

Sandbars in historical context: Comparison of images following the March 2008 high flow with images from the 1980s and earlier.

March 3, 2009

USGS cooperators Jack Schmidt and Milada Majerova of Utah State University are currently compiling historical photographs of selected study sites and comparing those images with photos taken during and following the 2008 high-flow experiment. These photographs will help scientists, managers, and stakeholders evaluate the present condition of sandbars and vegetation relative to the condition prior to the onset of regular monitoring, which began in the early 1990s.

The photograph comparisons and summaries contained in this document are a work in progress and represent an interim step in our effort to systematically analyze the 2008 high flow and place the event in context with other high flows and earlier sand storage conditions. Provided in the document are preliminary observations and summary tables of those observations. At this stage there is no attempt to provide interpretation, synthesize the observations, or make conclusions.

For each site, there is an opening map showing locations of the photo sites. This is followed by the photo matches themselves, organized sequentially in time and also including an explicit comparison of 1985 with 2008. Many of the photos have common features highlighted to facilitate comparison. Each site also includes a summary table, which lists the photos and a summary of observations regarding sand area and vegetation abundance.

Currently, sites from Lees Ferry to Redwall Cavern are included. This file will be updated as additional sites are completed.

Site	Page
Above Cathedral Wash (RM 2.44L and 2.47L)	2
Badger Creek Rapid (8.10R and 8.15L)	10
Soap Creek (11.6R)	34
Below Salt Wash (12.4L)	40
18 Mile Wash (18.35L)	46
Below 18 Mile Wash (18.5L)	59
19 Mile Canyon (19.41L)	65
20 Mile Camp (20.20L)	77
North Canyon Rapid (20.85R, 20.80-20.90L)	80
Silver Grotto (RM 29.50L)	86
RM 30.55R and 30.75R	105
Redwall Cavern (RM 33.30L)	124

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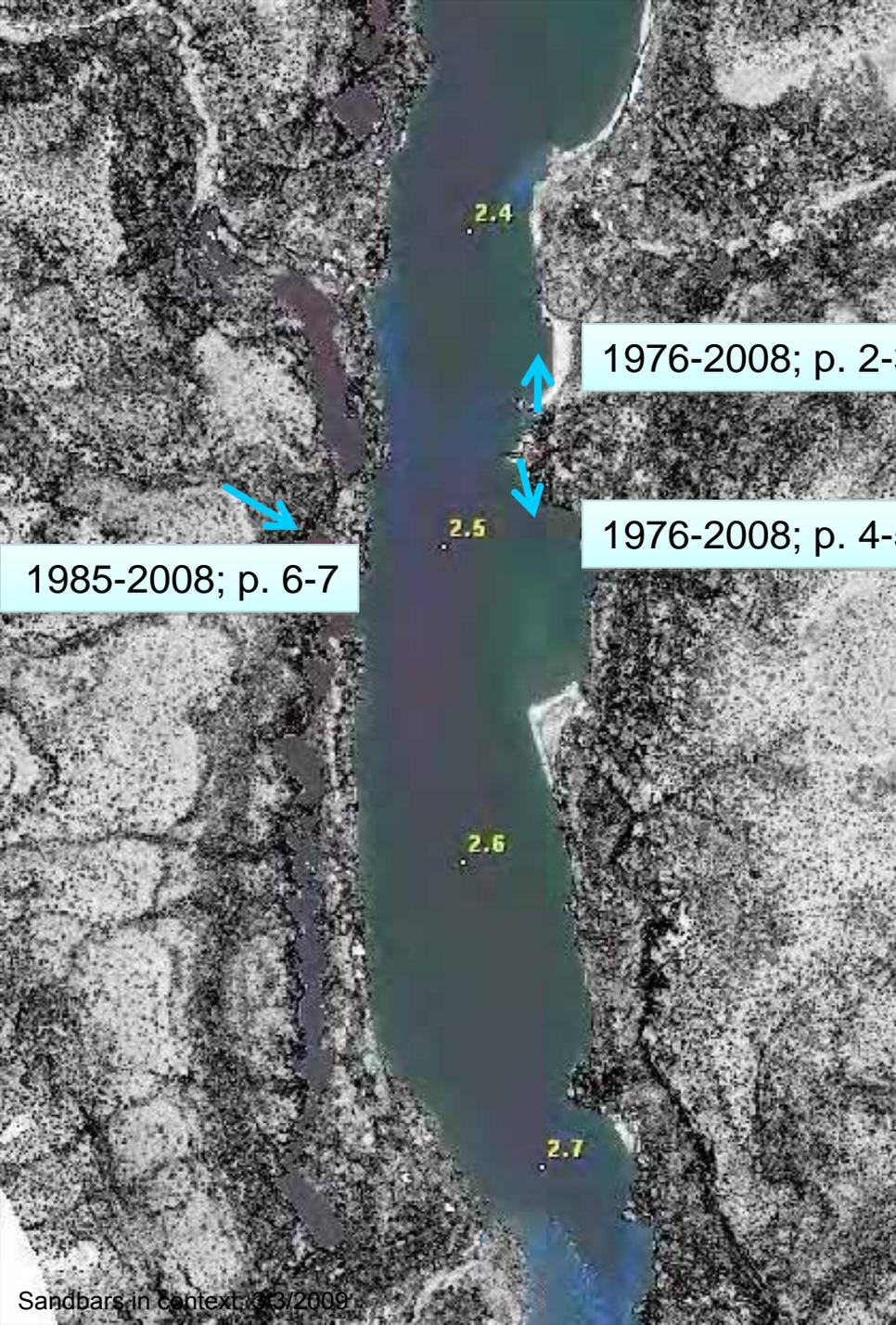
Paul Grams, USGS Grand Canyon Monitoring and Research Center, pgrams@usgs.gov,
928-556-7458

Photo comparisons
above Cathedral Wash

2.44L reattachment bar
2.47L reattachment bar

1985 and 2008 photos are at
comparable discharge

Changes in sand area and
vegetation summarized on
table (p. 8-9) are relative to
1985 condition



1976-2008; p. 2-3

1976-2008; p. 4-5

1985-2008; p. 6-7

RM 2.44L: 1976-1986 photo matches



1300 August 5,
1976
(~10,000 ft³/s,
increasing
at this time)



1400 May 18,
1985
(~45,300 ft³/s)



1140 July 29,
1985
(~28,700 ft³/s)



1230 October 4,
1985
(~12,500 ft³/s)



1000 January 10,
1986
(~7,800 ft³/s)



(see next page)

2.44L: 1985 – 2008 comparison



1230 October 4, 1985 (~12,500 ft³/s)

October 4, 1985 and May 10, 2008:
Cobble bar and sand bar is covered with vegetation in May 2008.

March 2008 and May 10, 2008:
Sand bar deposit contains sprouting vegetation in May. There was none in March.



1645 March 28, 2008
(~9,800 ft³/s)



0950 March 29, 2008
(~9,600 ft³/s)



1020 May 10, 2008
(~10,300 ft³/s)

RM 2.47L: 1976-1987 photo matches



1300 August 5, 1976
(~10,000 ft³/s,
increasing
at this time)



1230 October 4,
1985
(~12,500 ft³/s)



1400 May 18, 1985
(~45,300 ft³/s)



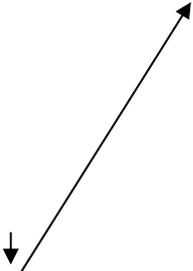
1000 January 10,
1986
(~7,800 ft³/s)



1140 July 29, 1985
(~28,700 ft³/s)



~October 16,
1987
(~3,000 ft³/s)



RM 2.47L: 1985-2008 comparison



1230 October 4, 1985
(~12,500 ft³/s)



1645 March 28, 2008
(~9,800 ft³/s*)



0950 March 29, 2008
(~9,600 ft³/s*)



0945 May 10, 2008
(~10,000 ft³/s*)

October 4, 1985 and May 10, 2008:

Negligible change in volume of sand, however, in 1985 there is more sand on downstream portion of bar that extends further out into the river. Bar in May has approximately 1.5m platform at upper end of bar which has been eroded by a cut bank.

March 29, 2008 and May 10, 2008:

5% loss of sand. Loss appears to have occurred near reattachment point.

* Unit values from GCMRC for Lees Ferry Sandbars in context, 3/3/2009

RM 2.44L and 2.47L:
View from the Kaibab Rim
1986-1988 photo match



May 1986 (~50,000 ft³/s)



May 1988

RM 2.47L: View from the Kaibab Rim 1985-2008 comparison



Photo from helicopter
December 1985

Sand bar seems bigger in March 2008 before HFE; although, 1985 photo is showing sand in higher elevations and farther downstream. Since discharge is unknown for 1985 it is difficult to compare.



0930 March 2, 2008, before HFE



1620 March 28, 2008, after HFE

(~10,000 ft³/s)

Sandbars in context, 3/2/08

Changes in Sand Bars and Vegetation

RM 2.44L

Year	Discharge (ft ³ /s)	Area of Sand			Vegetation
		Below 25,000 ft ³ /s	25,000-50,000 ft ³ /s	Above 50,000 ft ³ /s	
August 1976	10,000 ft ³ /s	Can't tell	Can't tell	Can't tell	Can't tell
May 1985	45,300 ft ³ /s	Can't tell	Can't tell	Can't tell	Can't tell
July 1985	28,700 ft ³ /s				
October 1985	12,500 ft ³ /s	Can't tell	Can't tell	Can't tell	Same
January 1986	7,800 ft ³ /s	Can't tell	Can't tell	Can't tell	Same
March 2008	9,800 ft ³ /s	Can't tell	More	More	More
May 2008	10,300 ft ³ /s	Can't tell *	Can't tell	Can't tell	More **

RM 2.47L

Year	Discharge (ft ³ /s)	Area of Sand			Vegetation
		Below 25,000 ft ³ /s	25,000-50,000 ft ³ /s	Above 50,000 ft ³ /s	
August 1976	10,000 ft ³ /s	More	Less	Can't tell	More
May 1985	45,300 ft ³ /s	Can't tell	Can't tell	Can't tell	Same
July 1985	28,700 ft ³ /s	Can't tell	Same	Can't tell	Same
October 1985	12,500 ft ³ /s				
December 1985	12,500 ft ³ /s	Can't tell	Can't tell	Can't tell	Can't tell
January 1986	7,800 ft ³ /s	Can't tell	Can't tell	Can't tell	Same
October 1987	3,000 ft ³ /s	Less	Less	Can't tell	More
March 2008	9,800 ft ³ /s	Less	Can't tell	Can't tell	More
May 2008	10,300 ft ³ /s	Less	Can't tell	Can't tell	More

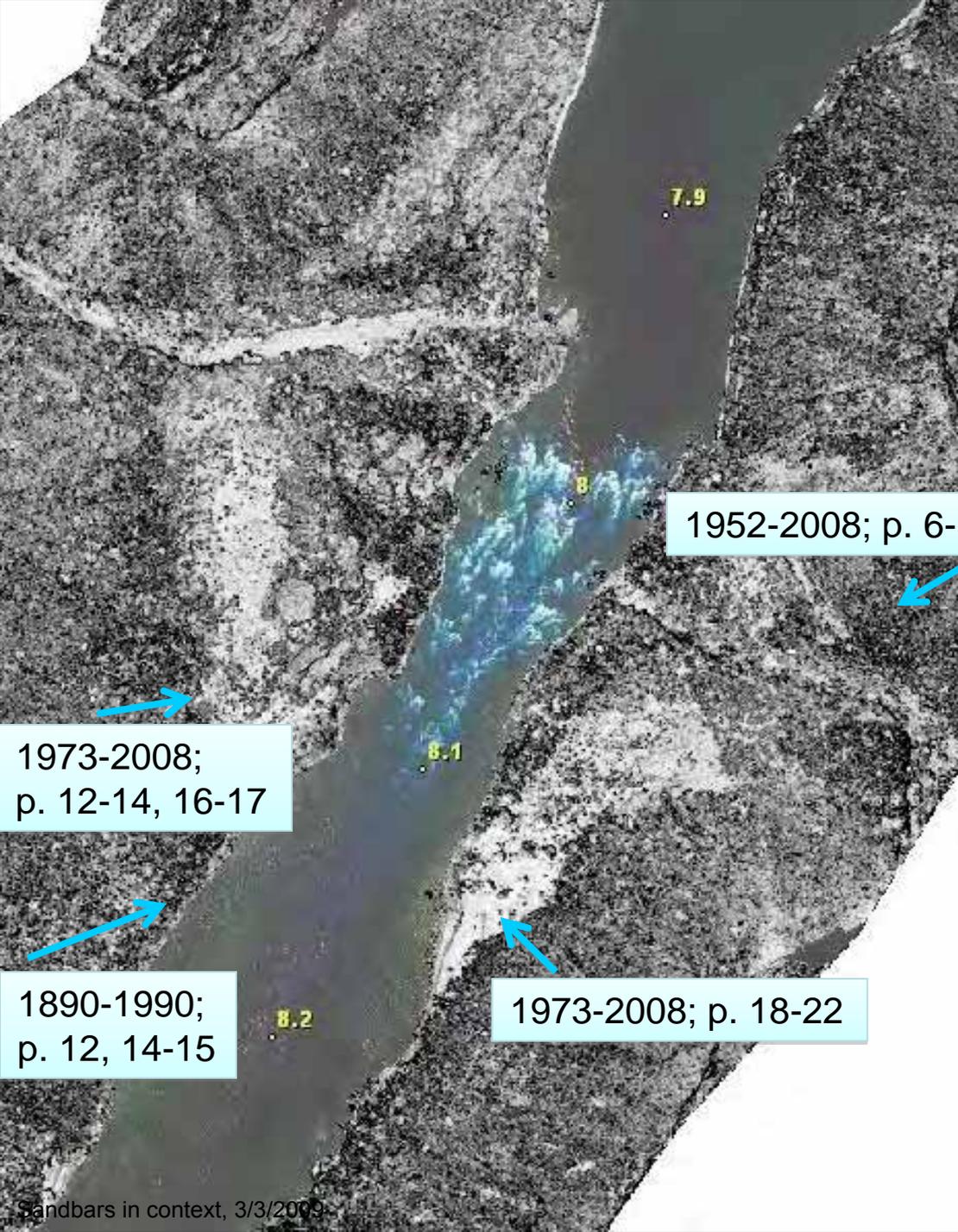
* Less sand when comparing to March 2008

Sandbars Newcomer 3/5/2009
 Vegetation on sand bar when comparing to March 2008

Photo comparisons
Badger Creek Rapid

8.10R separation and
reattachment bar
8.15L separation and
reattachment bar

Changes in sand area and
vegetation summarized on
table (p. 23-24) are relative to
1985 conditions

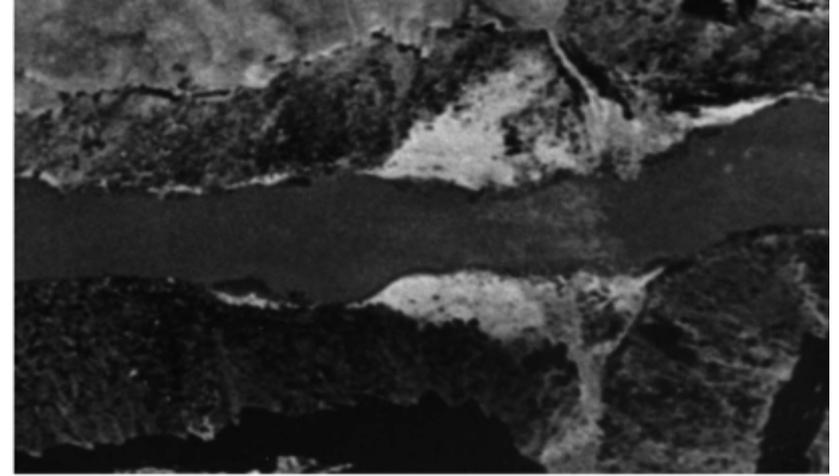


Badger Creek Rapid RM 8.10:

1935 – 1952 photo matches



1935 (flow between 3,000 – 6,000 ft³/s)



Mid-1930s (flow between 3,000 – 6,000 ft³/s)

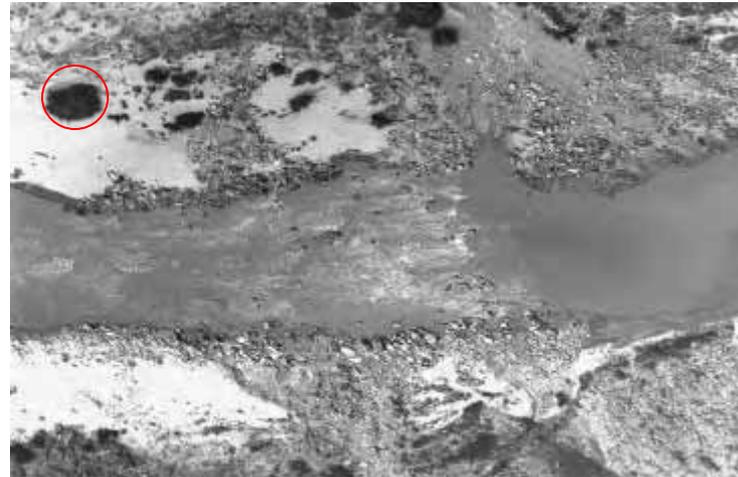


September 25, 1952 (flow between 8,900 – 11,100 ft³/s)

Badger Creek Rapid RM 8.10: 1957 – 1958 photo matches



May 6, 1957 (daily mean $\sim 26,500$ ft³/s)



October 4, 1958 (daily mean $\sim 5,700$ ft³/s)

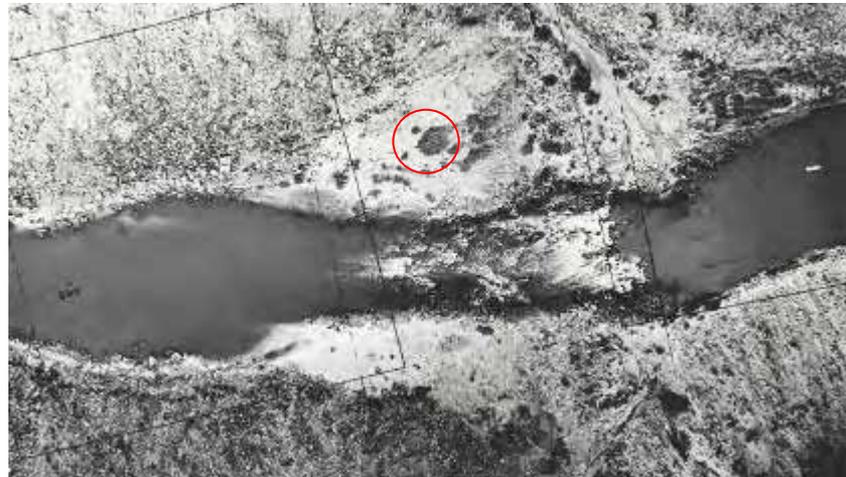
Badger Creek Rapid RM 8.10: 1965 – 1984 photo matches



