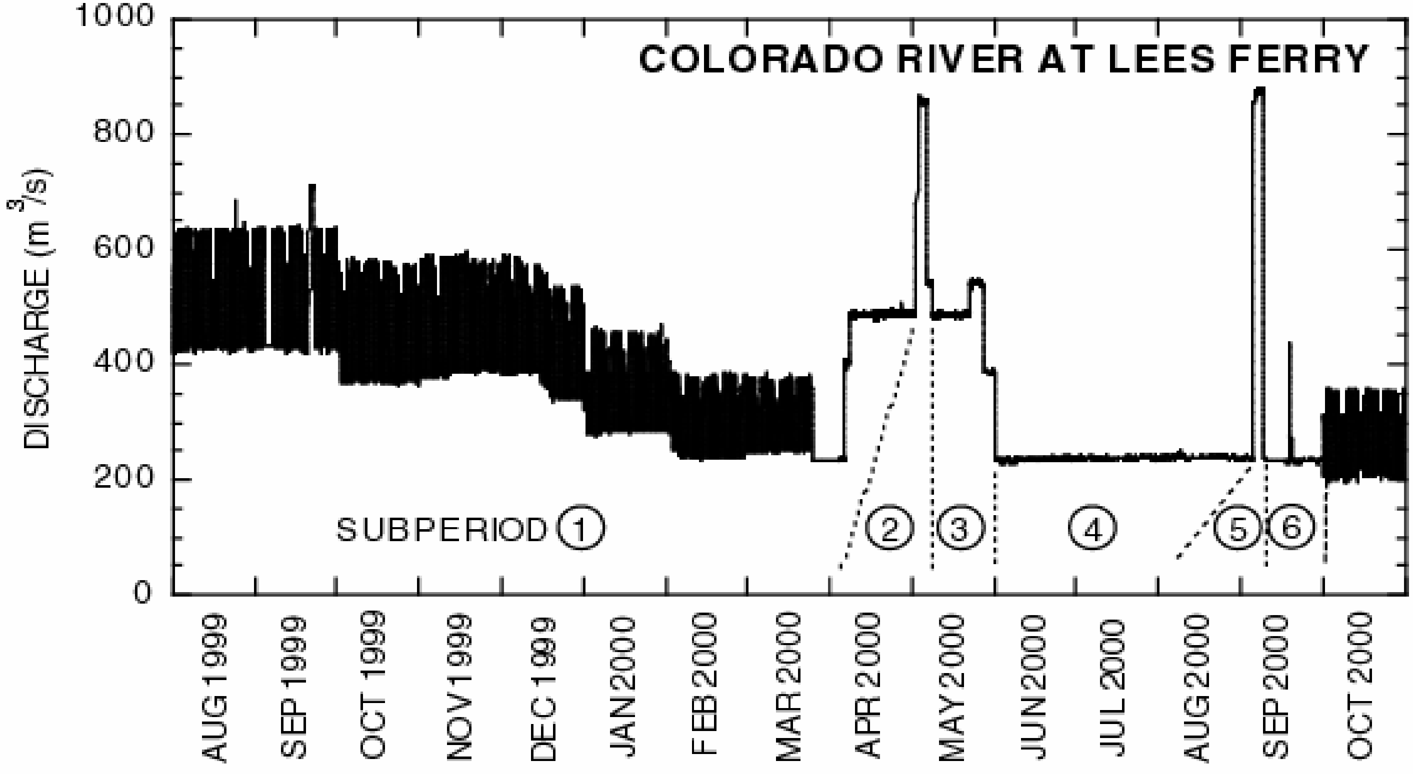
boxes - air photo analyses



Hypotheses

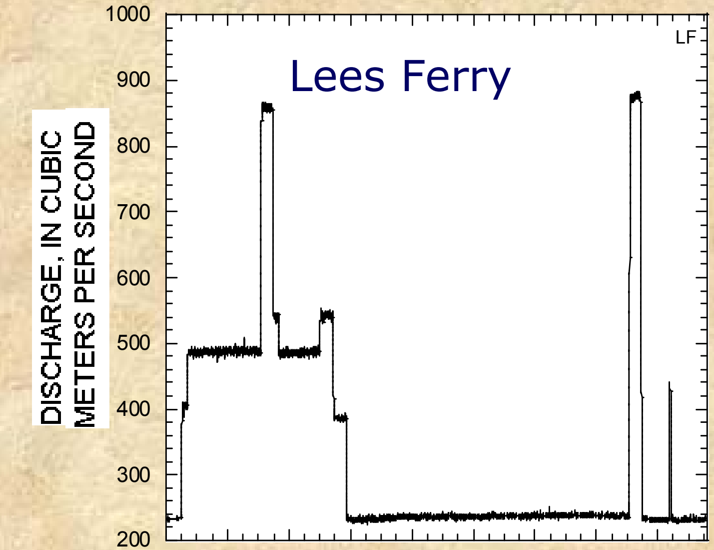
1) Sediment accumulates during low flows (<8000 ft^3/s)
2) Sand does not accumulate during normal dam operations
3) The "effectiveness" of a high flow is proportional to the amount of fine sediment available for transport immediately before the flood.
4) There will be a downstream shift in sources and sinks associated with a downstream increase in fine sediment supply and fine sediment transport.