May 14, 1965 (flow between 25,100 – 28 100 ft³/s)

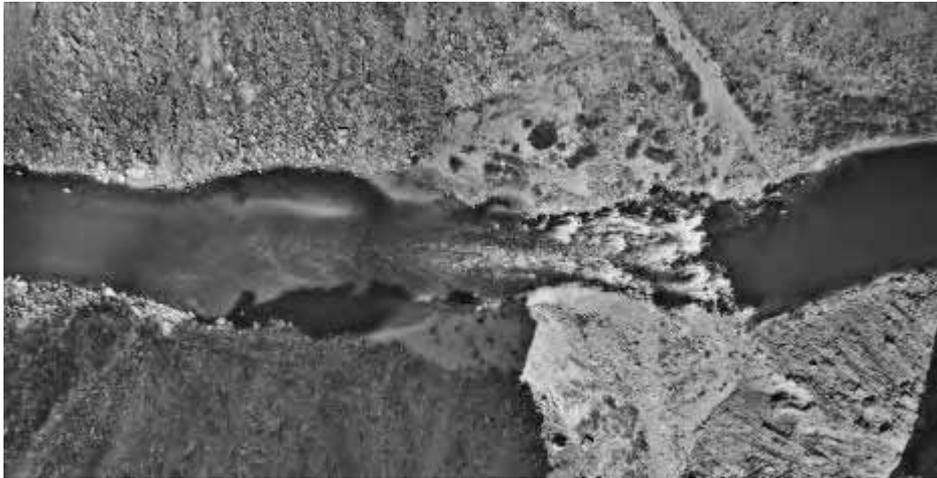


June 16, 1973 (flow between 2,700 – 6,000ft³/s)

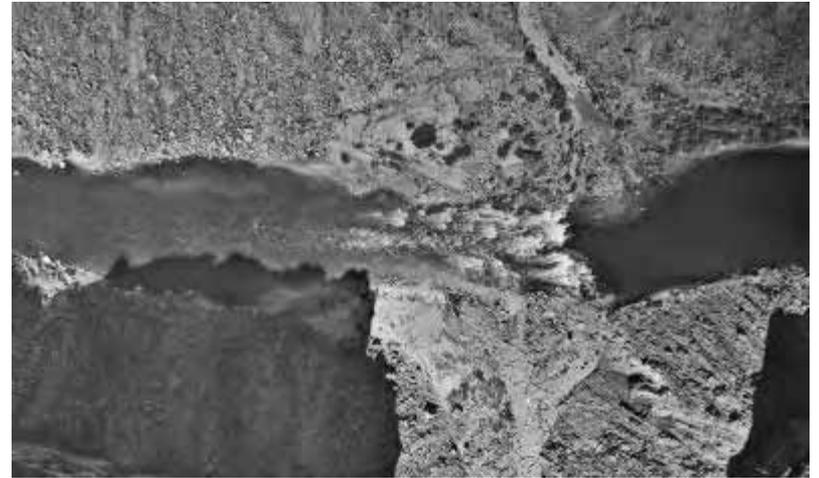


October 21, 1984 (flow between 5,300 – 5,300 ft³/s)

Badger Creek Rapid RM 8.10: 1996 – 2002 photo matches



March 24, 1996 (~8,000 ft³/s)



April 4, 1996 (~8,000 ft³/s)



2002

Badger Creek Rapid RM 8.10: 1952 – 1956 photo matches



June 19, 1952 (daily mean
98,800 ft³/s; taken by R. S.
Leding, National Park
Service)



January 2, 1954 (daily mean
4,400 ft³/s; taken by P. T. Reilly)



July 1956 (taken by Tad
Nichols)

Badger Creek Rapid RM 8.10: 1964 – 1968 photo matches



August 1964 (taken by Tad Nichols)



October 1968 (taken by Tad Nichols)

Badger Creek Rapid RM 8.10: 1972 – 1991 photo matches



August 21, 1972 (daily mean
18,700 ft³/s; taken by R. M. Turner,
USGS; boat in the rapid is 6.7 m
long)



October 4, 1991
(daily max 1,800 ft³/s,
daily min 6,100 ft³/s,
daily mean 9,300 ft³/s;
taken by R. H. Webb)

For pages 6-8: Note the extensive areas of bare sand on the separation bars on river left and river right in pre-dam photographs. Some talus blocks on the separation bar on river left were exposed in 1972 and more were exposed in 1991. Reattachment bars were more extensive in pre-dam photographs and did not exist in 1991. (John C. Schmidt, David J. Topping, Paul E. Grams, and Joseph E. Hazel. System-Wide Changes in the Distribution of Fine Sediment in the Colorado River Corridor Between Glen Canyon Dam and Bright Angel Creek, Arizona, 2004)

Badger Creek Rapid RM 8.10R and 8.15L: View from Badger overlook Before and after HFE 2008 comparison

1400 - 1500
 March 4, 2008
 (~11,700 ft³/s)

Before HFE
 →



Before HFE



Before HFE



Before HFE

1230 March 9,
 2008
 (~17,600 ft³/s)

After/during
 HFE
 →



After/during HFE



After/during HFE



After/during HFE

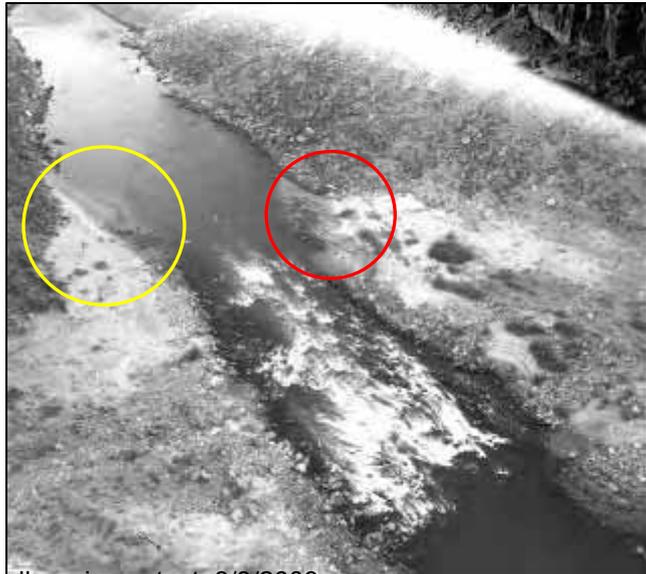
Badger Creek Rapid RM 8.10: 1972 – 2008 comparison



August 21,
1972
(daily mean
18,700 ft³/s)



1400 - 1500
March 4, 2008
(~11,700 ft³/s)



1989



1230 March 9,
2008
(~17,600 ft³/s)

RM 8.15L: Detailed comparison of Jackass beach before, after HFE 2008 and 1956



July 1956



1400 - 1500 March 4, 2008
(~11,700 ft³/s)



1230 March 9, 2008
(~17,600 ft³/s)

Rocks on the beach are more exposed in 2008. Generally more sand (on both upper and lower bar) in 1956. No vegetation on the beach in 1956.

Badger Creek Rapid RM 8.10: 1890 – 1973 photo match

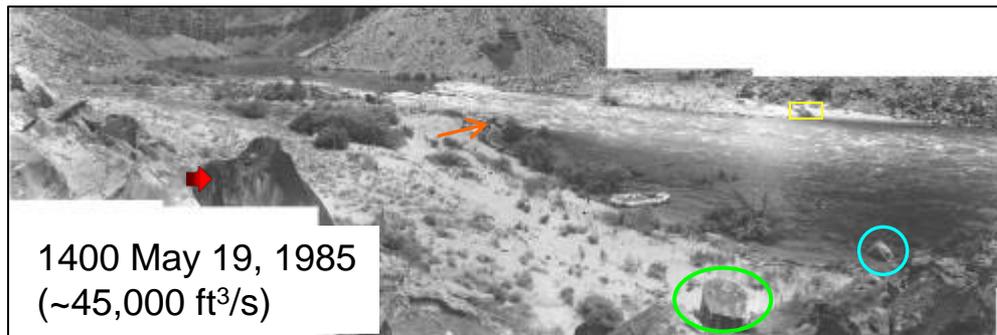


1890



1973 (~3,000 - 5,000 ft³/s)

Badger Creek Rapid RM 8.10: 1985 – 1986 comparison



Badger Creek Rapid RM 8.10: 1989 – 1990 comparison



January 1989

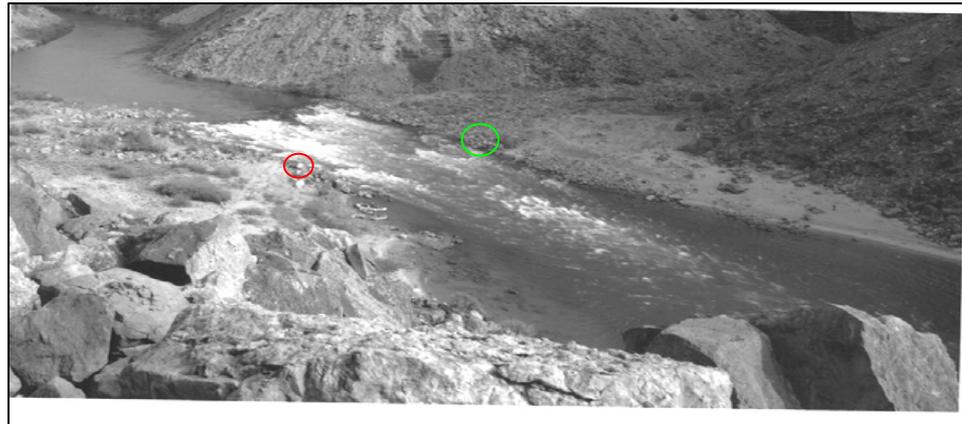


1400 January 18, 1990 (~20,100 ft³/s)

Badger Creek Rapid RM 8.10: 100 year comparison



1890



1400 January 18, 1990 (~20,100 ft³/s)

Badger Creek Rapid RM 8.10: 1985 – 2008 comparison



0830 October 6, 1985 (~3,000 ft³/s)



1020 March 29, 2008 (~9,100 ft³/s)



1145 May 10, 2008 (~10,300 ft³/s)

There appears to be increase in vegetation on 1983 and 1984/86 deposits. Higher sand of 1983 now partially deflated and has some new gullies in it. It seems there is less sand around 2008 water line. Small dune formed on the lower surface since 1985. Overall, it appears that the amount of sand is about the same on the lower surface. There is a starting gully formation in red ellipse on the higher surface.

Badger Creek Rapid RM 8.10: March and May 2008 comparison



1020 March 29, 2008
(~9,100 ft³/s)



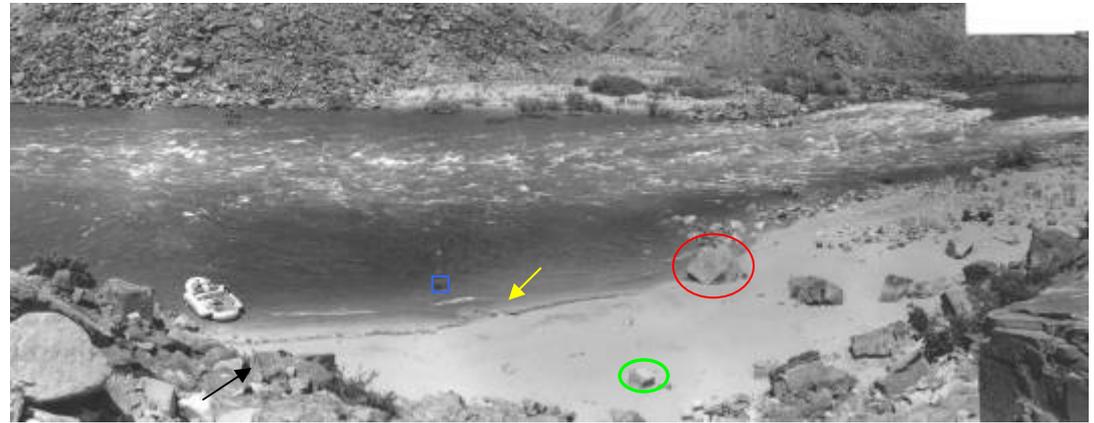
1145 May 10, 2008
(~10,300 ft³/s)

There appears to be less sand below 25,000 ft³/s line and above 50,000 ft³/s line in May. More sand accumulated around the drift wood line in May. Vegetation appears to be about same except little more sprouting vegetation right below drift wood line in May.

Jackass Canyon RM 8.15: 1973 – 1985 comparison



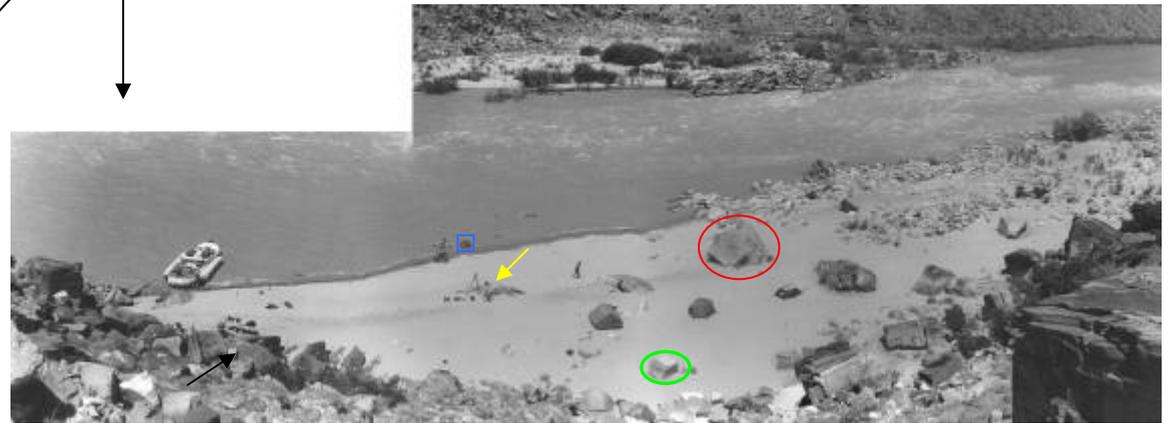
July 8, 1973 (daily mean 9,500 ft³/s;
Taken by Weeden)



1200 May 20, 1985 (~39,000 ft³/s)

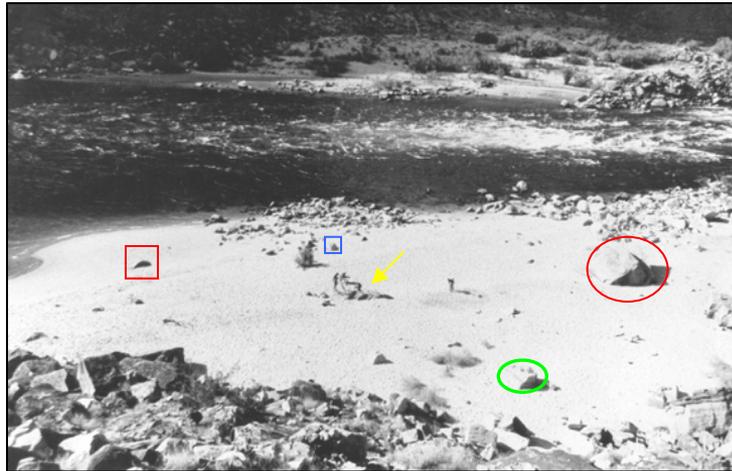


August 9, 1984
(~24,500-29,000 ft³/s)



0800 July 31, 1985 (~25,700 ft³/s)

Jackass Canyon RM 8.15: 1985 – 1986 comparison



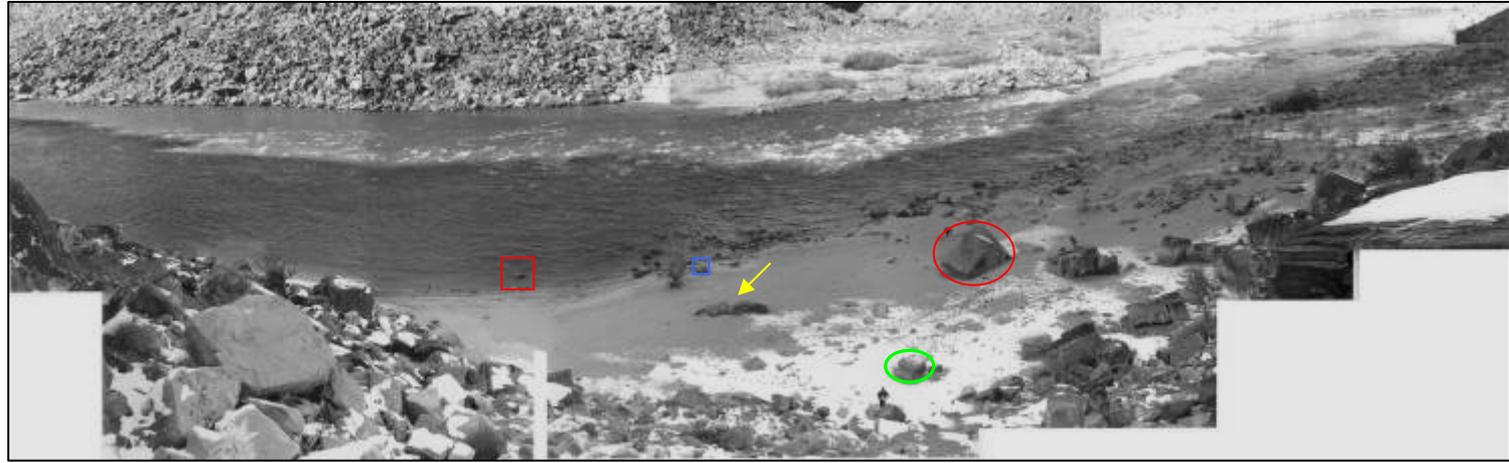
1445 October 5, 1985
(~7,800 ft³/s)



0945 January 12, 1986
(~2,100 ft³/s)

Rocks are more exposed on 1/1986 photo. Cluster of rocks upstream from red square not exposed in 10/1985. More obvious breaks in slope along waters edge and on beach in 1/1986. Generally there appears to be more sand in 10/1985 on the beach. Upstream beach has more changes in slope, large scours, and ravine formation.