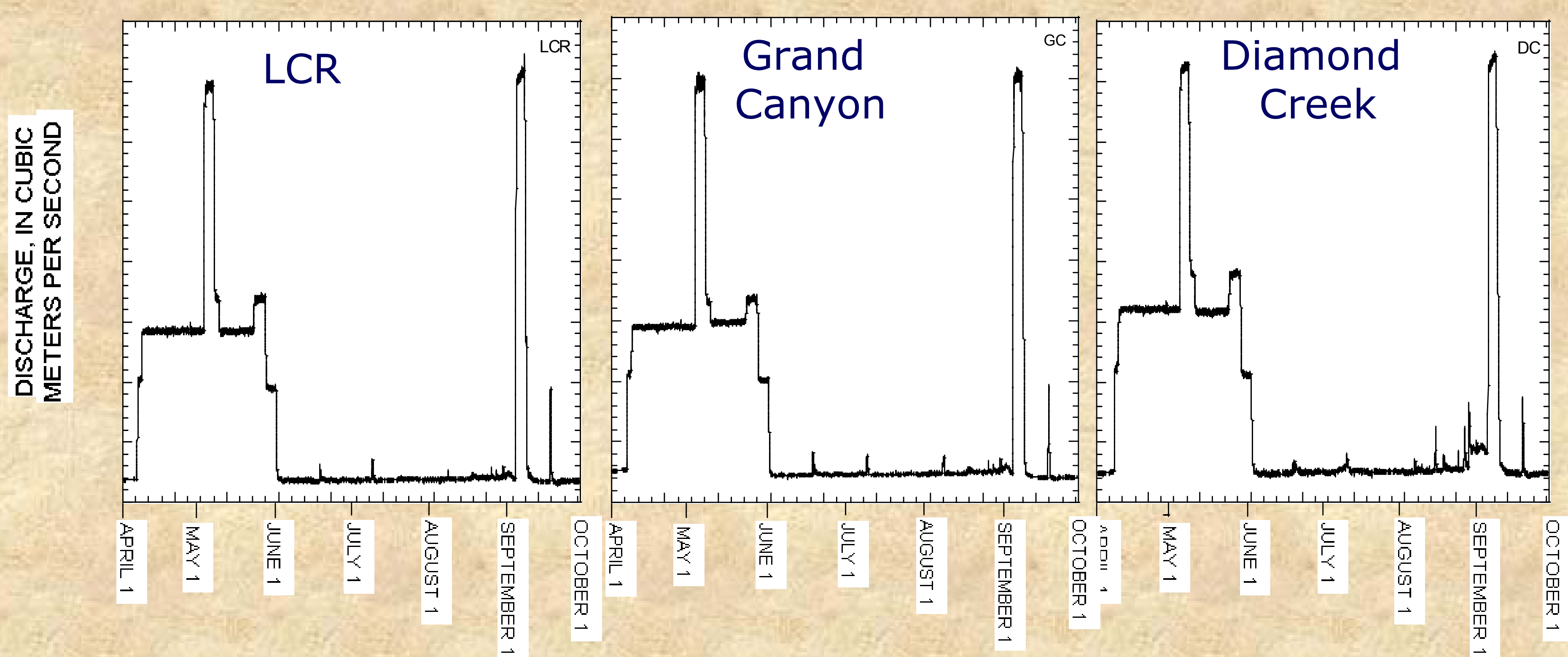
Hydrograph



COLORADO RIVER AT LEES FERRY
DISCHARGE (m3/s)
1000
800
600
400
200
0
SUBPERIOD 1
2
3
4
5
6
AUG 1999
SEP 1999
OCT 1999
NOV 1999
DEC 1999
JAN 2000
FEB 2000
MAR 2000
APR 2000
MAY 2000
JUN 2000
JUL 2000
AUG 2000
SEP 2000
OCT 2000

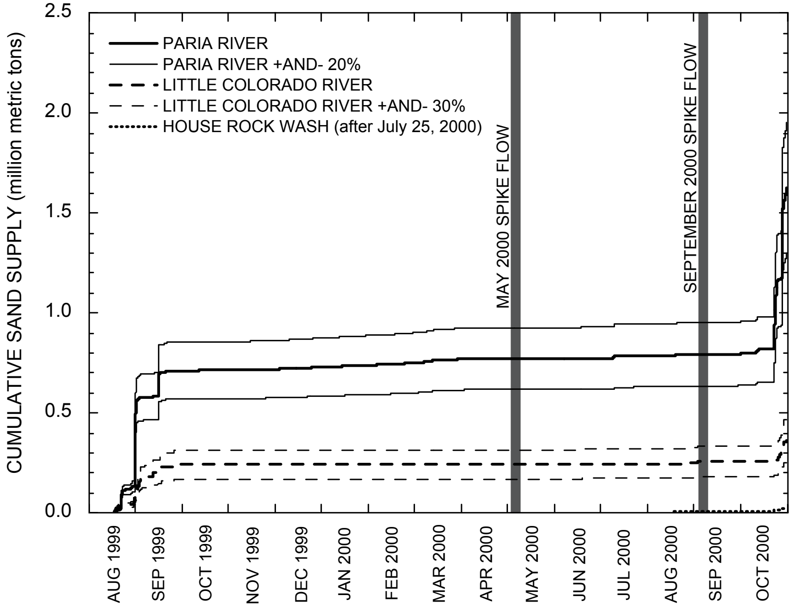
There was little inflow from tributaries.



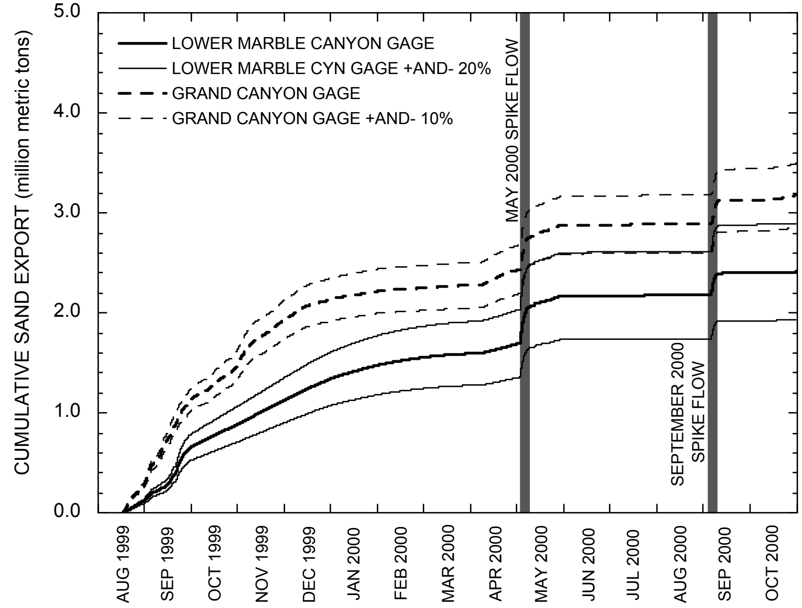


There was little fine sediment inflow

Sand supply from 3 tributaries

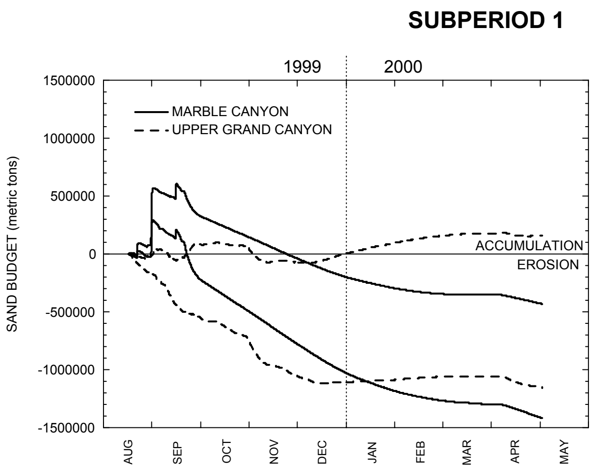


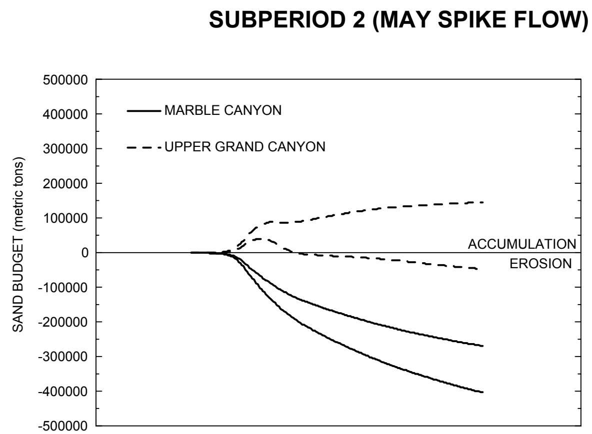
Sand export past lower Marble Canyon and Grand Canyon gages