Jackass Canyon RM 8.15: 1989 – 1991 comparison



1145 January 12, 1989 (~19,000 ft³/s)



August 3, 1991
(daily max 18,300 ft³/s,
daily min 10,300 ft³/s, daily
mean 14,100 ft³/s; taken by
R. H. Webb)

Jackass Canyon RM 8.15: March and May 2008 comparison



0930 March 8, 2008,
after HFE (~42,200 ft³/s)



1100 March 29, 2008
(~9,500 ft³/s)



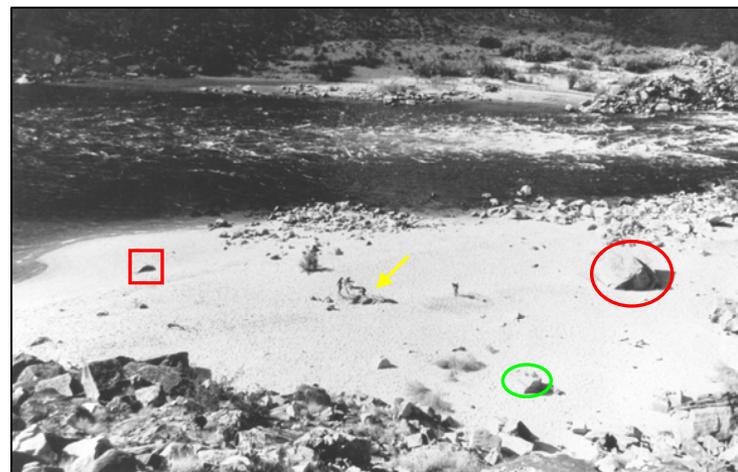
1145 May 10, 2008
(~10,300 ft³/s)

There appears to be some burial of the drift wood present in March, probably by wind, at the edge of boulder line.

Jackass Canyon RM 8.15: 1973 - 2008 comparison



July 8, 1973 (daily mean 9,500 ft³/s)



1445 October 5, 1985 (~7,800 ft³/s)



1145 May 10, 2008
(~10,300 ft³/s)

Changes in Sand Bars and Vegetation

Badger Creek Rapid beach RM 8.10L (p. 13-17)

Year	Discharge (ft ³ /s)	Area of Sand			Vegetation
		Below 25,000 ft ³ /s	25,000-50,000 ft ³ /s	Above 50,000 ft ³ /s	
1890	-	Less	Can't tell	Can't tell	Less
1973	3,000 – 5,000 ft ³ /s	More	More	Can't tell	Less
May 1985	45,000 ft ³ /s	Can't tell	Can't tell	Less	Same
July 1985	29,500 ft ³ /s	Can't tell	Same	Can't tell	Same
October 1985	3,000 ft ³ /s				
January 1986	2,000 ft ³ /s	Less	Same	Same	Same
January 1989	19,000 ft ³ /s	More	Less	Less	Same
January 1990	20,100 ft ³ /s	More	Can't tell	Can't tell	Same
March 2008	9,100 ft ³ /s	Same *	Less	Less	More
May 2008	10,300 ft ³ /s	Same *	Less	Less	More

* Same amount of sand differently distributed

Changes in Sand Bars and Vegetation

Jackass Creek beach RM 8.15R (p. 18-22)

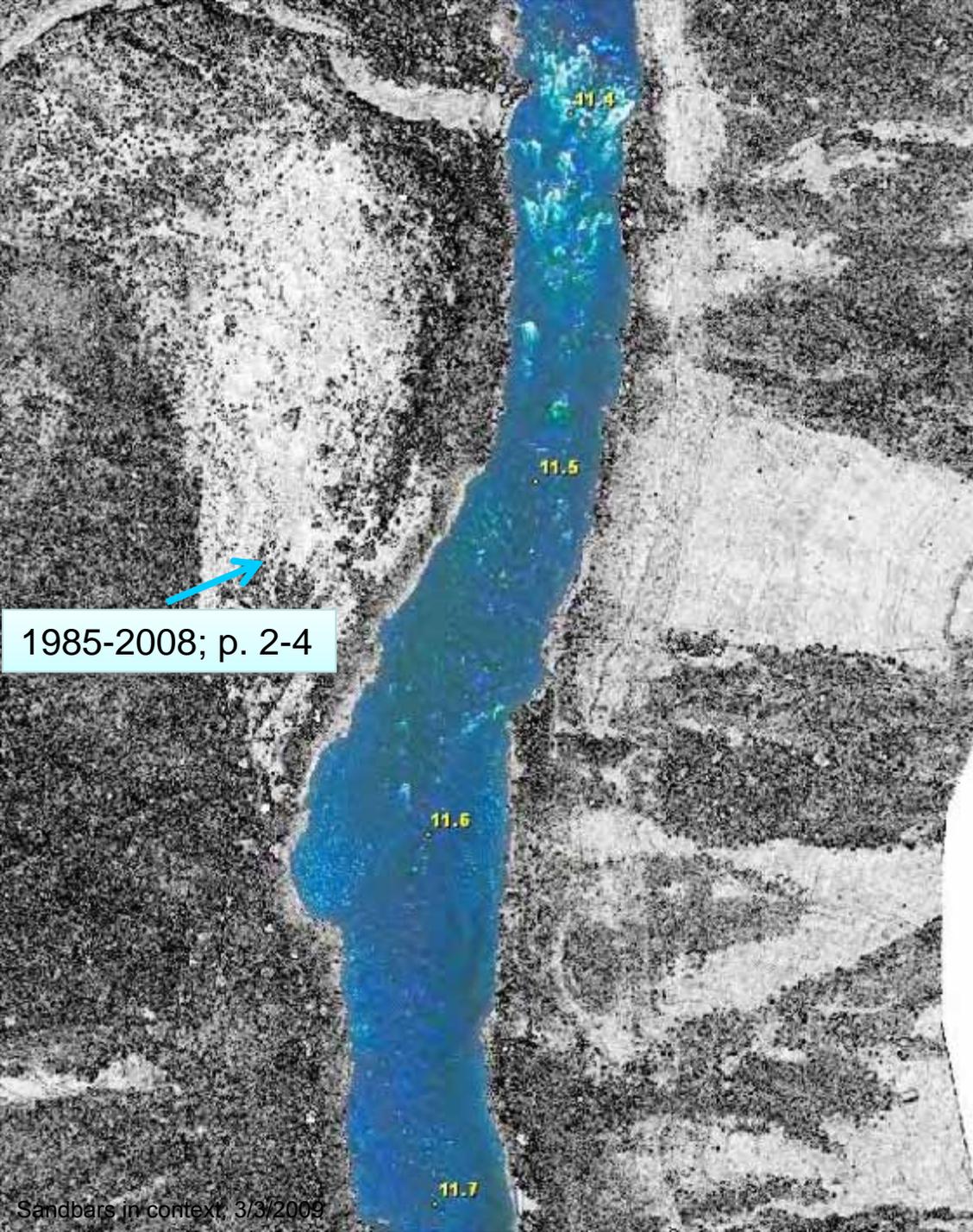
Year	Discharge (ft ³ /s)	Area of Sand			Vegetation
		Below 25,000 ft ³ /s	25,000-50,000 ft ³ /s	Above 50,000 ft ³ /s	
July 1973	9,500 ft ³ /s	Less	Less	More	More
August 1984	24,500 - 29,000 ft ³ /s	Can't tell	Less	Less	More
May 1985	39,000 ft ³ /s	Can't tell	Less	Less	Same
July 1985	25,700 ft ³ /s	Can't tell	Less	Less	More (grass)
October 1985	7,800 ft ³ /s				
January 1986	2,100 ft ³ /s	Less	Less	Less	Same
January 1989	19,000 ft ³ /s	Less	Less	Less	Same
August 1991	14,100 ft ³ /s(daily mean)	Less	Less	Less	More
March 2008	17,600 ft ³ /s	More	Less	Less	More
May 2008	10,300 ft ³ /s	More	Less	Less	More

Photo comparisons Soap Creek

11.6R reattachment bar

1986 and 2008 photos are at
comparable discharge

Changes in sand area and
vegetation summarized on
table (p. 6) are relative to 1985
conditions



Soap Creek RM 11.6R: 1985 photo match



0900 May 22, 1985 (~45,100 ft³/s)



1000 August 1, 1985 (~26,400 ft³/s)



1030 October 7, 1985 (~4.300 ft³/s)

Soap Creek RM 11.6R: 1986-1989/1990-2008 comparison



1500 January 12, 1986 (~17,400 ft³/s)



1989 or 1990



12:30 - 13:00 May 10, 2008 (~10,300 ft³/s)

Sandbars in context, 3/3/2009

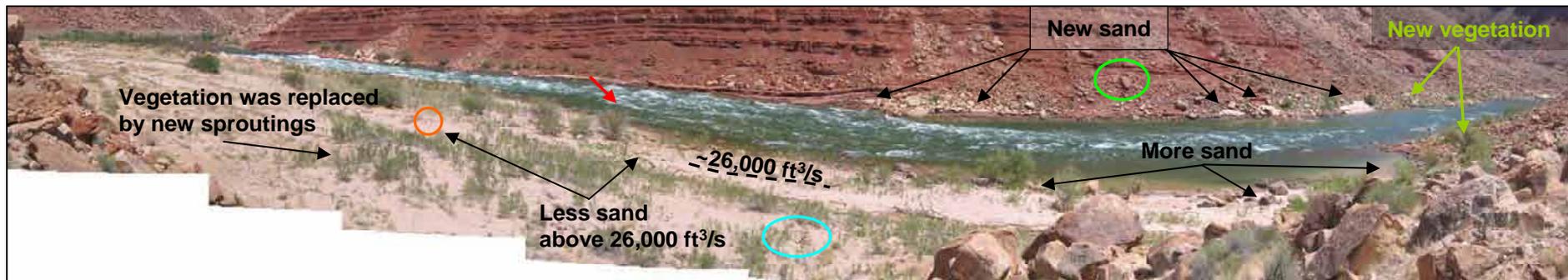
Soap Creek RM 11.6R: 1985-1986-2008 comparison



1030 October 7, 1985 (~4,300 ft³/s)



1500 January 12, 1986 (~17,400 ft³/s)



~12:30 May 10, 2008 (~10,300 ft³/s)

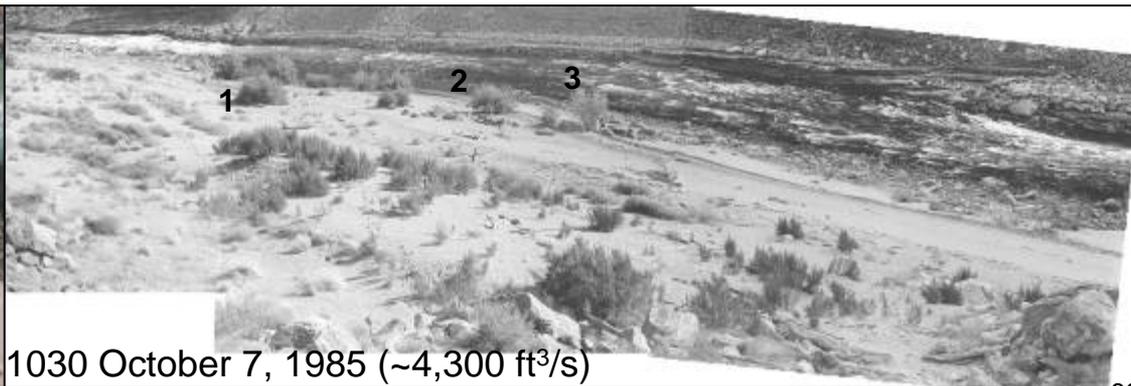
Soap Creek RM 11.6R



Unknown



Unknown



1030 October 7, 1985 (~4,300 ft³/s)

Changes in Sand Bars and Vegetation

Soap Creek RM 11.6 R

Year	Discharge (ft ³ /s)	Area of Sand			Vegetation
		Below 25,000 ft ³ /s	25,000-50,000 ft ³ /s	Above 50,000 ft ³ /s	
May 1985	45,100 ft ³ /s	Can't tell	Can't tell	More	Less
August 1985	26,400 ft ³ /s				
October 1985	4,300 ft ³ /s	Can't tell	Less	More	Little more
January 1986	17,400 ft ³ /s	Can't tell *	Less **	More	Little more
1989 or 1990	Unknown	Can't tell	Can't tell	More	Less
May 2008	10,300 ft ³ /s	Can't tell ***	Less ****	Same *****	More

* Little less sand when comparing to October 1985

** More sand around 43,000 ft³/s line, and more sand when comparing to October 1985, wood burial

*** More sand than in October 1985; rocks seem more exposed below 10,000 ft³/s line in October 1985

**** Less sand on the sand bar itself but more sand on margins bars/ new margin bars created

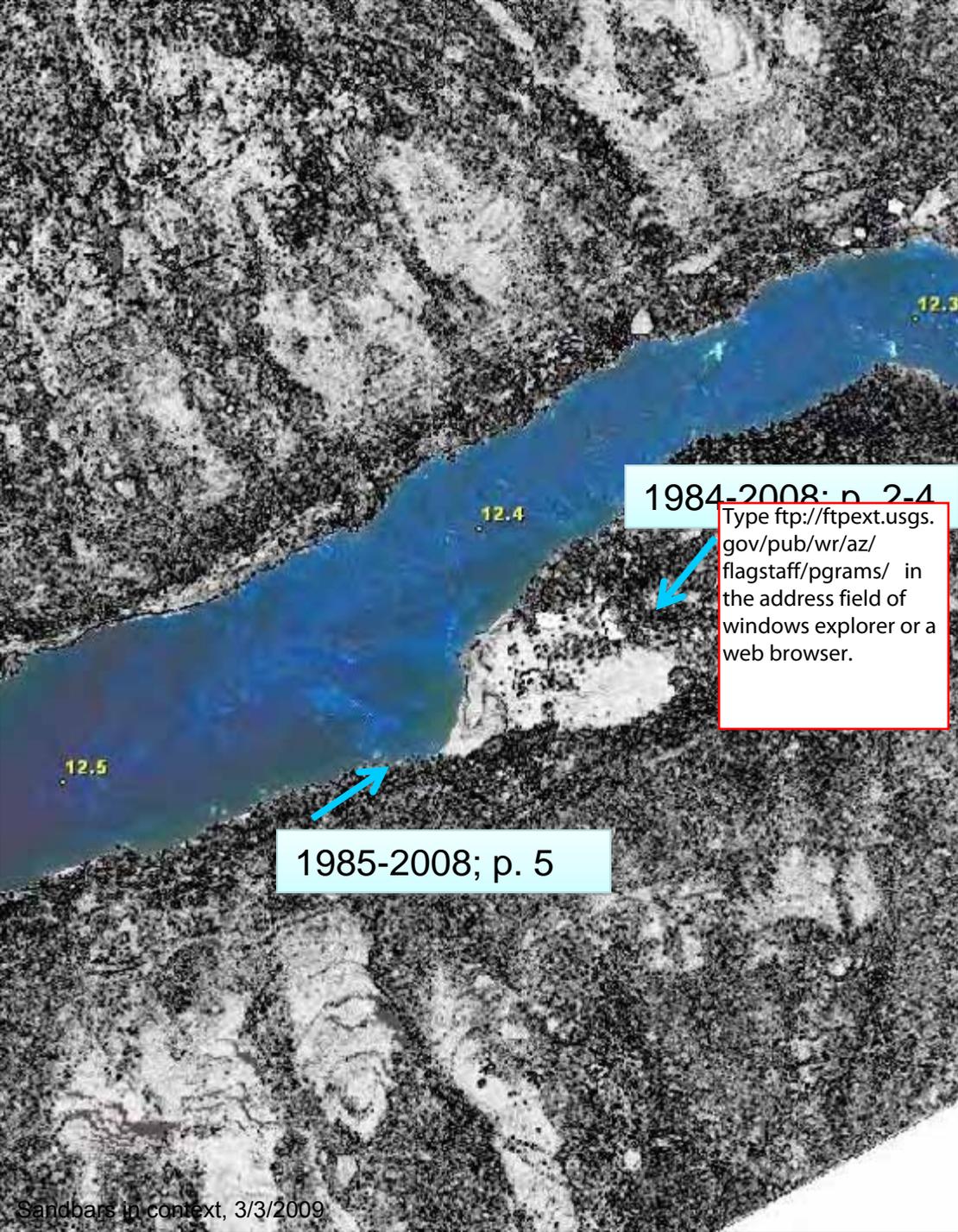
***** Same amount of sand little differently distributed

Photo comparisons
below Salt Wash

12.4L separation bar

1985 and 2008 photos are at
comparable discharge

Changes in sand area and
vegetation summarized on
table (p. 6) are relative to 1985
conditions



1984-2008; p. 2-4

Type <ftp://ftpext.usgs.gov/pub/wr/az/flagstaff/pgrams/> in the address field of windows explorer or a web browser.

1985-2008; p. 5

Below Salt Wash RM 12.4L: 1986-1986 comparison



1500 August 1, 1985 (~30,100 ft³/s)



0900 October 8, 1985 (~4,200 ft³/s)



0915 January 13, 1986 (~ 2,500 ft³/s)

January 1986 photo is showing sand removal from sand dune. Compare the reference middle rock (green rectangle), and size and shape of dune to both sides of the rock. Comparing to 2008, there is a margin sand bar on river right about 100 m downstream from eddy that did not exist in 1985 (p. 3).

Below Salt Wash RM 12.40L: 1985-2008 comparison



0900 October 8, 1985 (~4,200 ft³/s)



0720 March 30, 2008 (~8,400 ft³/s)



1345 May 10, 2008 (~11,900 ft³/s)

Very little change in both upper surface sands and sand along the river margins for March and May 2008. Notable is the sidewalk of sand along both river margins. Comparing to 1985, there is a margin sand bar on river right about 100 m downstream from eddy that did not exist in 1985 (p. 2). Upper sand surface is extremely deflated along left wall.

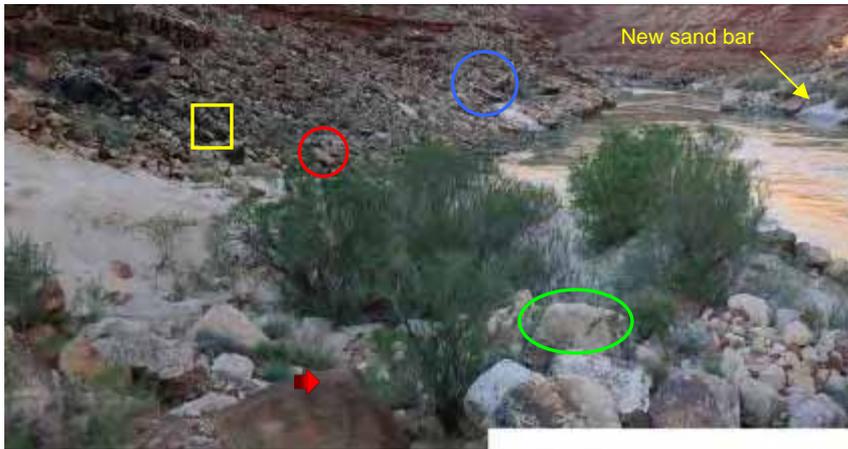
Below Salt Wash RM 12.40L: 1984-2008 comparison



August 10, 1984 (daily mean $\sim 24,200$ ft³/s)



1400 August 1, 1985 ($\sim 29,500$ ft³/s)



1820 March 30, 2008 ($\sim 8,400$ ft³/s)

Upper sand surface is extremely deflated along left wall. There does not appear to be a sidewalk of sand in 1984-1985. Also for 2008, there is a margin sand bar on river right about 100 m downstream from eddy that did not exist in 1985.

Below Salt Wash RM 12.40L: View from downstream 1985-2008 comparison



0900 October 8, 1985 (~4,200 ft³/s)



January 13, 1986
Photos showing
fluctuating flow
during the day
(~1000 – 2,100 ft³/s,
1200 – 4,000 ft³/s,
1400 – 13,200 ft³/s,
1600 – 17,700 ft³/s,
1800 – 18,700 ft³/s)



0730 March 30, 2008 (~7,700 ft³/s)

Changes in Sand Bars and Vegetation

RM 12.40L

Year	Discharge (ft ³ /s)	Area of Sand			Vegetation
		Below 25,000 ft ³ /s	25,000-50,000 ft ³ /s	Above 50,000 ft ³ /s	
August 1984	24,200 ft ³ /s	Can't tell	Less *	Can't tell **	Same
August 1985	30,100 ft ³ /s	Can't tell	More	Little Less	Same
October 1985	4,200 ft ³ /s				
January 1986	2,500 ft ³ /s	Same	Same	Little Less ***	Less
March 2008	8,400 ft ³ /s	More ****	Less	Less	More
May 2008	11,900 ft ³ /s	Can't tell	Less	Less	More

* Seems less sand but there is a different distribution of sand – bigger upper sand dune with leveled top surface and leveled lower beach in 1984

** Different sand distribution; can't tell for 1984 because photo is not showing upper part of the sand dune in 1984

*** Top of the sand dune moved uphill and buried the grass

**** New vegetation in 2008 is obstructing the view of the lower portion of the sand bar when looking downstream. From upstream view photo, (p.5) there appears to be more sand below 25,000 ft³/s.

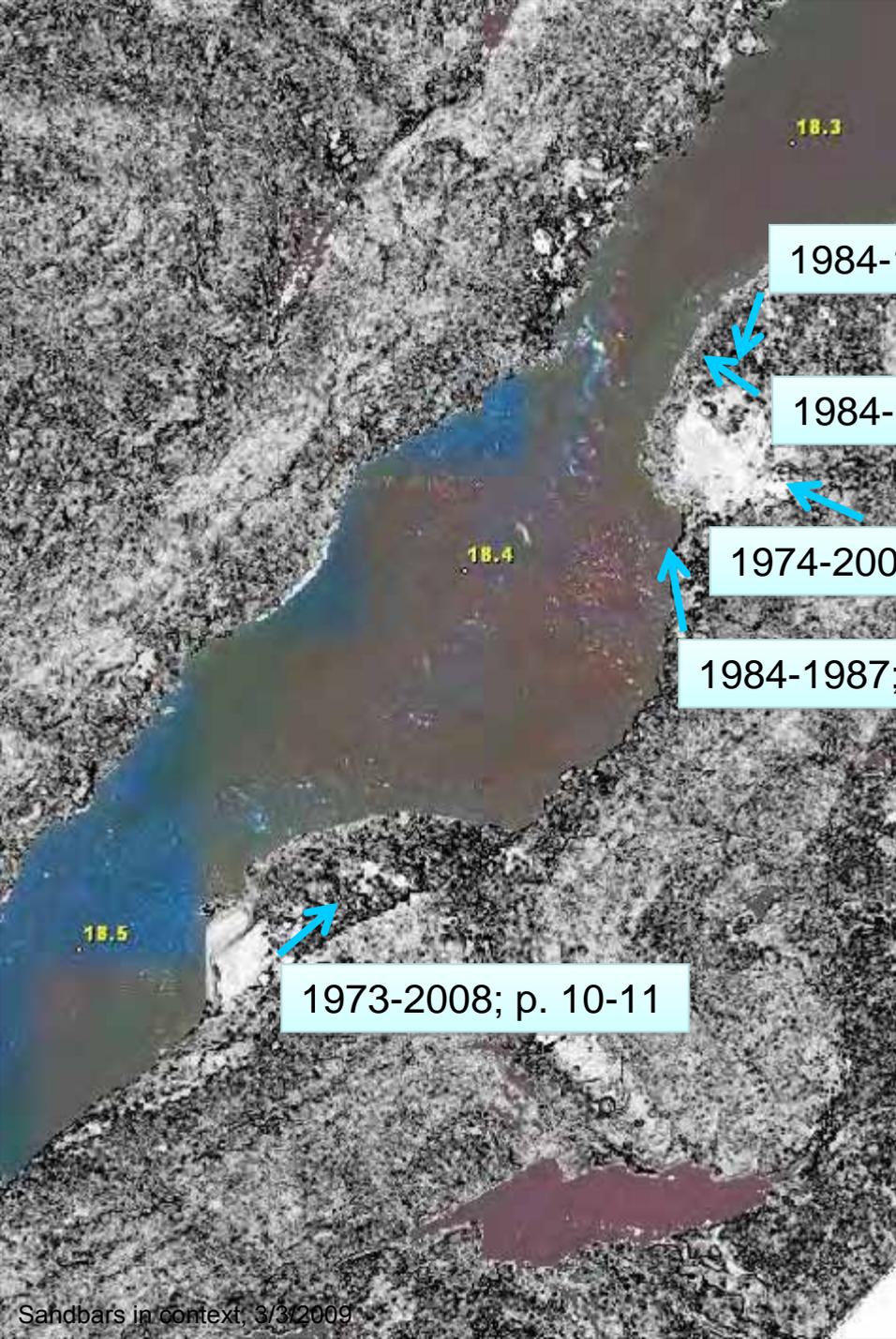


Photo comparisons
18 Mile Wash

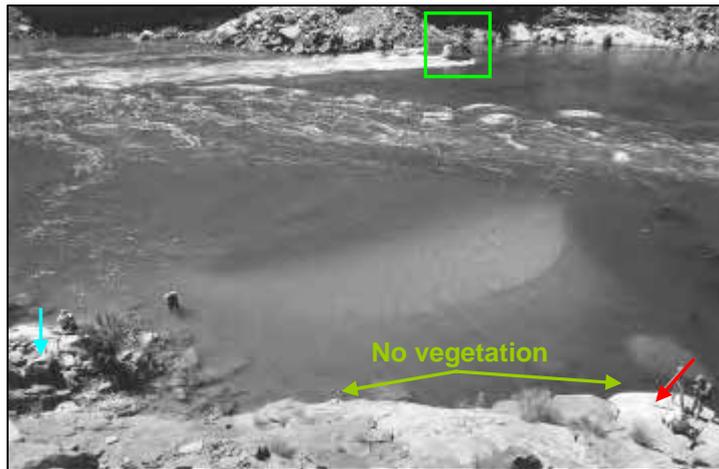
18.35L separation bar
Above 18.35L margin bars

Changes in sand area and
vegetation summarized on
table (p. 12-13) are relative to
1985 conditions

18 Mile Wash RM 18.35L : 1974-1985/1986 comparison



1974



1430 May 21, 1985 (~43,800 ft³/s)



1130 August 2,
1985
(~28,700 ft³/s)

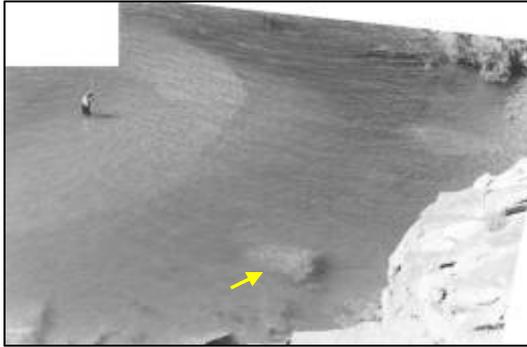


0930 October 9,
1985
(~4,200 ft³/s)



1530 January 13,
1986
(~15,700 ft³/s)

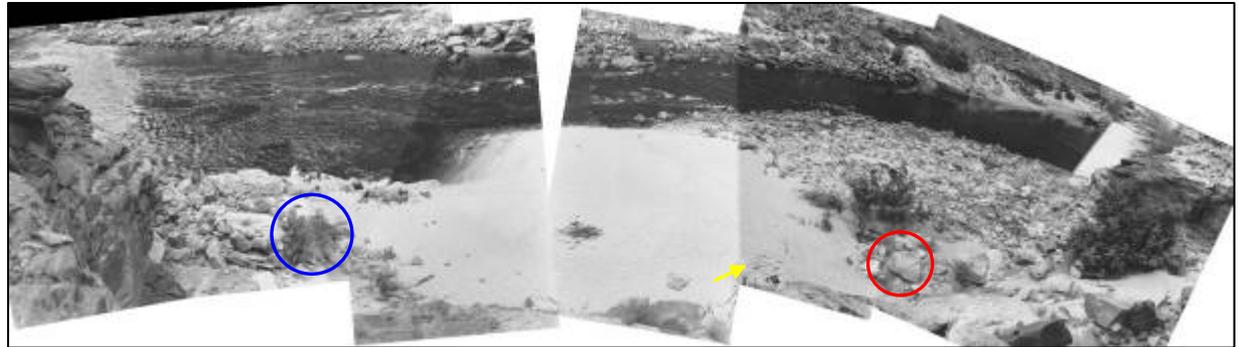
18 Mile Wash RM 18.35L : 1985-1987 comparison



1430 May 21, 1985 (~43,800 ft³/s)



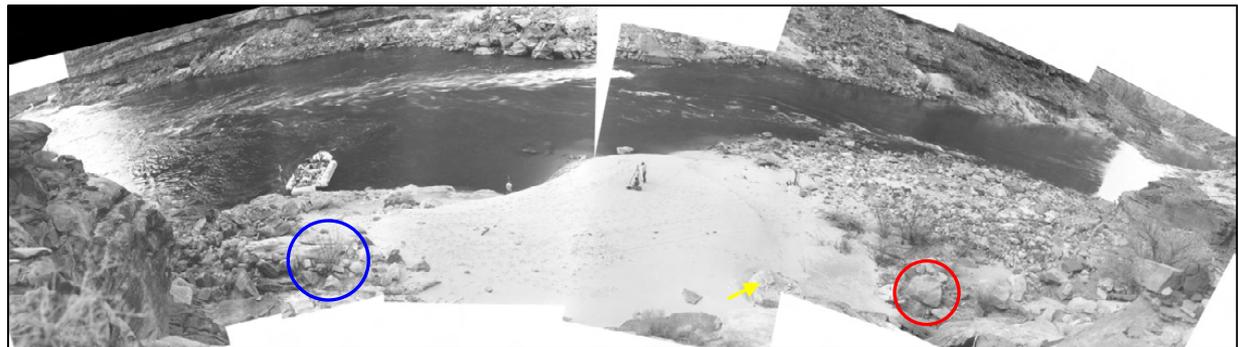
1130 August 2, 1985 (~28,700 ft³/s)



0930 October 9, 1985 (~4,200 ft³/s)



July 29, 1987 (daily mean
21,000 ft³/s)

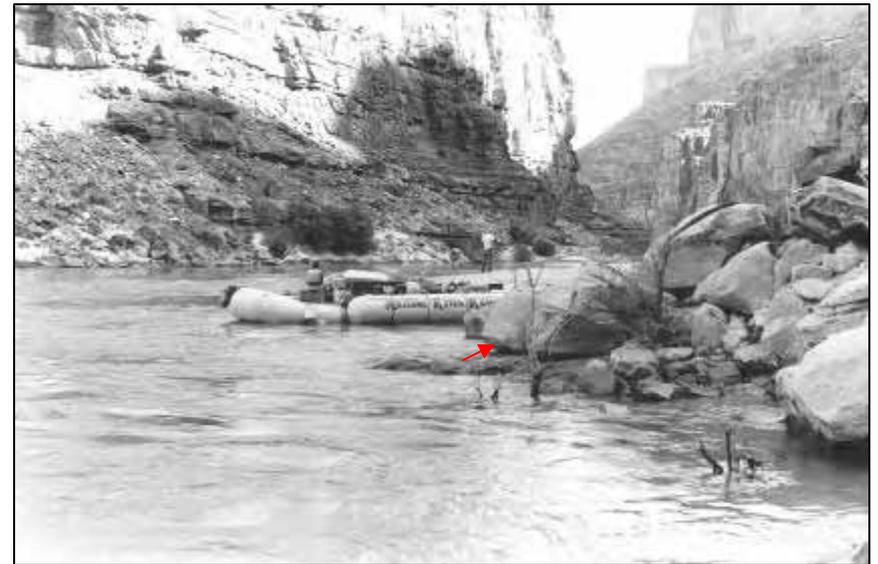


1530 January 13, 1986 (~15,700 ft³/s)

18 Mile Wash RM 18.35L : 1984-1985 photo match



August 10, 1984 (daily mean $\sim 24,200$ ft³/s)



0830 August 2, 1985 ($\sim 27,600$ ft³/s)

18 Mile Wash RM 18.35L : 1985-1987 photo matches



1130 October 9, 1985 (~4,400 ft³/s)



1530 January 13, 1986 (~15,700 ft³/s)



July 29, 1987 (daily mean ~21,000 ft³/s)

18 Mile Wash RM 18.35L : 1984-1985 photo matches



July 1984



August 10, 1984 (daily mean $\sim 24,200$ ft³/s)



0830 August 2, 1985 ($\sim 27,600$ ft³/s)

18 Mile Wash RM 18.35L : 1984-1985 photo matches



July 1984



July 1984



August 10, 1984 (daily mean $\sim 24,200$ ft³/s)



0830 August 2, 1985 ($\sim 27,600$ ft³/s)

18 Mile Wash RM 18.35L : March and May 2008 (after HFE) comparison



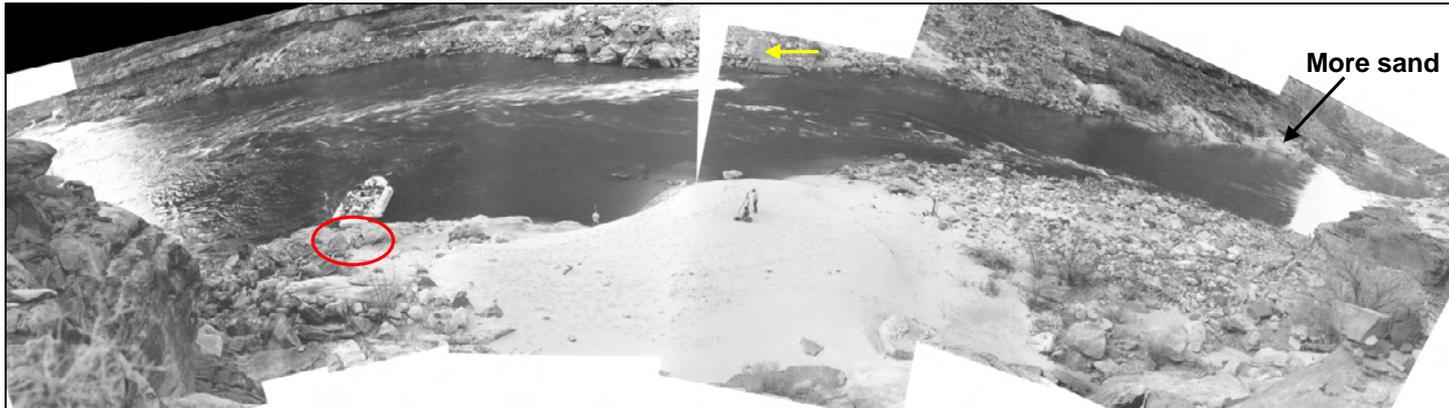
1420 March 30, 2008 (~8,300 ft³/s)



0920 May 10, 2008 (~9,600 ft³/s)

There appears to be more sand on the sand bar in March. Bar leveled by May probably by wind and sand got distributed
Sat upstream on 1/3 of the sand bar.

18 Mile Wash RM 18.35L : 1986-2008 comparison



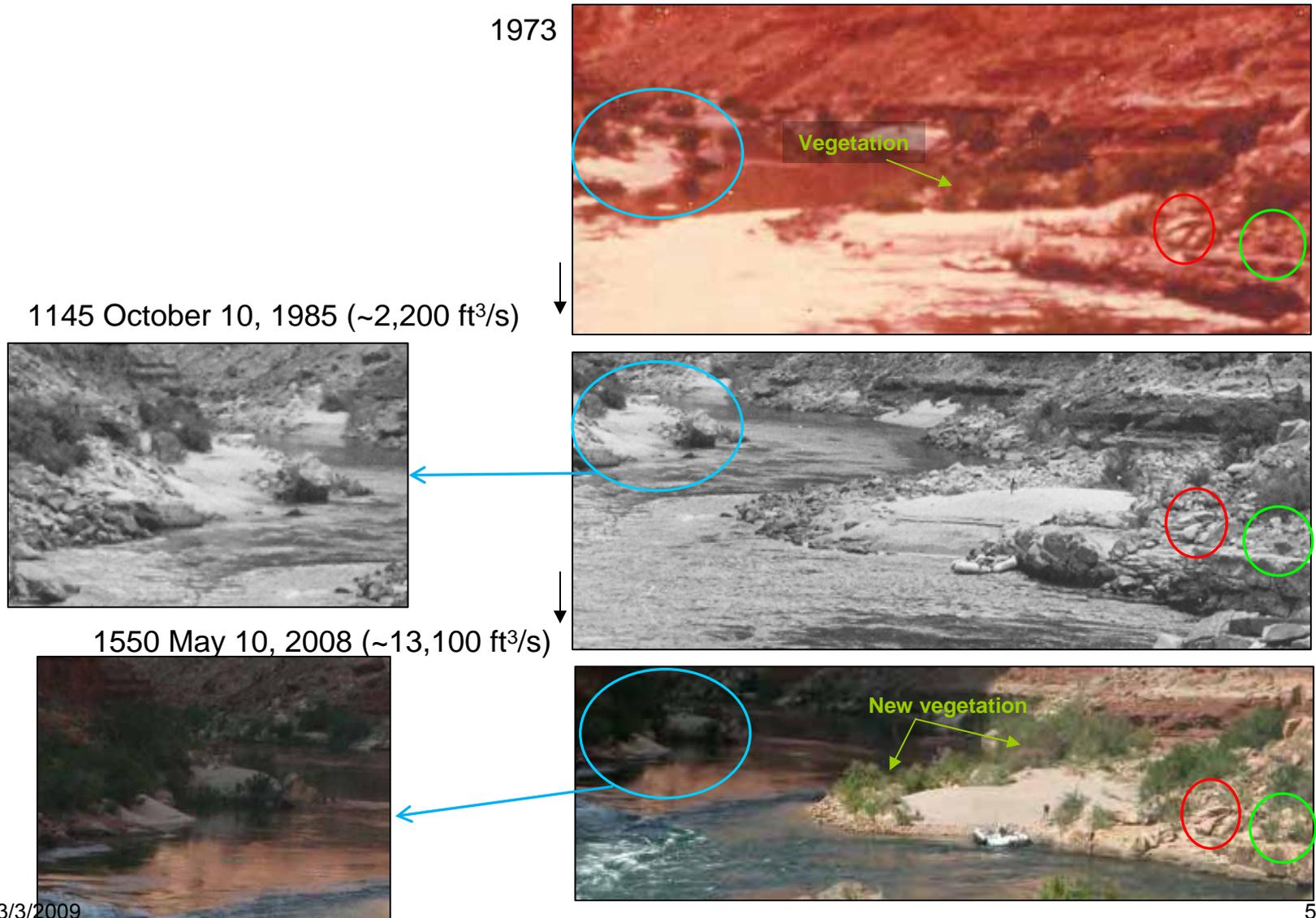
1530 January 13, 1986 (~15,700 ft³/s)



0920 May 10, 2008 (~9,600 ft³/s)

Rocks are more exposed at the upstream end of the site in year 1986. More vegetation in this part in 2008. The sand bar seems to be bigger in 1986. There is more sand in between 25,000 and 50,000 ft³/s - compare two boulders in the red ellipse.