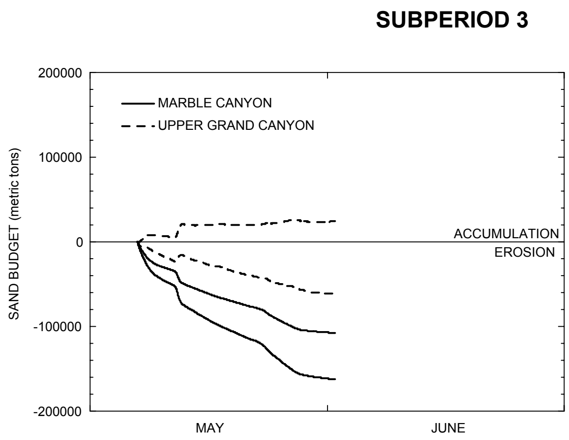


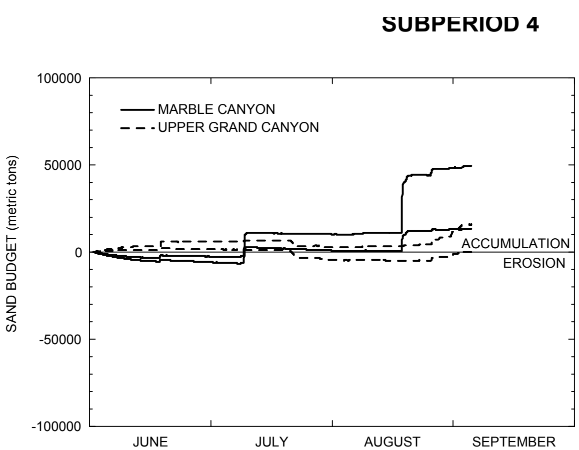
(D. Topping)

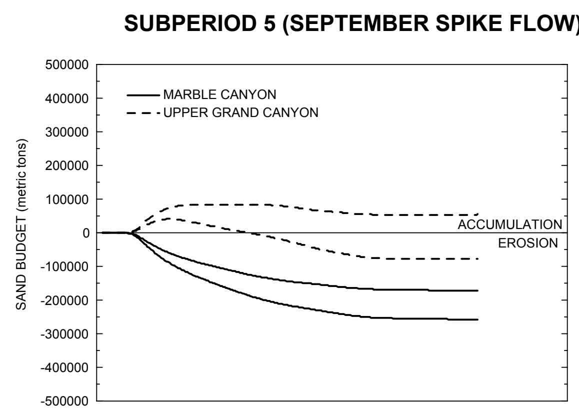
Fine sediment accumulated in Marble Canyon when flows < 8000 ft³/s







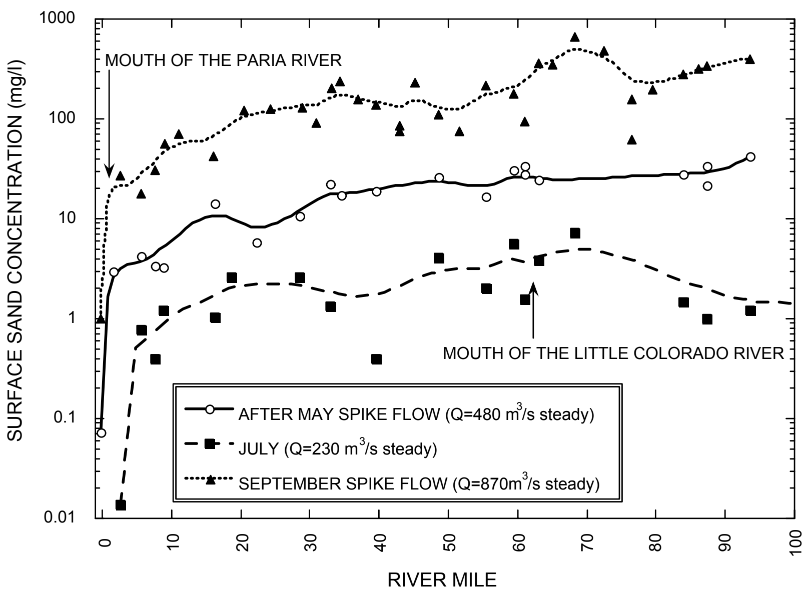




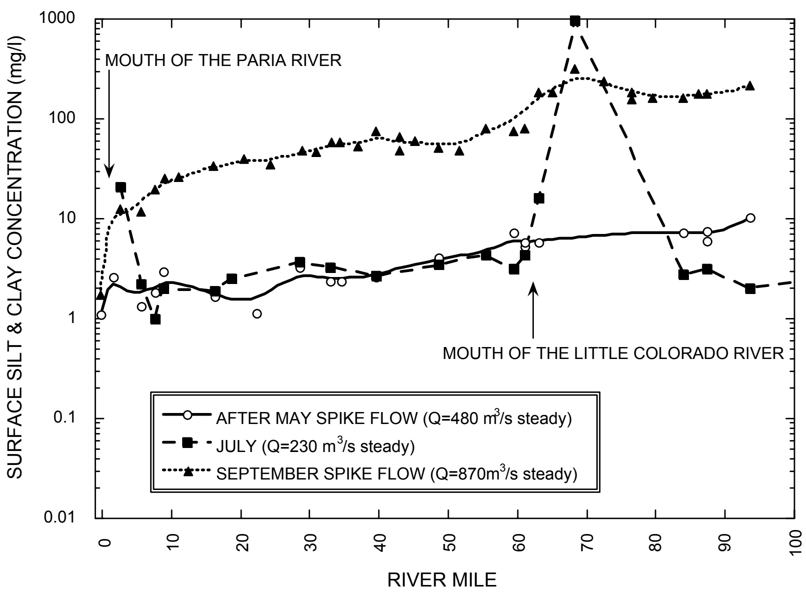
(D. Topping)

The concentration of fine sediment in transport increased downstream

Sand



Silt and clay



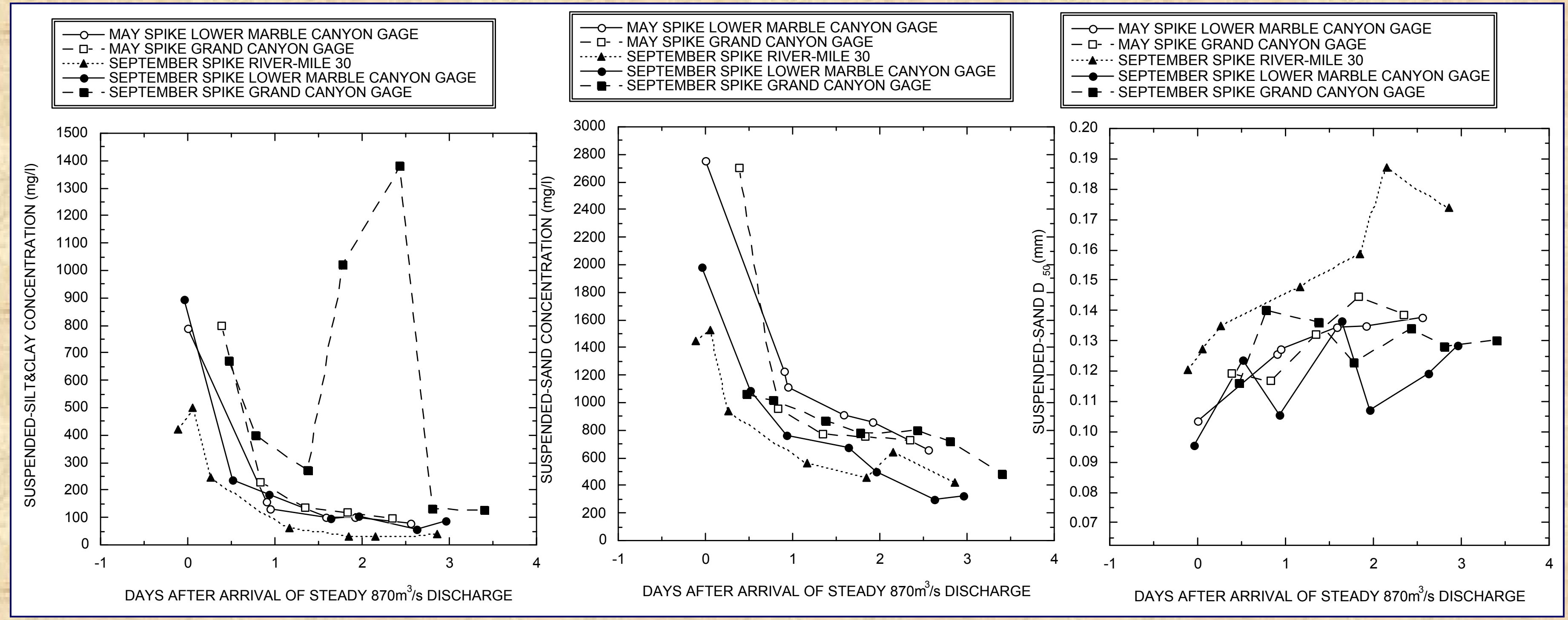
(D. Topping)