18 Mile Wash RM 18.35L : View from downstream (18.5L beach) 1973-1985-2008 comparison



18 Mile Wash RM 18.35L :

Margin bar located upstream from 18 Mile Wash, RR

1985-2008 comparison

Margin bar upstream from 18 Mile Wash, RR
Photo taken from downstream (18.5L beach)



0930 October 9, 1985 (~4,200 ft³/s)

Margin bar upstream from 18 Mile Wash, RR
Photo taken from 18 Mile Wash Beach



0920 May 10, 2008 (~9,600 ft³/s)



Changes in Sand Bars and Vegetation

18 Mile Wash Bar

Year	Discharge (ft ³ /s)	Area of Sand			Vegetation
		Below 25,000 ft ³ /s	25,000-50,000 ft ³ /s	Above 50,000 ft ³ /s *	
1973	-	More	Less	Can't tell	More
1974	-	More	Less	Can't tell	More
July 1984	-	Can't tell	Less	Can't tell	Same
August 1984	24,200 ft ³ /s(daily mean)	Can't tell	Less **	Can't tell	Same
May 1985	43,800 ft ³ /s	Can't tell	Can't tell	Can't tell	Same
August 1985	28,700 ft ³ /s	Can't tell	More	Can't tell	Same
October 1985	4,200 ft ³ /s				
January 1986	15,700 ft ³ /s	Less	Same	Can't tell	Same
July 1987	21,000 ft ³ /s(daily mean)	Can't tell	Same ***	Can't tell	Same
March 2008	8,300 ft ³ /s	Less	More	Can't tell	More
May 2008	9,600 ft ³ /s	Less ****	More	Can't tell	More

Margin Bar Upstream from 18 Mile Wash Bar

Year	Discharge (ft ³ /s)	Area of Sand			Vegetation
		Below 25,000 ft ³ /s	25,000-50,000 ft ³ /s	Above 50,000 ft ³ /s	
1973	-	More	Can't tell	Can't tell	More
October 1985	4,200 ft ³ /s				
May 2008	13,100 ft ³ /s	More	Can't tell *****	Can't tell	More

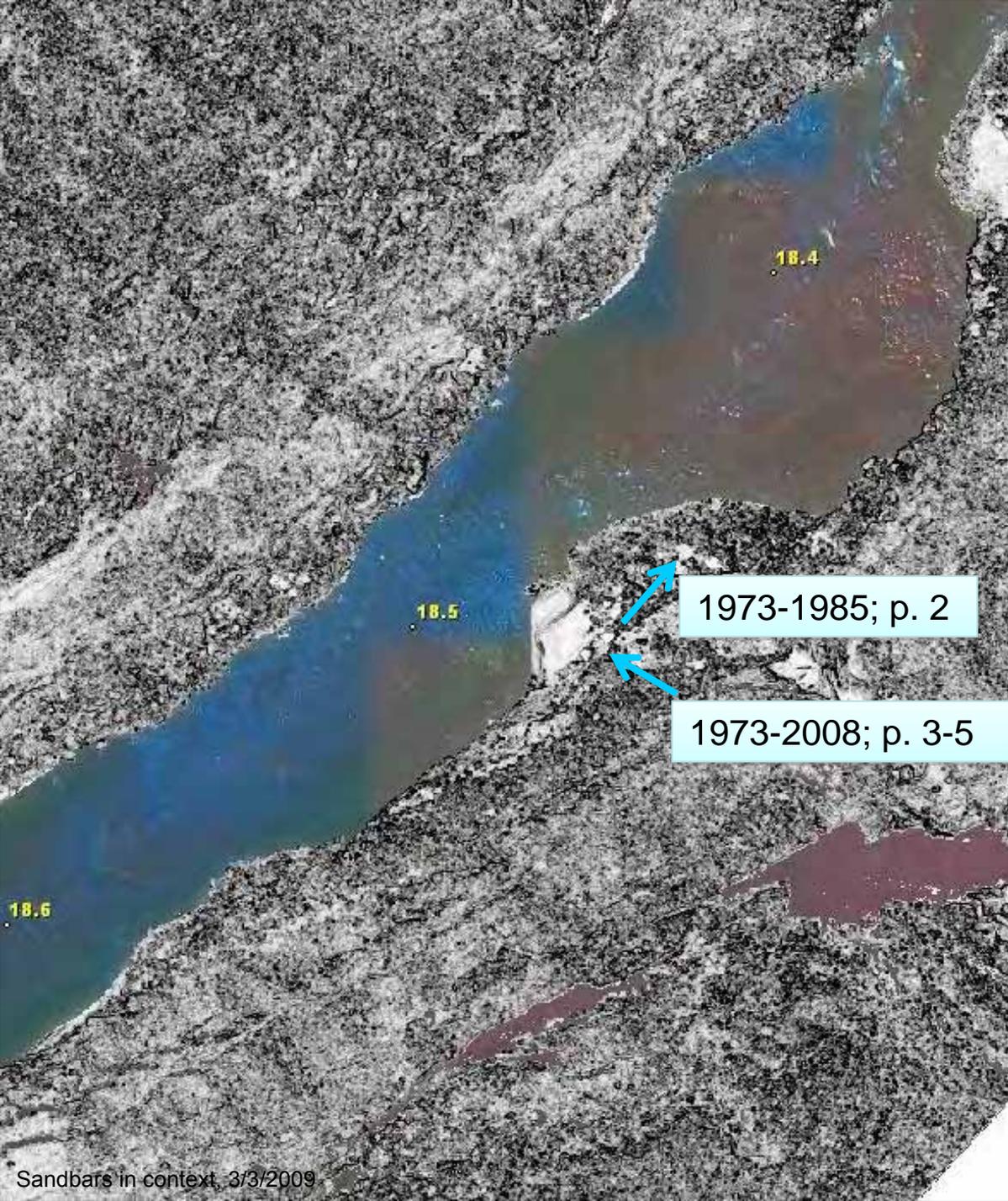
Changes in Sand Bars and Vegetation

- * Sand bar under water around 43,000 ft³/s (see photo from 1430 May 21, 1985 (~ 43,800 ft³/s))
- ** More sand around boulders at the higher surface when comparing to July 1985
- *** More sand right next to the wall and in between the wall and reference rock (yellow arrow)
- **** Also less sand when comparing to March photo
- ***** Margin bar covered with new vegetation, can't compare the sand surfaces

Photo comparisons
below 18 Mile Wash

18.5L separation bar

Changes in sand area and
vegetation summarized on
table (p. 6) are relative to 1985
condition



Below 18 Mile Wash RM 18.5L:
Upstream end of the bar
1973-1985-2008 comparison



1973



1630 August 2, 1985
(~29,100 ft³/s)



1145 October 10, 1985
(~2,200 ft³/s)

Below 18 Mile Wash RM 18.5L: 1973-1985-2008 comparison



1973



1630 August 2, 1985 (~29,100 ft³/s)



1145 October 9, 1985 (~4,900 ft³/s)



1030 March 30, 2008 (~7,600 ft³/s)

There appears to be more sand on river right, as well as new vegetation in 2008. When comparing 1985 and 2008 upper sand bar seems to have more sand, lower sand bar has more exposed rocks – less sand in 2008; although, part of it is under water. New vegetation on river left as well.

Below 18 Mile Wash RM 18.5L: Changes caused by 2008 HFE

There appears to be more sand on river left in May; although, can't see the upstream end of the site with the rocks because of the vegetation.
Amount of sand on river right (between river and wall) appears to be smaller in May; probably result of cut bank and wind erosion.



1030 March 30, 2008 (~7,600 ft³/s)



1550 May 10, 2008 (~13,100 ft³/s)

Below 18 Mile Wash RM 18.5L: 1985-2008 comparison



1630 August 2, 1985 (~29,100 ft³/s)



1550 May 10, 2008 (~10,100 ft³/s)

Changes in Sand Bars and Vegetation

Below 18 Mile Wash, RM 18.50L

Year	Discharge (ft ³ /s)	Area of Sand			Vegetation
		Below 25,000 ft ³ /s	25,000-50,000 ft ³ /s *	Above 50,000 ft ³ /s **	
1973	-	More	Little Less	-	More/Less ***
August 1985	29,100 ft ³ /s	Can't tell	Same	-	Same
October 1985	2,200/4,900 ft ³ /s				
March 2008	7,600 ft ³ /s	Less	More	-	More
May 2008	13,100/10,100 ft ³ /s	Less ****	More	-	More

Margin bars on opposite bank

Year	Discharge (ft ³ /s)	Area of Sand			Vegetation
		Below 25,000 ft ³ /s	25,000-50,000 ft ³ /s	Above 50,000 ft ³ /s *	
October 1985	4,900 ft ³ /s				
March 2008	7,600 ft ³ /s	More	Less	-	More
May 2008	13,100 ft ³ /s	More *****	Less	-	More

* Sand in between 25,000 – 50,000 ft³/s flow line is only in small patches on the rock ledge

** Entire site is under water when flow is around 50,000 ft³/s

*** More vegetation below 25,000 ft³/s flow line but less on the upper surface of the bar

**** More sand when comparing to March 2008

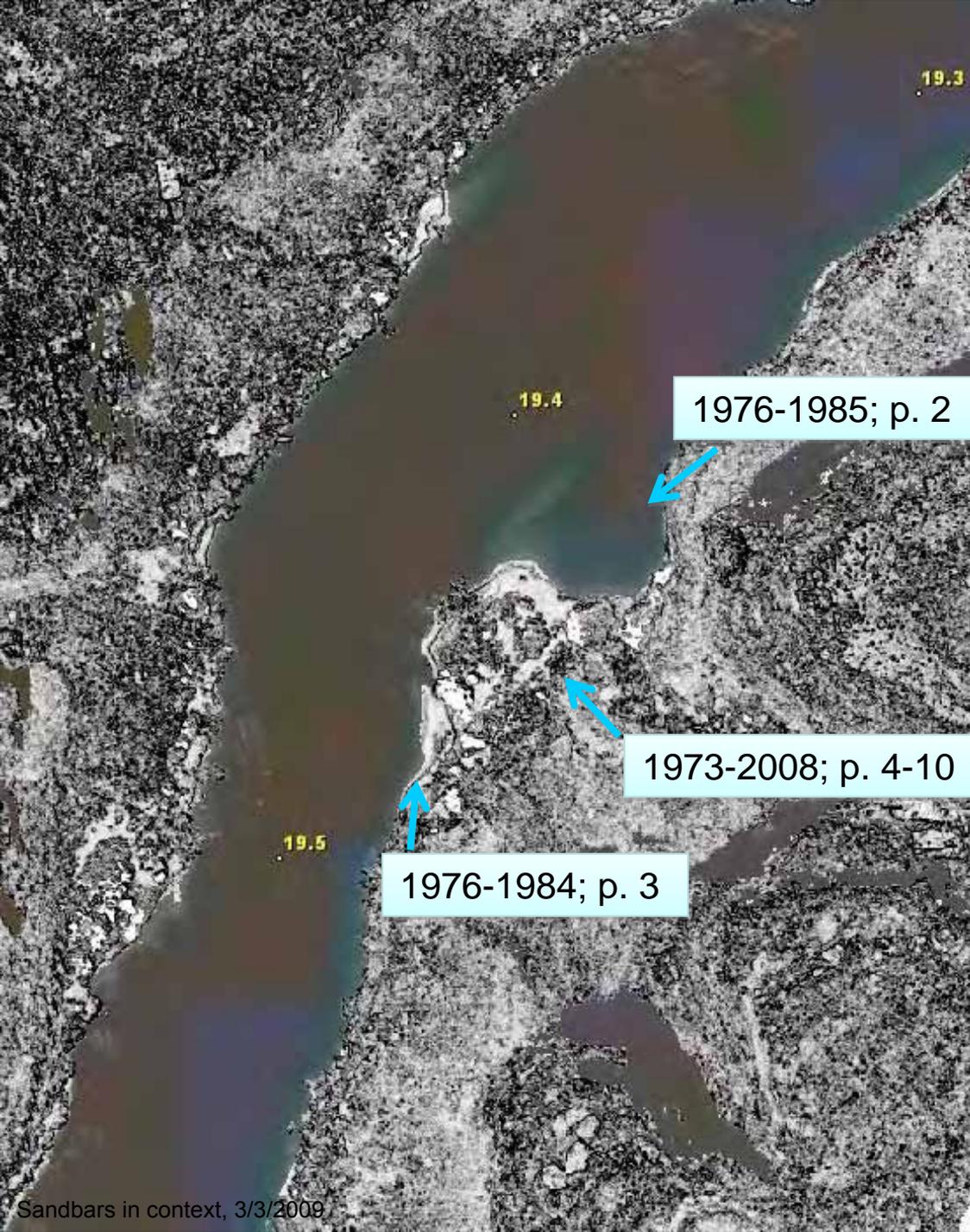
***** Less sand when comparing to March 2008

Photo comparisons 19 Mile Canyon

19.41L reattachment bar
and margins bars on river right

1985 and 2008 photos are at
comparable discharge

Changes in sand area and
vegetation summarized on
table (p. 11-12) are relative to
1985 conditions



19 Mile Wash RM 19.41L: 1976-1984/1985 comparison



Morning August 6, 1976 (~3,500 ft³/s;
E. M. Laursen, E. Silverston, 1976)



August 11, 1984 (~24,300 ft³/s)



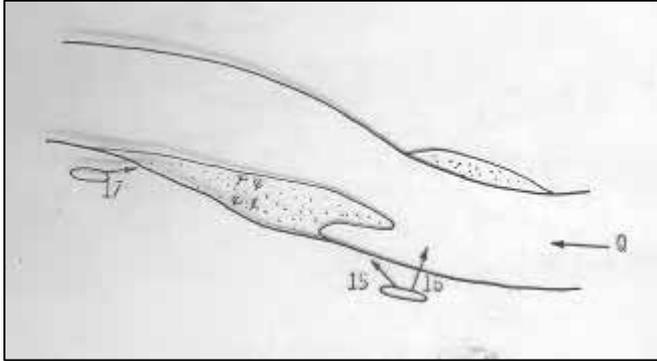
1100 May 23, 1985 (~42,100 ft³/s)



0930 August 3, 1985 (~23,800 ft³/s)

Sand bar on river left more exposed due to the low water level in 1976. There is more vegetation in the green circle area in 1976. There appears to be more sand in that same area (above the vegetation line) in 1985. Less sand at inside bend of left sand bar in 1984 than 1976. Vegetation seems reduced (can see the dead branches) in 1984 and 1985.

19 Mile Wash RM 19.41L: View from downstream end 1976-1984 comparison



Site sketch from E. M. Laursen, E. Silverston, 1976



Morning
August 6,
1976
(~3,500 ft³/s;
E. M.
Laursen, E.
Silverston,
1976)

August 11, 1984
(~24,300 ft³/s)



Vegetation reduced by 1984. Beach doesn't exist in the 1984 water level. Debris fan that separates upper and lower beach very low. There appears to be erosion of the beach due to lack of eddy at high flow.

19 Mile Wash RM 19.41L: 1984-1985 comparison



August 11, 1984
(~24,300 ft³/s)



0945 May 23, 1985
(~41,800 ft³/s)

19 Mile Wash RM 19.41L: August and October 1985 comparison



0930 August 3, 1985 (~23,800 ft³/s)



1115 October 10, 1985 (~4,100 ft³/s)

19 Mile Wash RM 19.41L: 1986-1989 comparison



0930 January 14, 1986 (~5,900 ft³/s)



1530 January 15, 1989 (~7,500 ft³/s)

19 Mile Wash RM 19.41L:



Unknown

19 Mile Wash RM 19.41L: 1985-2008 comparison



1115 October
10, 1985
(~4,100 ft³/s)



1100 March 30, 2008 (~7,700 ft³/s)

The sand bar on river left has some new vegetation and there appears to be more upper surface sand (between 25,000 and 40,000 ft³/s). There are new margin bars on river right (black ellipses) in 2008. The most upstream one existed in 1973 and 1976 (see the sketch – page 3). Bar that is downstream from them (red ellipse) got more vegetated over time. There is noticeable sidewalk of sand on river right with some new vegetation in 2008.

19 Mile Wash RM 19.41L: 1973-1985-2008 comparison



1973



1115 October 10, 1985 (~4,100 ft³/s)

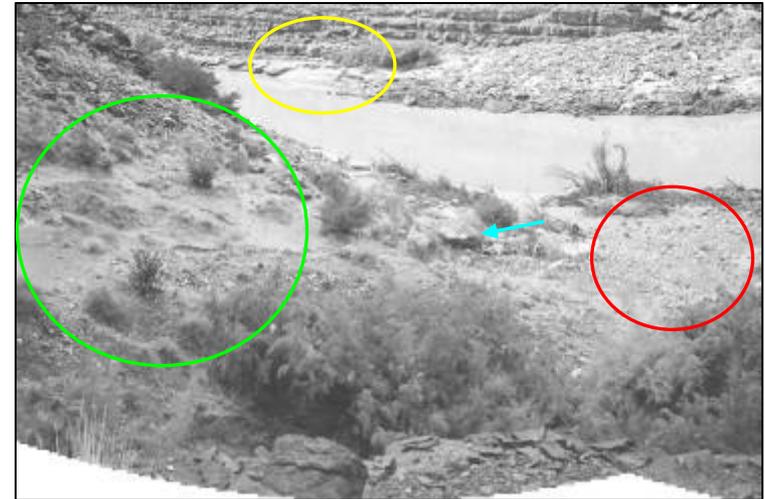


1100 March 30, 2008 (~7,600 ft³/s)

19 Mile Wash RM 19.41L: 1973-1985-2008 comparison



1973



1115 October 10, 1985 (~4,100 ft³/s)



1100 March 30, 2008 (~7,600 ft³/s)

There appears to be more sand in the area of green circle in 1973 comparing to 1985 and 2008. The sand bar area between 25,000 and 45,000 ft³/s (red circle) has more sand in 1973 than 1985. 2008 photo shows small sand dunes formed in the same area. Sidewalk of sand along the river right (around 43,000 ft³/s) is visible in 2008. Small margin bar on river right seems smallest in 1973, showing more vegetation growth in 2008 (yellow ellipse).

Changes in Sand Bars and Vegetation

RM 19.41L

Year	Discharge (ft ³ /s)	Area of Sand			Vegetation
		Below 25,000 ft ³ /s	25,000-50,000 ft ³ /s	Above 50,000 ft ³ /s	
1973	Lower	Can't tell	More	More	More
August 1976	3,500 ft ³ /s	Can't tell	Less	Can't tell	More
August 1984	24,300 ft ³ /s	Can't tell	More	More	Same
May 1985	41,800 – 42,100 ft ³ /s	Can't tell	Can't tell	Same	Same
August 1985	23,800 ft ³ /s				
October 1985	4,100 ft ³ /s	Can't tell	Little More	Same	Less
January 1986	5,900 ft ³ /s	Can't tell	Little More	Same	Can't tell
January 1989	7,500 ft ³ /s	Can't tell	Little More	Less (gully formation)	Can't tell
Unknown	Lower	Can't tell	More	Same	Less
March 2008	7,600 ft ³ /s	More	More	Less	More

Changes in Sand Bars and Vegetation

RM 19.40R (margin bars, sidewalk sand on opposite bank)

Year	Discharge (ft ³ /s)	Area of Sand			Vegetation
		Below 25,000 ft ³ /s	25,000-50,000 ft ³ /s	Above 50,000 ft ³ /s	
1973	Lower	Less	More	Same	More
August 1976	3,500 ft ³ /s	Can't tell	Less	Less	More
August 1984	24,300 ft ³ /s	Can't tell	Can't tell	Can't tell	Same
May 1985	41,800 – 42,100 ft ³ /s	Can't tell	Can't tell	Same	Same
August 1985	23,800 ft ³ /s				
October 1985	4,100 ft ³ /s	Can't tell	More	Same	Less
January 1986	5,900 ft ³ /s	Can't tell	Same	Same	Can't tell
January 1989	7,500 ft ³ /s	Less	Same	Same	More
Unknown	Lower	Can't tell	Same	Same	Same
March 2008	7,600 ft ³ /s	More	More	Less	More



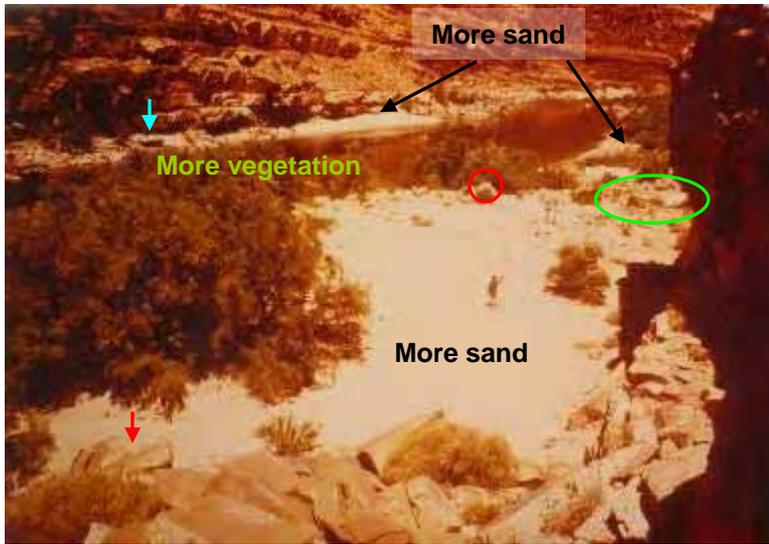
Photo comparisons 20 Mile Camp

20.20L separation bar

1986 and 2008 photos are at
comparable discharge

Changes in sand area and
vegetation summarized on
table (p. 3) are relative to 1986
conditions

20 Mile Camp RM 20.20L: 1973, 1986 and 2008 comparison



1973 (lower than 1986)



1430 January 14, 1986 (~4,500 ft³/s)



1230 March 30, 2008 (~7,600 ft³/s)

There appears to be more sand in 1973 on bar itself and on margin bars as well. There is more vegetation in 1973, especially by waters edge. New vegetation growth since 1986 in 2008 photo. Much less sand on the sand bar itself; although, boulders seem more buried in the finer material at the upstream end of the bar (see green ellipse) in 2008. Margin bars seem to have more sand on the upper surfaces in 1986. There is some new rock fall on the rock ledge in 2008.

Changes in Sand Bars and Vegetation

RM 20.2L

Year	Discharge (ft ³ /s)	Area of Sand			Vegetation
		Below 25,000 ft ³ /s	25,000-50,000 ft ³ /s	Above 50,000 ft ³ /s *	
1973	< 4,500 ft ³ /s	More	More	Can't tell	More
January 1986	4,500 ft ³ /s				
March 2008	7,600 ft ³ /s	Less	Less	Can't tell	More

Sand and margin bars on river right

Year	Discharge (ft ³ /s)	Area of Sand			Vegetation
		Below 25,000 ft ³ /s	25,000-50,000 ft ³ /s	Above 50,000 ft ³ /s *	
1973	< 4,500 ft ³ /s	More	More	Can't tell	Same
January 1986	4,500 ft ³ /s				
March 2008	7,600 ft ³ /s	Less	Less **	Can't tell	More

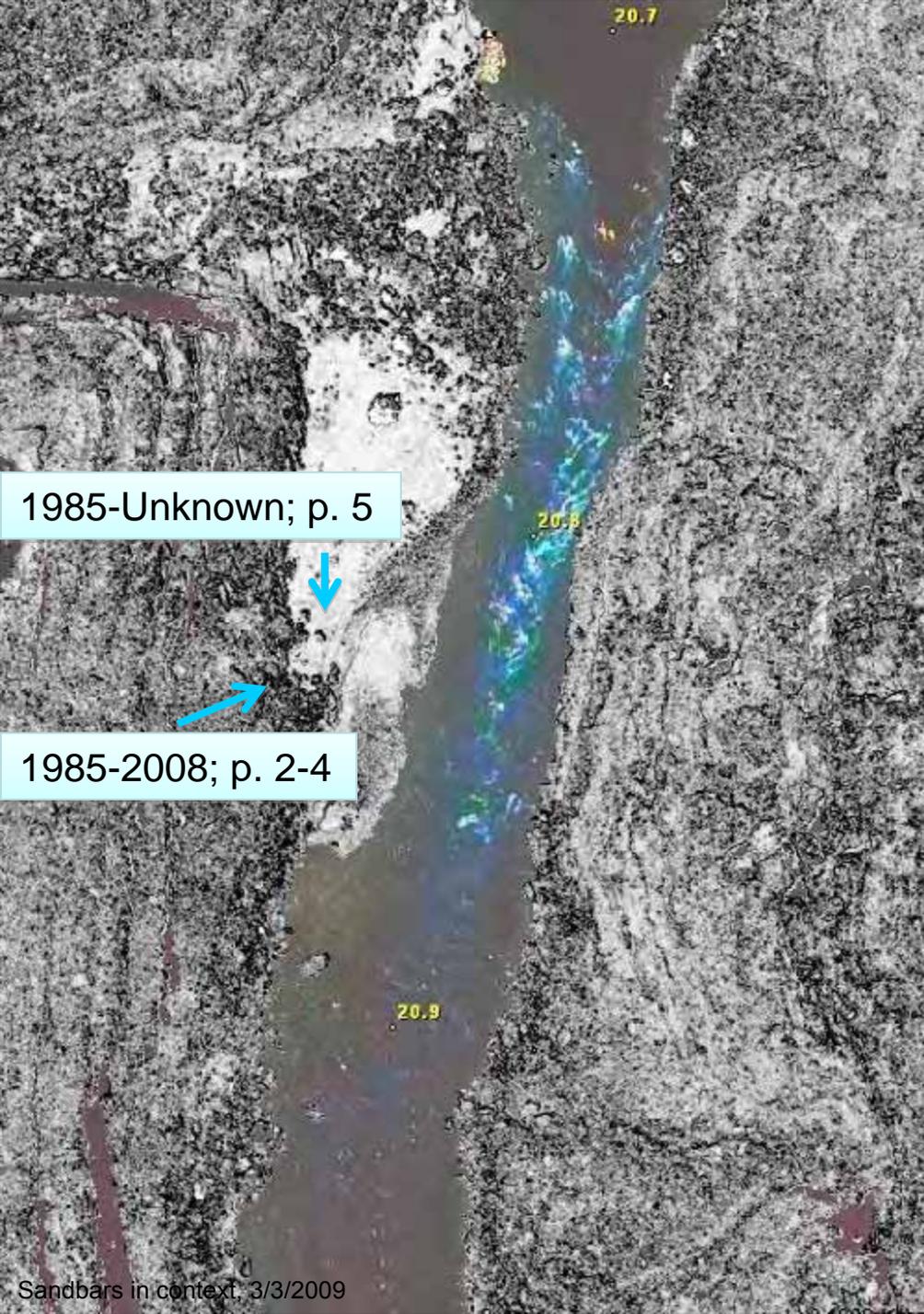
* There seems to be little more sand on the higher surfaces of margin bars; although, new vegetation is obstructing complete view in 2008

** Site and margin bars under water when flow is around 50,000 ft³/s

Photo comparisons
North Canyon Rapid

20.85R separation bar
20.80-2.90L margin bars

Changes in sand area and
vegetation summarized on
table (p. 6) are relative to 1985
conditions



1985-Unknown; p. 5



1985-2008; p. 2-4



North Canyon RM 20.85R: 1985-1990 comparison



1400 August 3, 1985 (~25,800 ft³/s)



January 20, 1990 (~17,900 ft³/s)

There appears to be more sand below 25,000 ft³/s, between 25,000 and 50,000 ft³/s, and above 50,000 ft³/s line in 1985. The front boulder (red arrow) seems almost completely buried in sand in 1985.

North Canyon RM 20.85R: March and May 2008 comparison



1250 March 30, 2008 (~8,000 ft³/s)



1715 May 10, 2008 (~12,600 ft³/s)

Large sand pile was eroded by fluctuating flows at the downstream end of the bar (green ellipse). Amount of sand above 50,000 ft³/s seems same just little different distribution by wind. There is some new vegetation sprouting below May water line (green ellipse). There seems to be more sand on margin bars on river left above 25,000 ft³/s line in March.

North Canyon RM 20.85R: 1985-2008 comparison



1400 August 3, 1985 (~25,800 ft³/s)



1715 May 10, 2008 (~12,600 ft³/s)

The line of drift wood in 1985 represents flow around 45,000 – 47,000 ft³/s. Sand has been evacuated around this line in mid and downstream part of sand bar. There is no sand in the area of downstream end (green ellipse) near 2008 water line in 1985. There are some new sand deposits above May 2008 water line. Sand has been eroded away showing cobbles and boulders below the 2008 water line. Additionally, fluctuating flow has eroded a cut bank at water's edge leaving ~2 ft scarp. There appears to be more sand above 50,000 ft³/s line along the boulders in 1985. There is new vegetation on the bar and river margins on river left.

North Canyon RM 20.85R: Downstream view



1400 August 3, 1985
(~25,800 ft³/s)



Unknown

Amount of sand seems about the same, except around the left lower corner of photo (between 25,000 and 50,000 ft³/s)

Changes in Sand Bars and Vegetation

RM 20.85 R

Year	Discharge (ft ³ /s)	Area of Sand			Vegetation
		Below 25,000 ft ³ /s	25,000-50,000 ft ³ /s	Above 50,000 ft ³ /s	
August 1985	25,800 ft ³ /s				
January 1990	17,900 ft ³ /s	Less	Less	Less	Same
March 2008	8,000 ft ³ /s	Less	Less	Less	More
May 2008	12,600 ft ³ /s	Less *	Less	Less	More
Unknown	Less than 25,800 ft ³ /s	Can't tell	Little less	Same	Same

Sand and margin bars on river left

Year	Discharge (ft ³ /s)	Area of Sand			Vegetation
		Below 25,000 ft ³ /s	25,000-50,000 ft ³ /s	Above 50,000 ft ³ /s	
August 1985	25,800 ft ³ /s				
January 1990	17,900 ft ³ /s	Can't tell	Same	Same	Same
March 2008	8,000 ft ³ /s	Can't tell	More	Same	More
May 2008	12,600 ft ³ /s	Can't tell **	More	Same	More

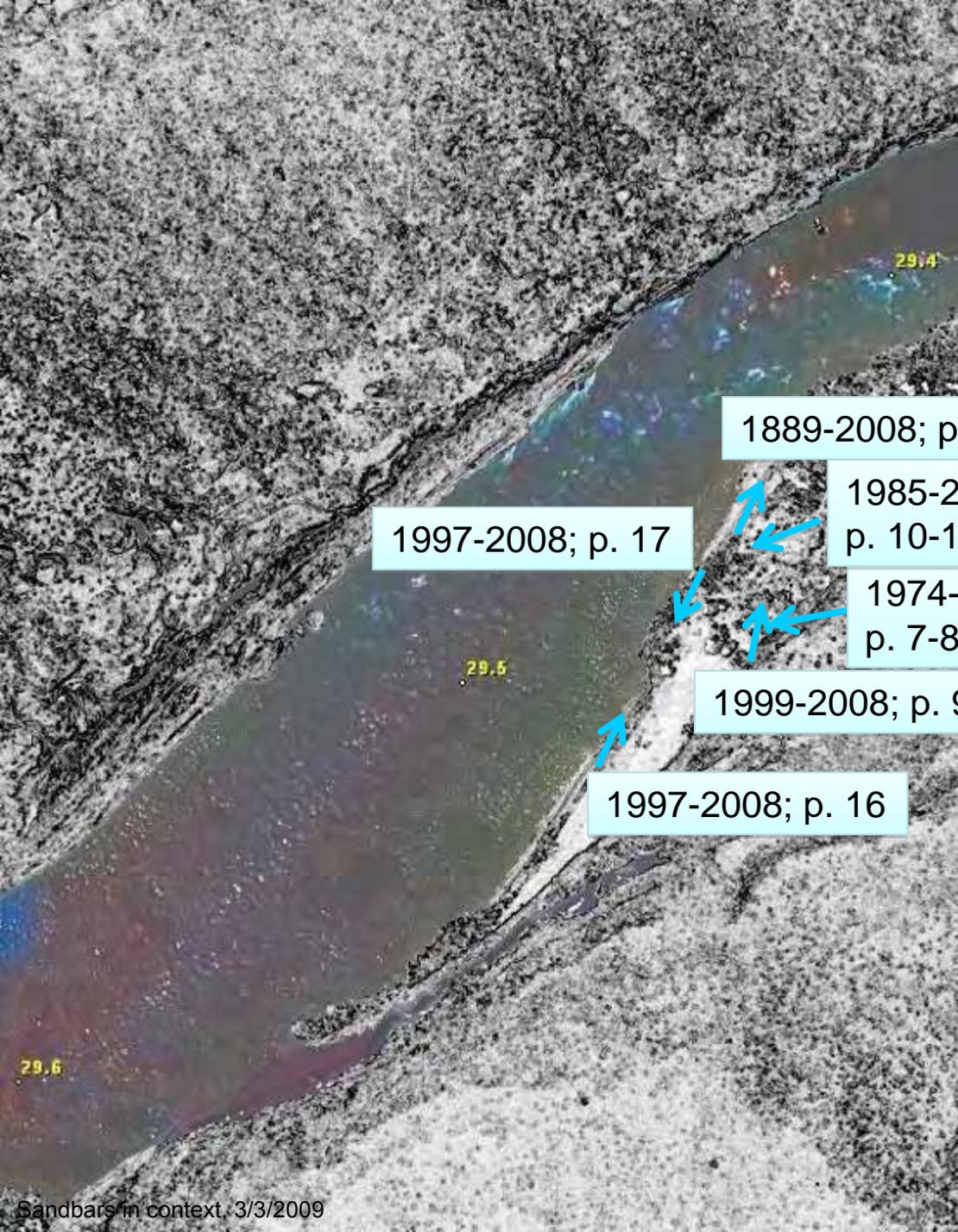
* Generally less sand but showing new deposits above 12,600 ft³/s line in May 2008

** Less sand in May than in March of 2008

Photo comparisons
Silver Grotto

29.50L separation bar

Changes in sand area and vegetation summarized on table (p. 18-19) are relative to 1985 conditions



1889-2008; p. 2-6

1985-2008;
p. 10-15

1974-1999;
p. 7-8

1999-2008; p. 9

1997-2008; p. 16

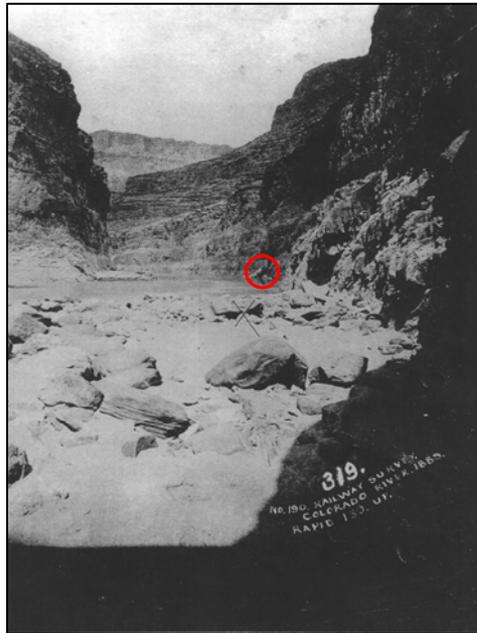
1997-2008; p. 17

29.4

29.5

29.6

Silver Grotto, Upstream View RM 29.50L: 1889-2008 comparison



July 16, 1889,
by Franklin Nims



↑ February 23, 1993
(~11,000 ft³/s)



March 28, 1999
(~11,000 ft³/s)



0900 May 14, 2008
(~13,000 ft³/s)



1974

The vegetation growth is the most significant change in about 100 years. There is new sand deposition as well. 1974 photo is included here for better illustration; although, the view is slightly different. Three more photos that fall in this period (between 1889 and 1993) are compared on the next page.