High sand concentrations were not sustained during high flows

Suspended silt and clay concentrations

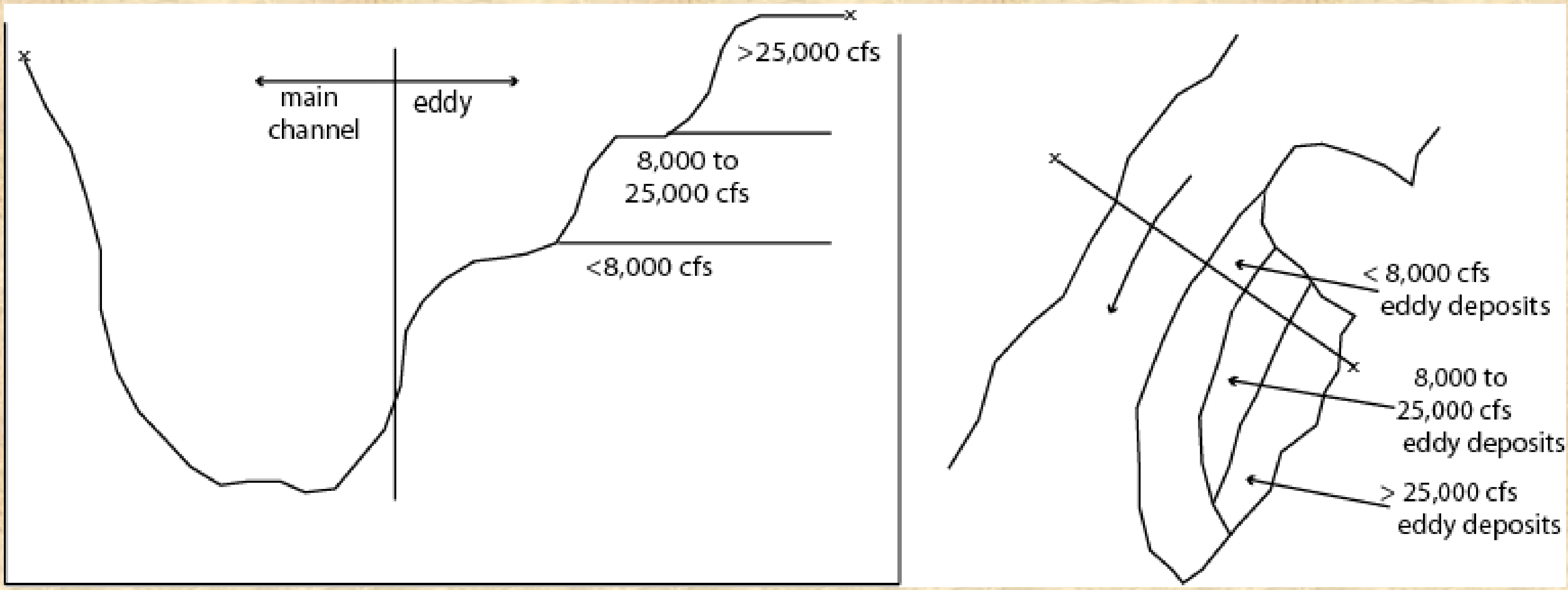
Suspended sand concentrations

Median size of suspended sand



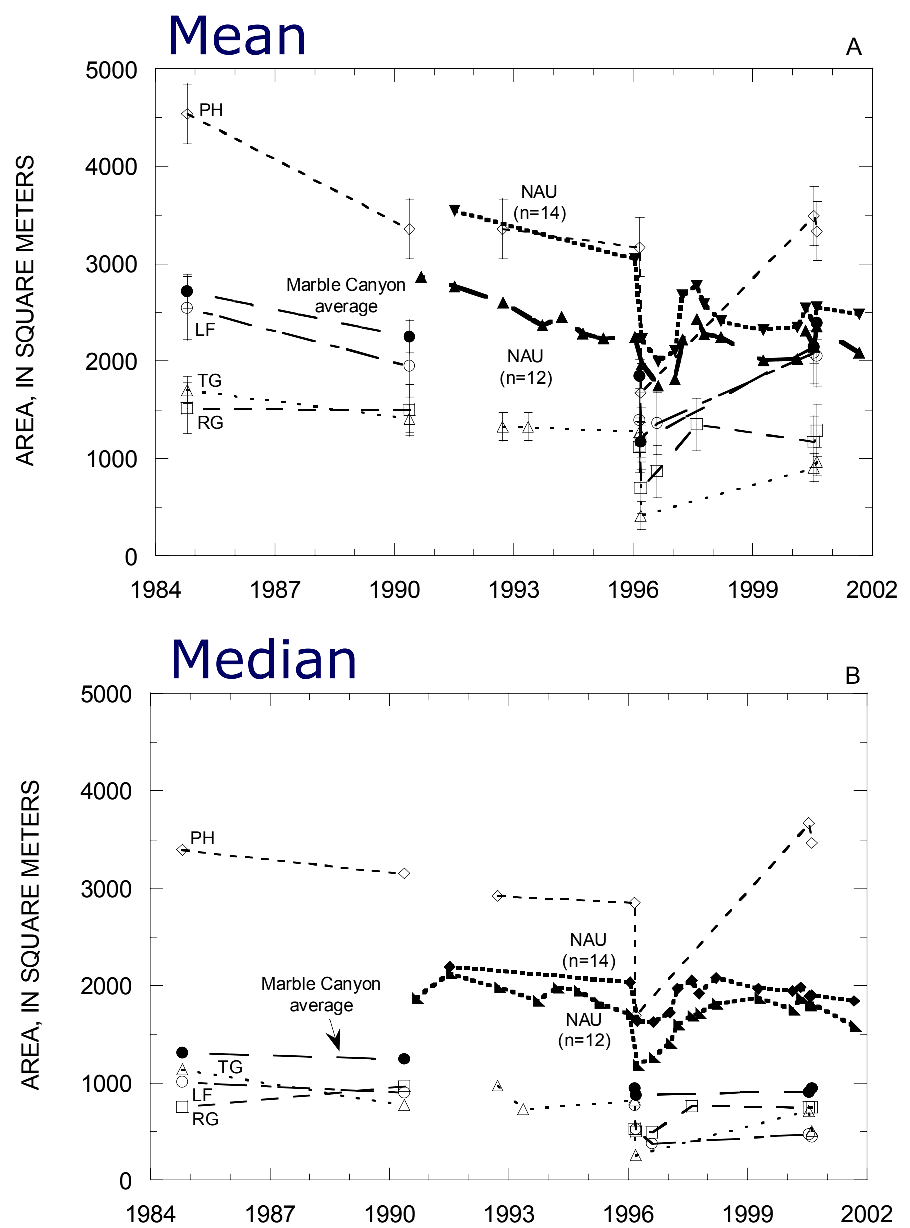
(D. Topping)

Accounting for sand bar change



Long-term trends, 8-25K zone:

Today's area is smaller than in 1984. Today's area probably smaller than in 1990.



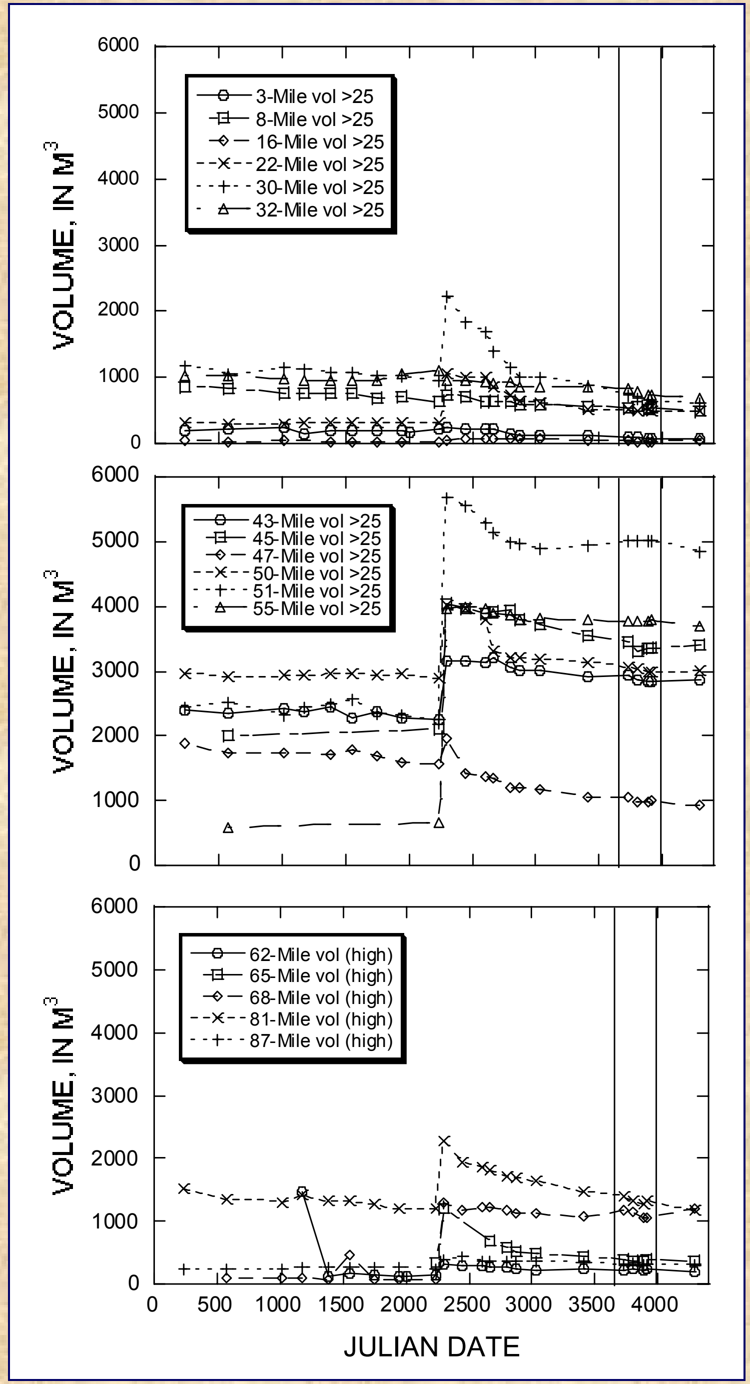
(USU and NAU)

There was no significant change in the volume of eddy sand bars at elevations higher than the stage of 25,000 ft^3/s. There was no reversal of long-term trends.