Silver Grotto, Upstream View RM 29.50L: 1889-1985-2008 comparison



1045 May 24, 1985 (~43,500 ft³/s)

1715 August 3, 1985
(~26,500 ft³/s)

1045 January 17, 1989
(~8,500 ft³/s)

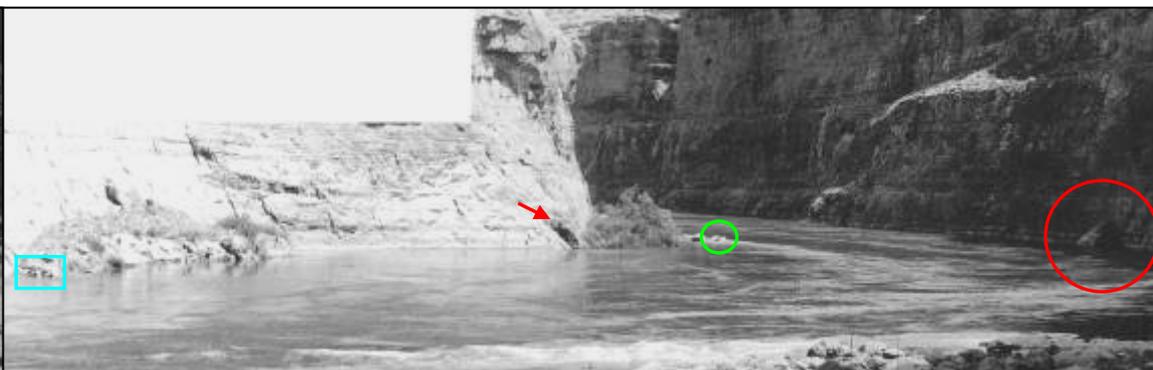
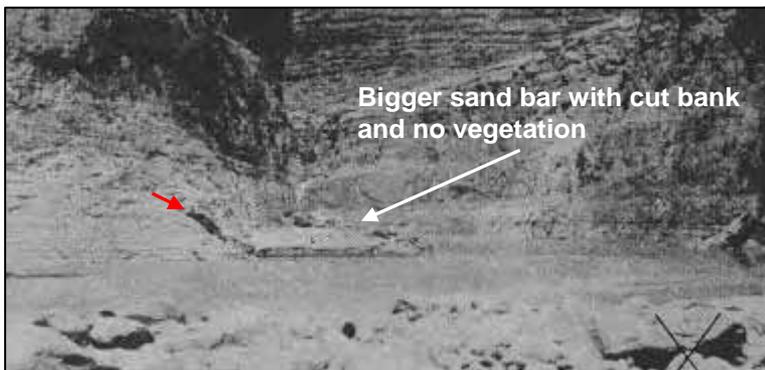
0900 May 14, 2008
(~13,000 ft³/s)



Photos are compared to 1985 year:

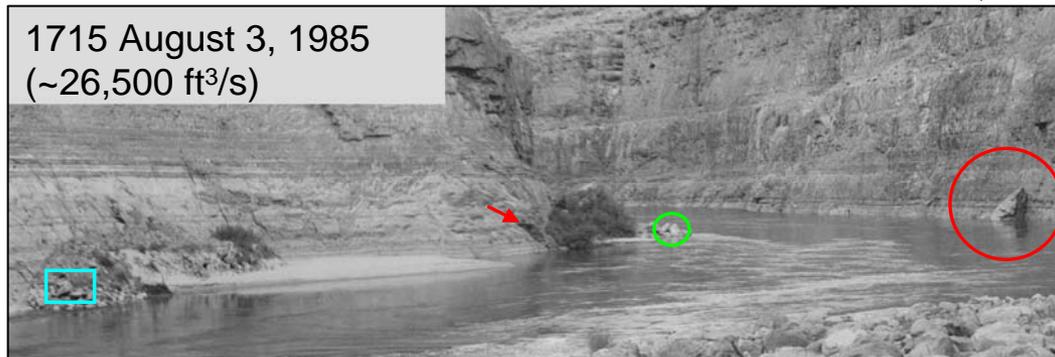
There is new vegetation growth since 1889 till 1985 and the same from 1985 to present. There seems to be more vegetation in 1974 photo (p. 2) than in 1985. Much more sand in 2008 than in 1985.

Silver Grotto RM 29.50L: Margin Bar 1974-1989 comparison



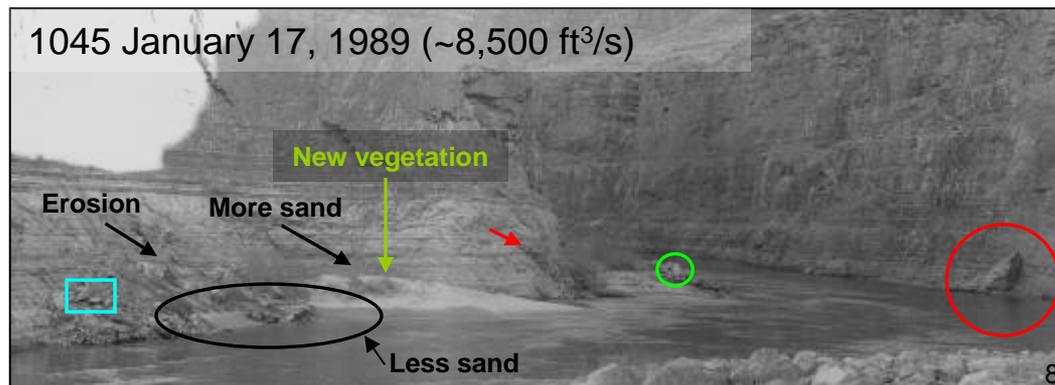
July 16, 1889, by Franklin Nims

1045 May 24, 1985 (~43,500 ft³/s)



1715 August 3, 1985
(~26,500 ft³/s)

1974



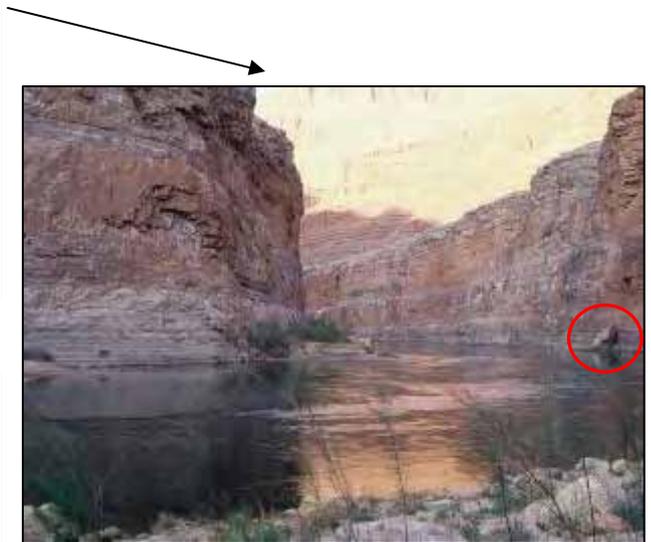
1045 January 17, 1989 (~8,500 ft³/s)

Upstream sand bar seems bigger in 1889 with sand in higher elevation. There appears to be more sand 1974 as well; although, hard to compare due to bad picture quality. When comparing 1985 and 1989 photos, there appears to be less sand on downstream end (black ellipse) and more sand on upper surface of the bar in 1989. New vegetation on the sand bar in 1989.

Silver Grotto RM 29.50L: Margin Bar 1985-1999-2008 comparison



1715 August 3, 1985 (~26,500 ft³/s)



March 28, 1999 (~11,000 ft³/s)



0900 May 14, 2008 (~13,000 ft³/s)

There appears to be new sand depositions in 2008 (black ellipses); although, the top of the bar itself seems at lower elevation. Also, bar in 1985 stretches little more downstream than in 2008. Sand around the big boulder on river right has some new deposits and vegetation in 2008. 1985 water level is marked in 2008 photo for better illustration.

Silver Grotto RM 29.50L: Margin Bar March 2008-May 2008 comparison



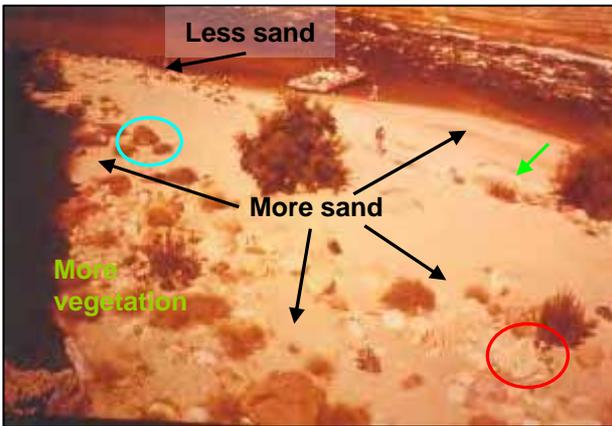
1000 March 30, 2008 (~12,700 ft³/s)

There appears to be about the same amount of sand on margin bar. Same applies to the sand around the big boulder on river left (red circle).



0900 May 14, 2008 (~13,000 ft³/s)

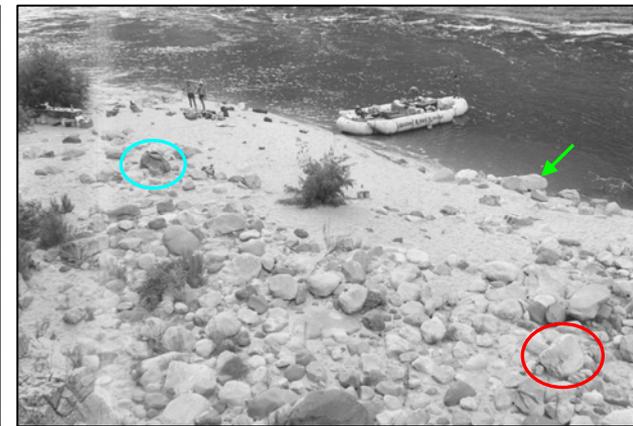
Silver Grotto RM 29.50L: 1974-1985 comparison



1974



1045 May 24, 1985 (~43,500 ft³/s)



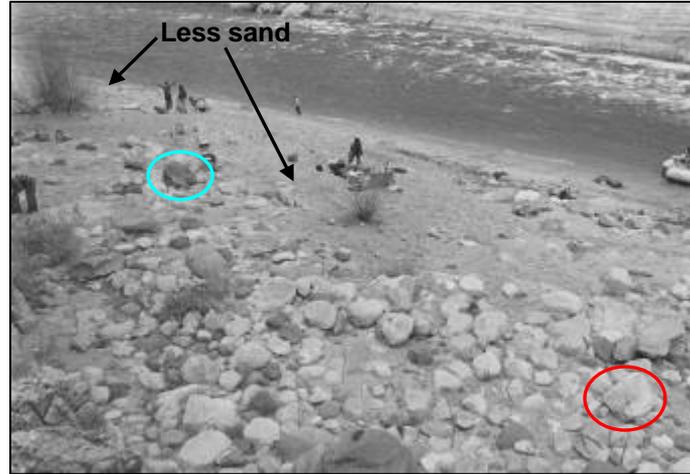
1715 August 3, 1985 (~26,500 ft³/s)

Flow from right to left. Generally, there is more sand in 1974 except the downstream end of the photo. There is more vegetation, mainly grass, in 1974 as well.

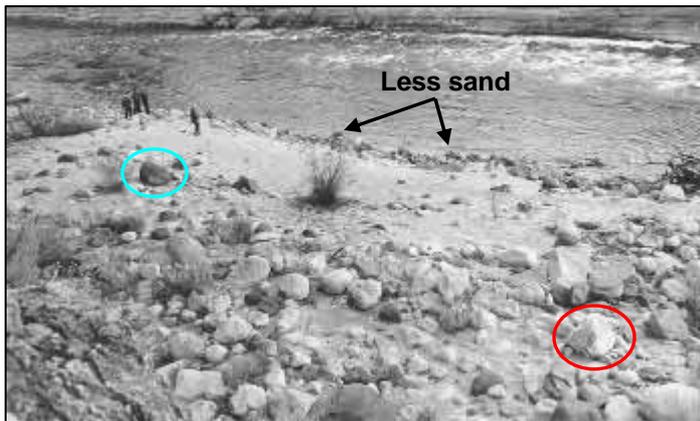
Silver Grotto RM 29.50L: 1985-1986-1989-1999 comparison



1715 August 3, 1985 (~26,500 ft³/s)



0900 January 15, 1986 (~10,900 ft³/s)



1130 January 17, 1989 (~7,600 ft³/s)



March 28, 1999 (~11,000 ft³/s)

Flow from right to left. 1986 and 1989 photos show less sand below 15,000 ft³/s and about the same amount of sand above this line. There is less sand on entire sand bar and some new vegetation growing in 1999.

Silver Grotto RM 29.50L: 1999-2008 comparison



March 28, 1999 (~11,000 ft³/s)



1000 March 30, 2008 (~9,500 ft³/s)



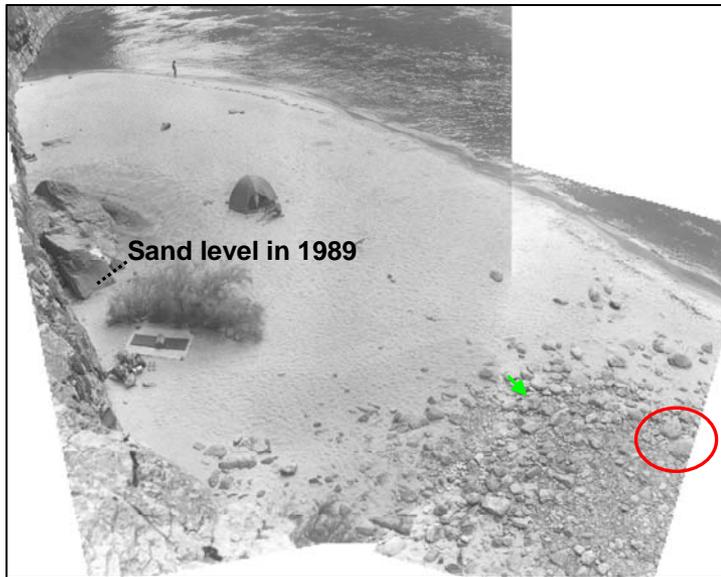
0900 May 14, 2008
(~12,700 ft³/s)

All photos are compared to May 2008:

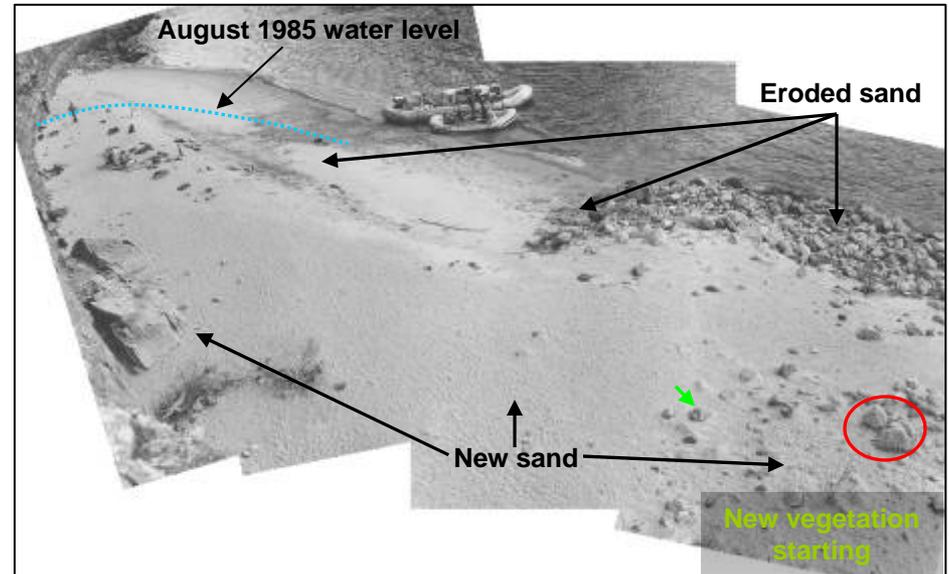
There is less sand below 20,000 ft³/s line in 1999 and in the left bottom corner of the photo. Upper surface of the bar has more sand in 1999. There is new vegetation growth after 1999. When comparing March and May 2008 photos, there is generally less sand in March. Rocks are more exposed at the waters edge in March 2008 (black ellipse).

Fluctuating flow eroded cut bank at the upstream end of the beach in May 2008.

Silver Grotto, Lower Beach RM 29.50L: 1985-1989-1999 comparison



1715 August 3, 1985 (~26,500 ft³/s)



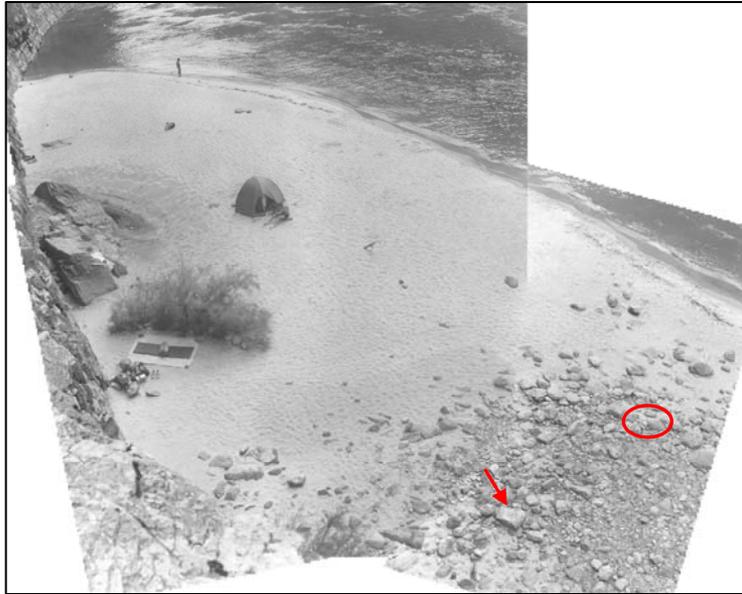
1130 January 17, 1989 (~7,600 ft³/s)



March 28, 1999 (~11,000 ft³/s)

When comparing to 1985 photo, there appears to be more sand on the upper sand bar surface with new vegetation growing in 1989 and established trees in 1999. Some grasses are spreading along the wall as well. Lower surface was eroded between 1985 and 1989, and some new sand was deposited around 25,000 ft³/s line after 1989 which is visible in 1999 photo. The far downstream end has less sand in 1999.