Upper Marble

Lower Marble

Upper Grand Canyon



(NAU)

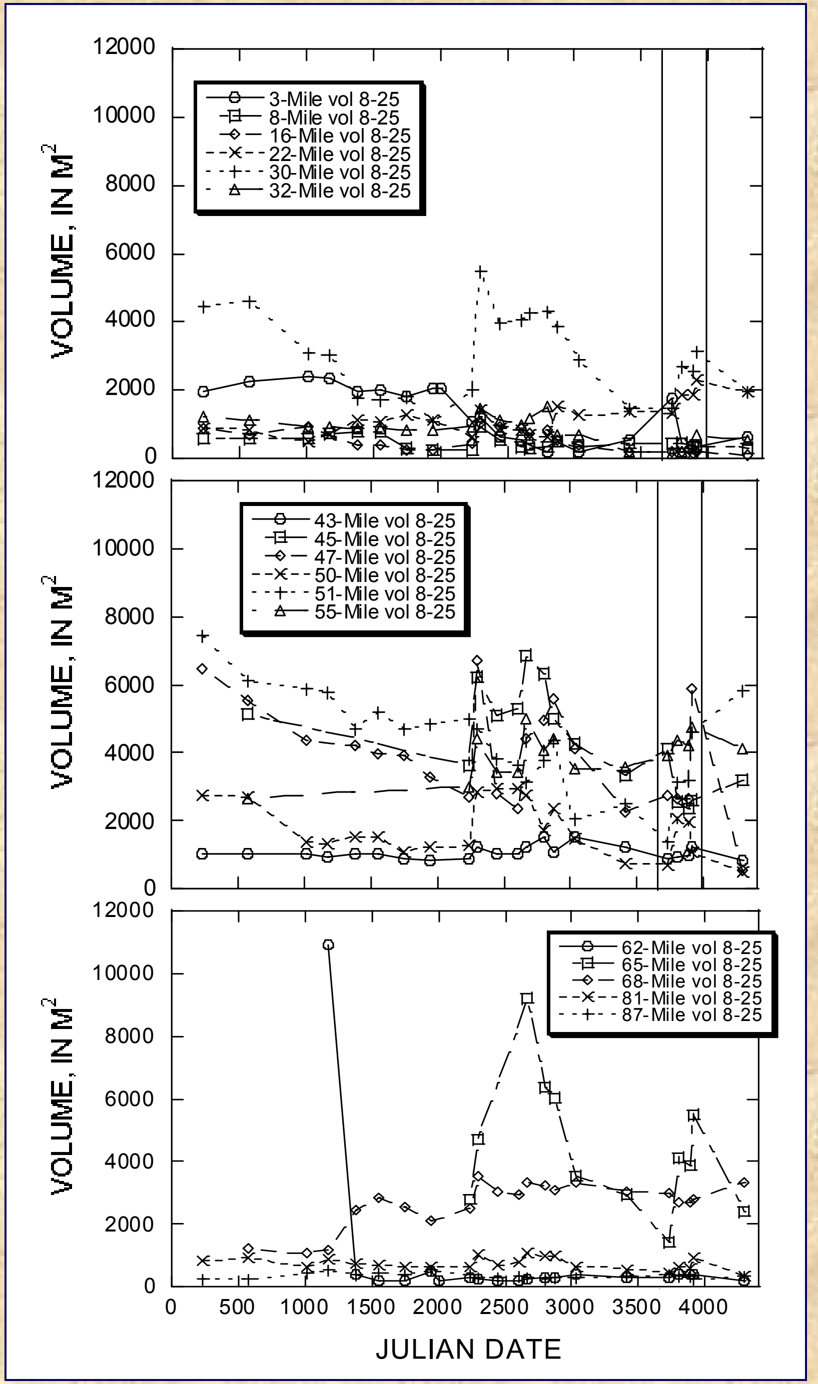
Site to site changes in the volume of sand at elevations between 8000 and 25,000 ft^3/s were highly variable.

Deposition during spike flows: RM 30, 51, 55, 65
Erosion during May spike flow: RM 3, 45, 68
Erosion during September spike flow: RM 50, 87

Upper Marble

Lower Marble

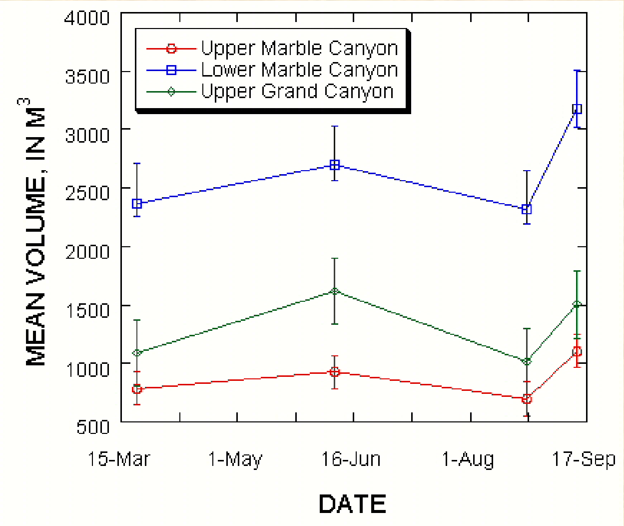
Upper Grand Canyon



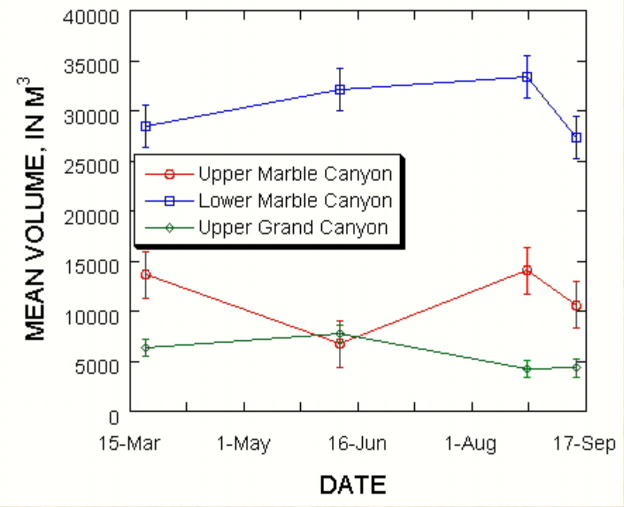
(NAU)

Average changes

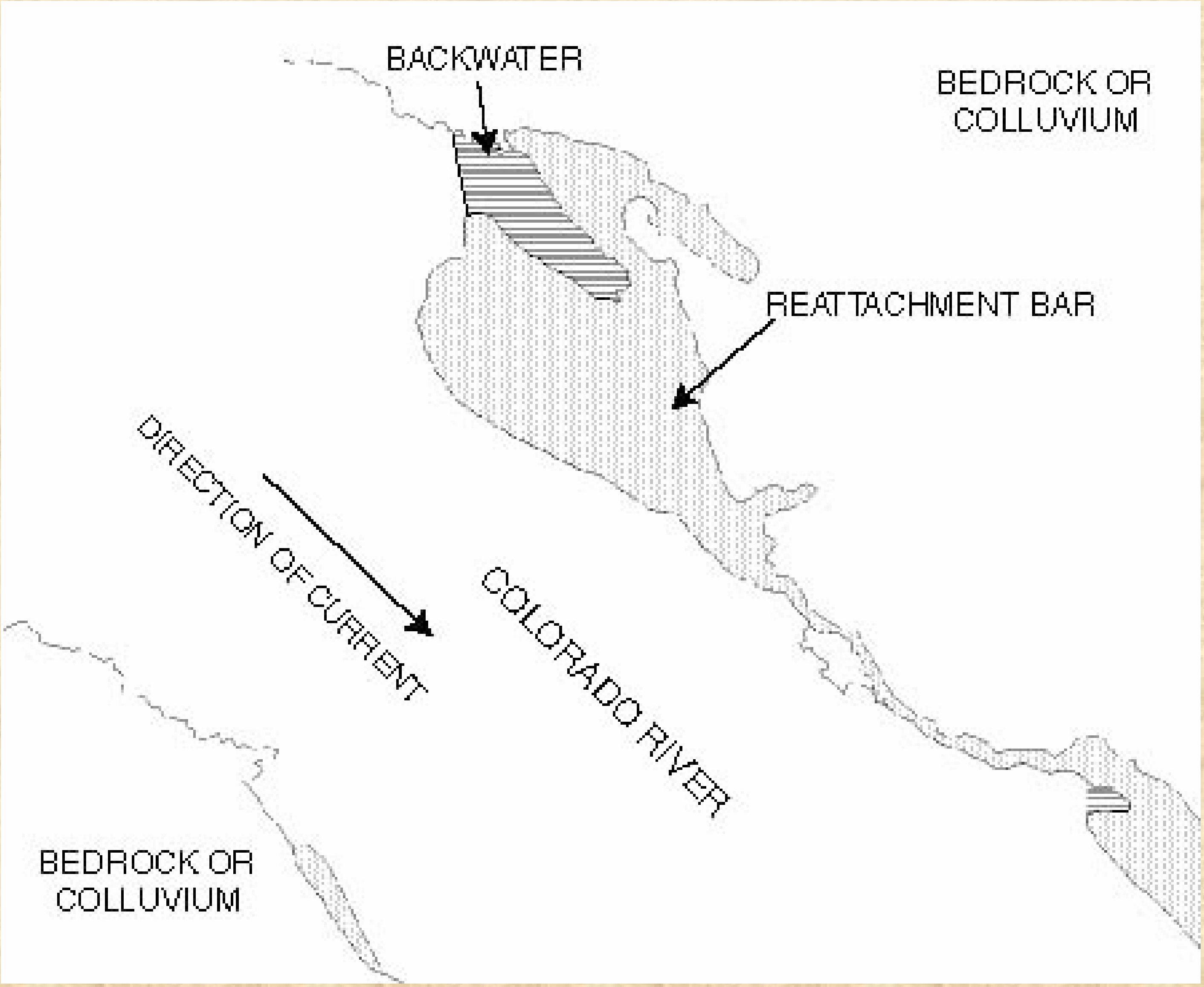
- Eddy sand was exchanged between low and med elevations.
- During high flows, sand is eroded from low elevation and transferred to higher elevations. Evidence points to more erosion near Lees Ferry than elsewhere.
- During low flows, banks erode and some of this sand accumulates in the eddy at lower elevation.
- Trends differ in UGC, perhaps indicating more sand on bed.



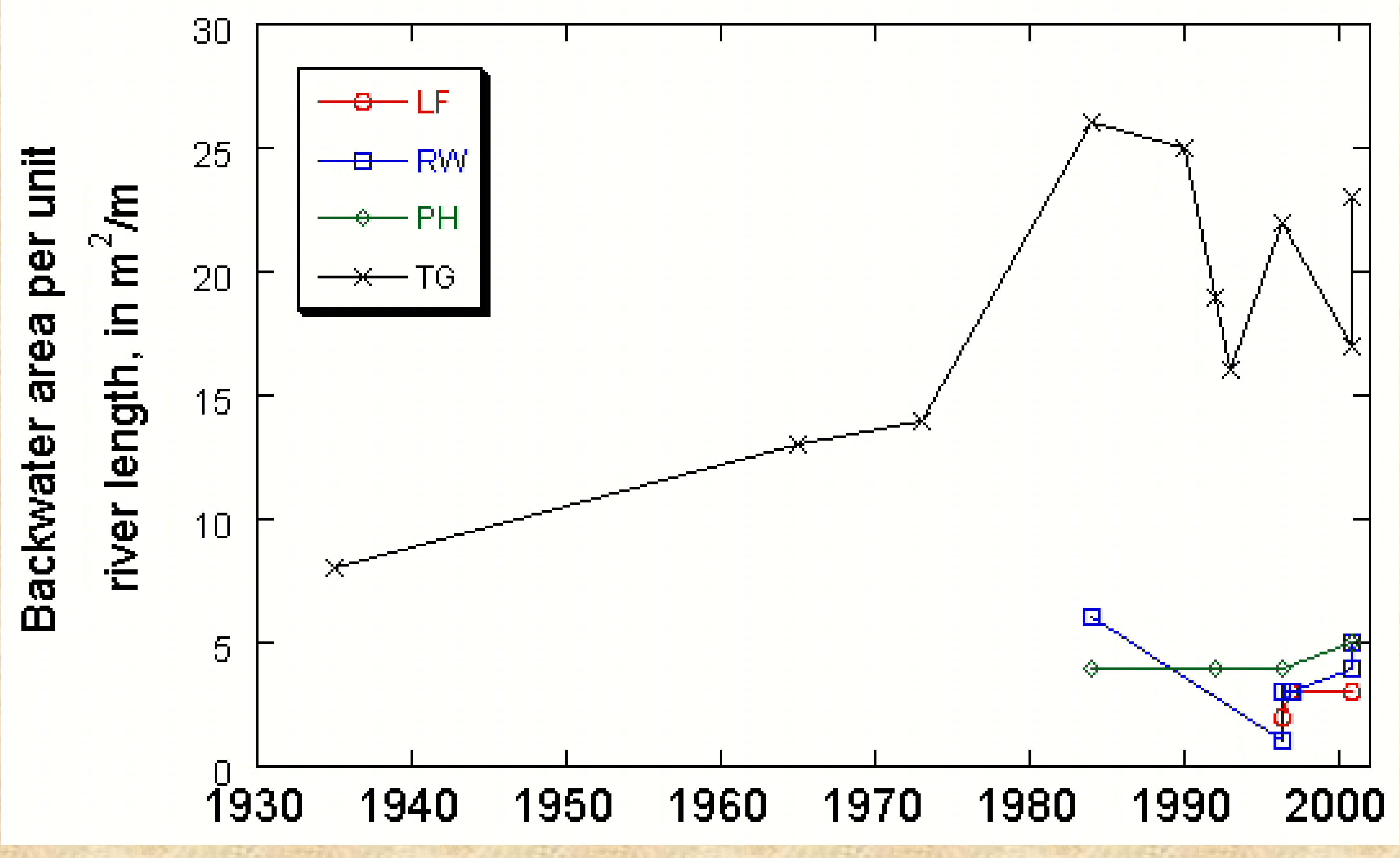
8-25K



< 8K


BACKWATER
BEDROCK OR COLLUVIUM
REATTACHMENT BAR
DIRECTION OF CURRENT
COLORADO RIVER
BEDROCK OR COLLUVIUM

Although the Sept spike increased the area of backwaters, the resultant change was no different from what has existed in the past.

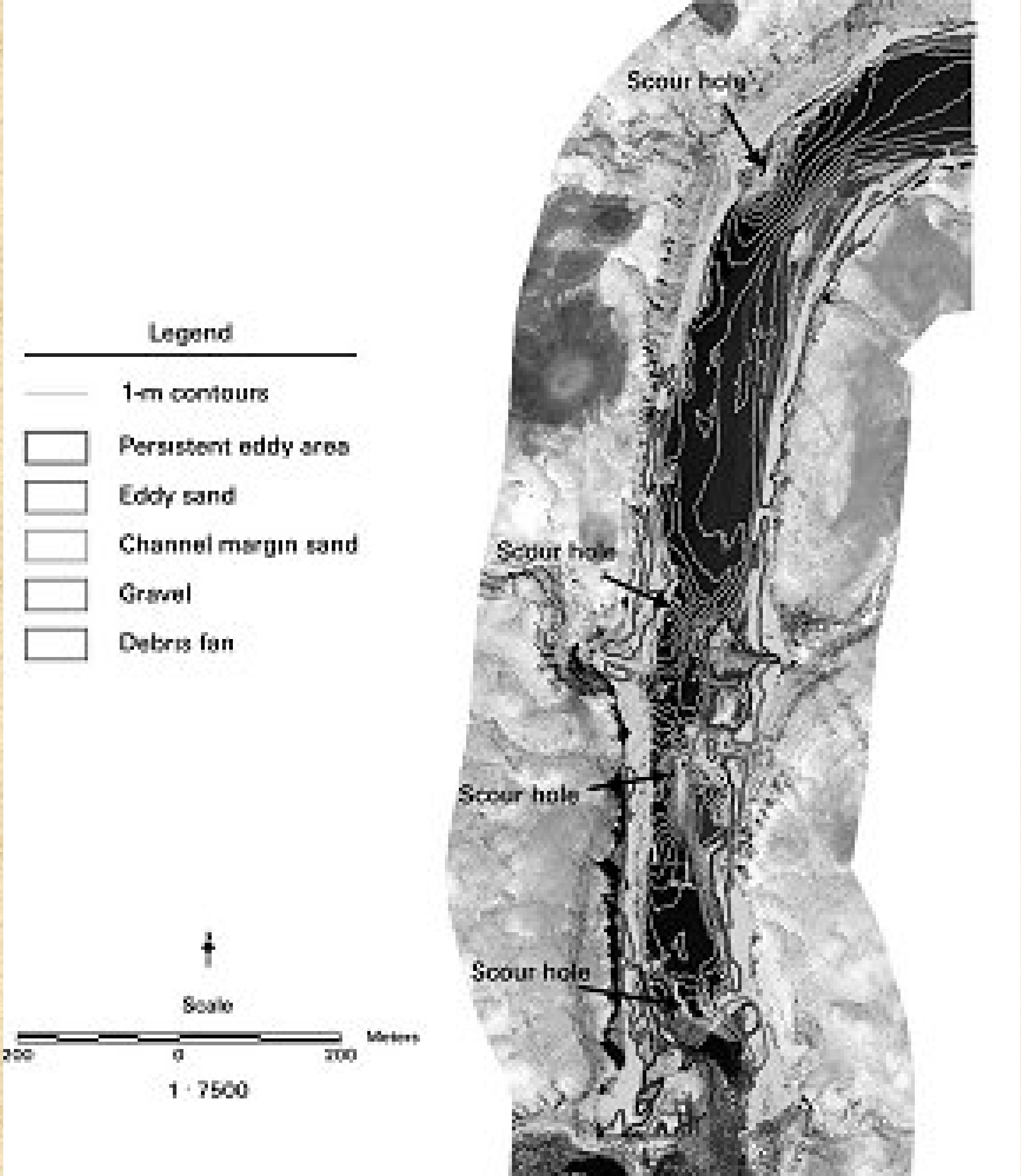


Conclusions

- Continued evidence of supply limitation during high flows.
- Fine sediment accumulates when flow < 8K
- During LSSF (< 8K), eddy-bar at the waters edge was eroded but sand accumulated < 8 K stage.
- Indications of greater erosion of bars near Lees Ferry;
- Changes in bar topography during spike flow increase the area of backwaters, but not significantly different than historical conditions

Implications

- Flows < 8 K to retain fine sediment on bed and in eddies
- High flows cause erosion of low-elevation eddy sand and deposit high elevation sand under conditions of limited supply
- Changes caused by 2000 did not reverse long-term degradation trends. Erosion may be greater near Lees Ferry than further downstream.


Scour hole
Legend
1-m contours
Persistent eddy area
Eddy sand
Channel margin sand
Gravel
Debris fan
Scour hole
Scour hole
Scour hole
Scale
200
0
200
Meters
1 : 7500

Summary of the effects of the LSSF experiment on Marble and upper Grand Canyons

<table>
<tr><th colspan="8">Marble Canyon</th></tr>
<tr><th></th><th>Sand mass</th><th>Bed grain size</th><th>Reach-wide bar area</th><th>Mid-elev. bar area (n=19)</th><th>Low-elev. bar area (n=19)</th><th>Mid-elev. bar volume (n=19)</th><th>Low-elev. bar volume (n=19)</th></tr>
<tr><td>1</td><td>↓</td><td></td><td></td><td rowspan="3">↑</td><td rowspan="3">↑</td><td rowspan="3">↑</td><td rowspan="3">↓</td></tr>
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<tr><th colspan="8">Upper Grand Canyon</th></tr>
<tr><td>1</td><td>nc</td><td>↓ , ↑</td><td></td><td rowspan="3">↑</td><td rowspan="3">↑</td><td rowspan="3">↑</td><td rowspan="3">↑</td></tr>
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