Silver Grotto, Lower Beach RM 29.50L: 1999-2008 comparison



1715 August 3, 1985 (~26,500 ft³/s)



1000 March 30, 2008 (~9,500 ft³/s)

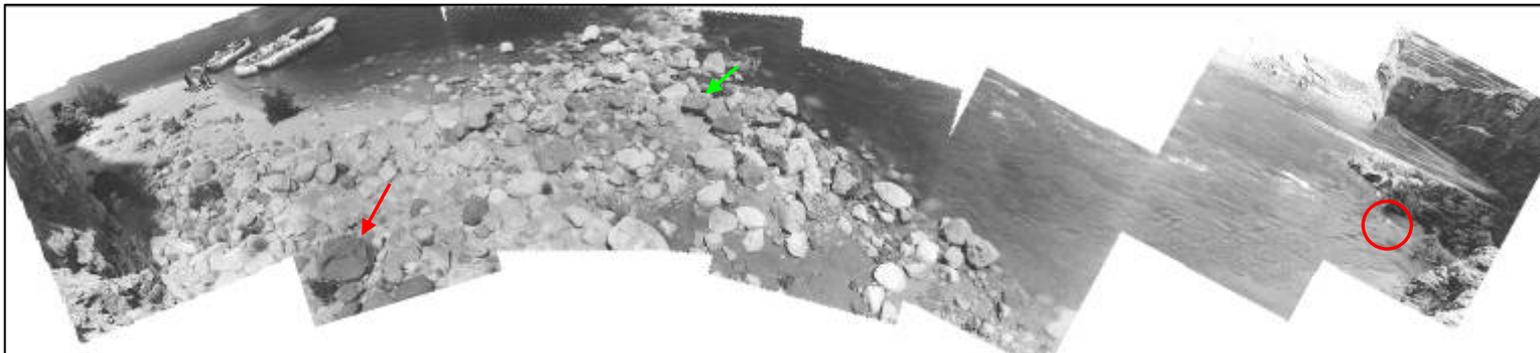


0900 May 14, 2008 (~12,700 ft³/s)

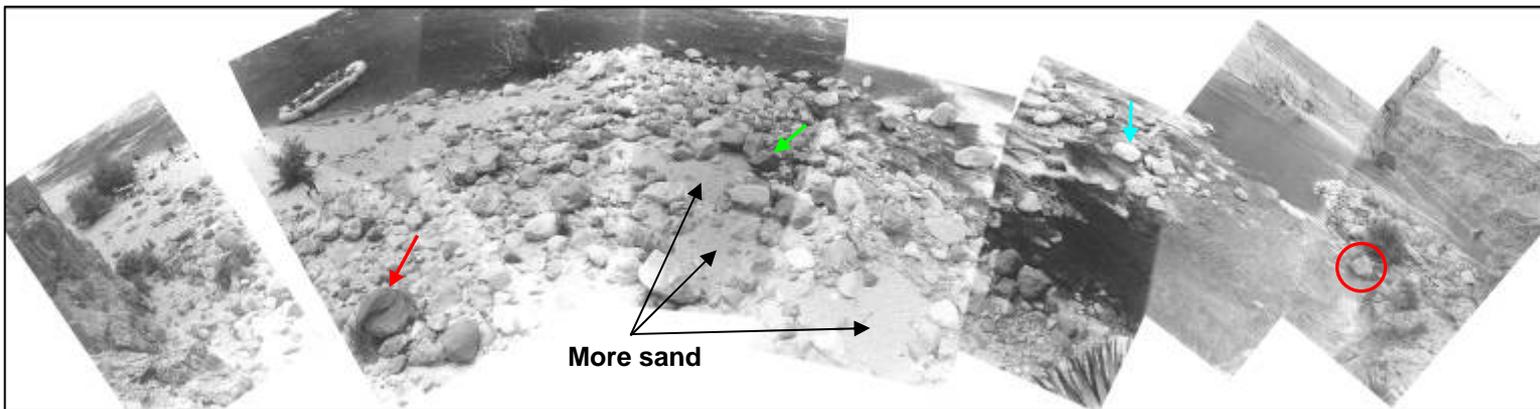
There appears to be new sand deposition on entire sand bar. Sand bar is higher in elevation. The far downstream end of the bar has sand deposition in higher elevation as well, with some new vegetation (white circle). Overall, there is more established trees in 2008. The tree existing in 1999 (p. 10) died. Vegetation visible along the wall in 1999 is gone as well.

When comparing March and May 2008, the sand was eroded little bit below 15,000 ft³/s, which can be seen at the far downstream end (white circle) and behind the trees at the waters edge (see boulders) in May. The upper surface was leveled probably by wind.

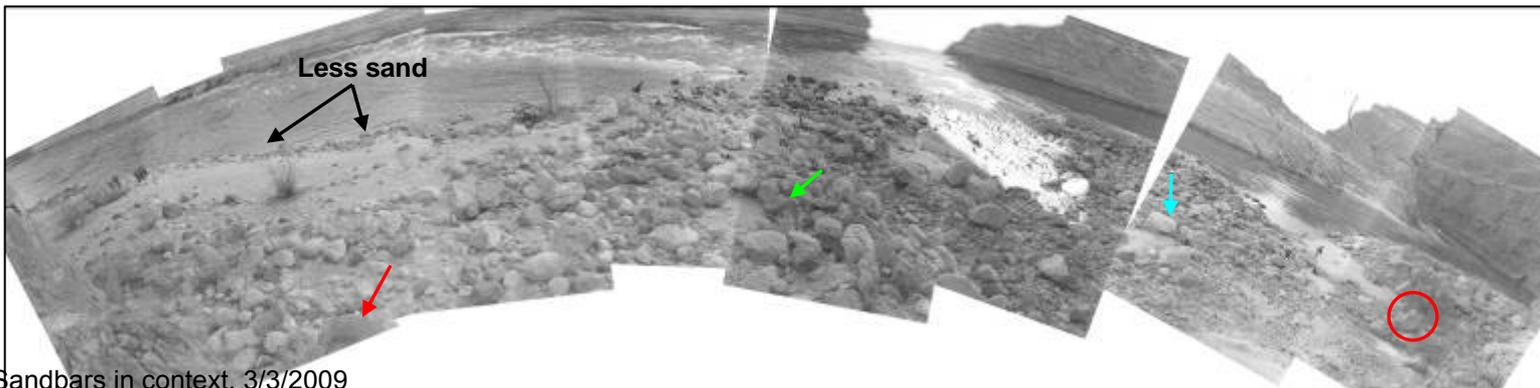
Silver Grotto, RM 29.5L: 1985-1989 comparison



1045 May 24, 1985
(~43,500 ft³/s)

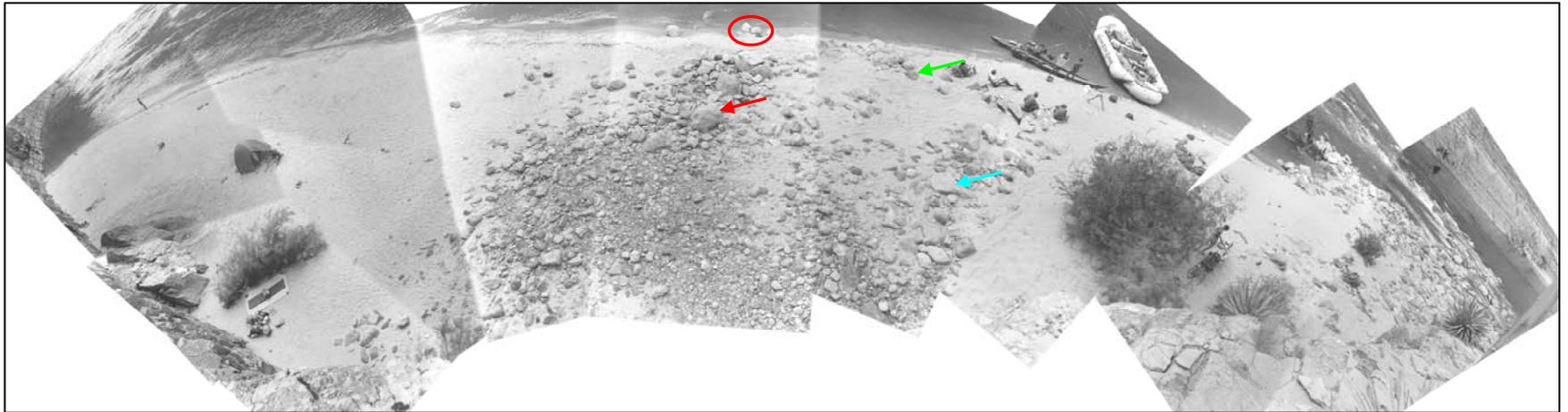


1715 August 3,
1985 (~26,500 ft³/s)

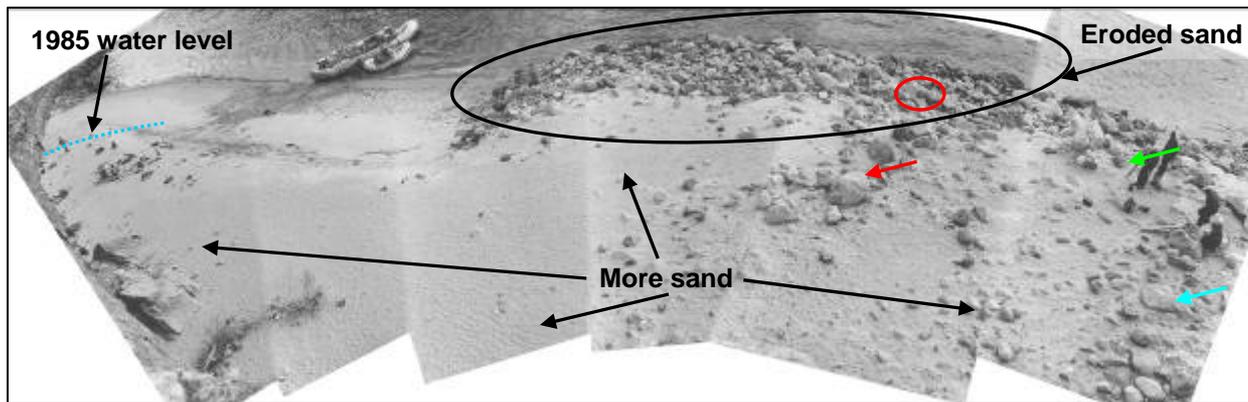


1045 January 17,
1989 (~8,500 ft³/s)

Silver Grotto, RM 29.5L: 1985-1989 comparison



1715 August 3, 1985 (~26,500 ft³/s)



1045 January 17, 1989 (~8,500 ft³/s)

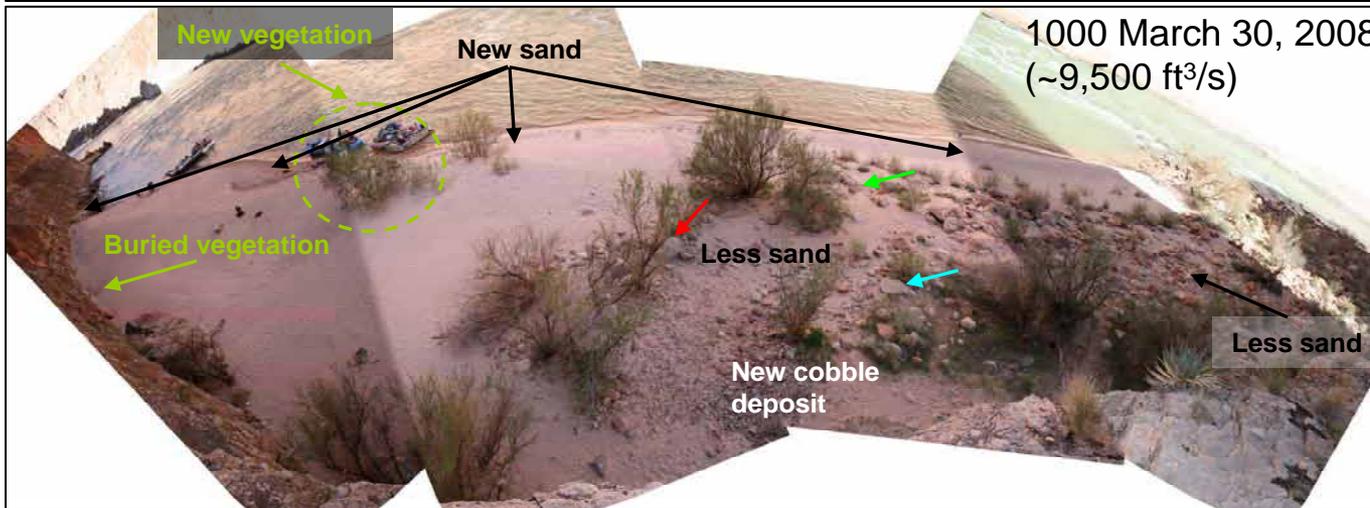
There appears to be more sand on the upper sand bar surface in 1989. Lower surface was eroded between 1985 and 1989 (black ellipse). Compare cluster of boulders (red ellipse) on both photos for better illustration.

Silver Grotto, RM 29.5L: 1999-2008 comparison



March 28, 1999
(~11,000 ft³/s)

There appears to be new sand deposition on entire sand bar. Sand bar is higher in elevation. The far downstream end of the bar has sand deposition in higher elevation as well, with some new vegetation. Upper surface of the upstream end of the bar has more sand in 1999. Overall, there is more established trees in 2008. The tree growing by the wall in 1999 died. Vegetation visible along the wall in 1999 is gone as well.

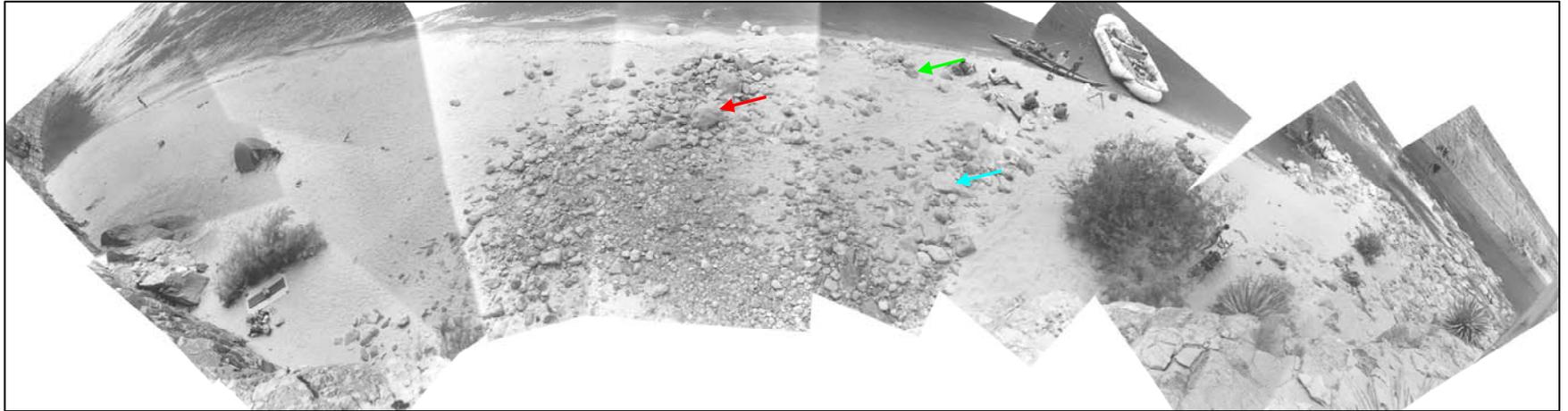


1000 March 30, 2008
(~9,500 ft³/s)

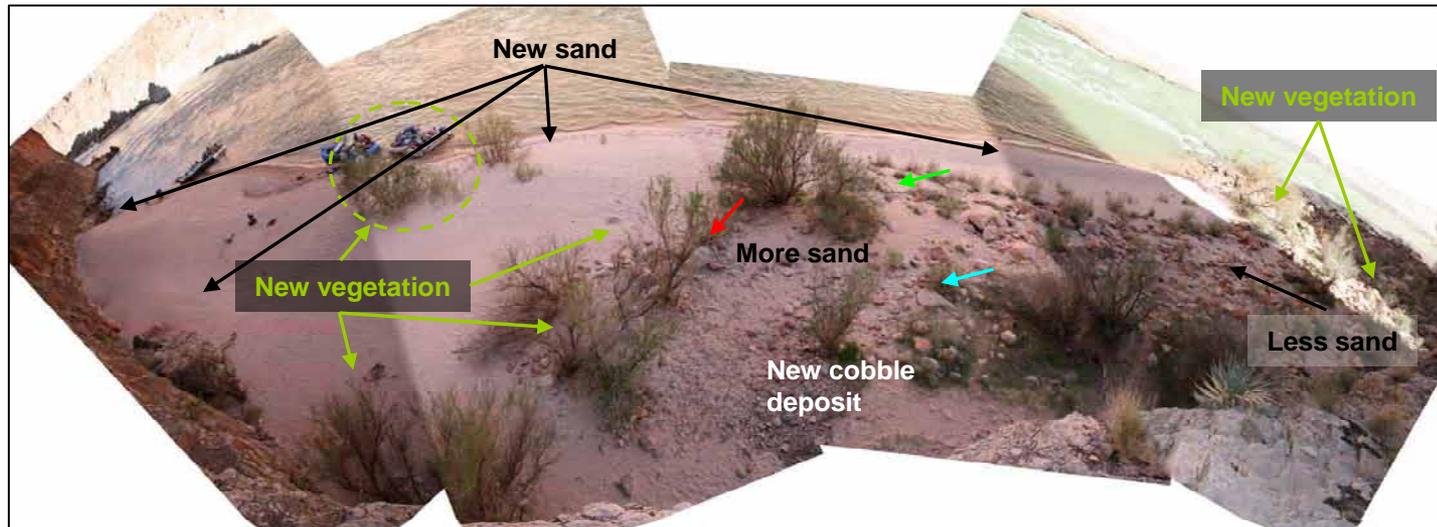


0900 May 14, 2008
(~12,700 ft³/s)

Silver Grotto, RM 29.5L: 1985-2008 comparison



1715 August 3, 1985 (~26,500 ft³/s)

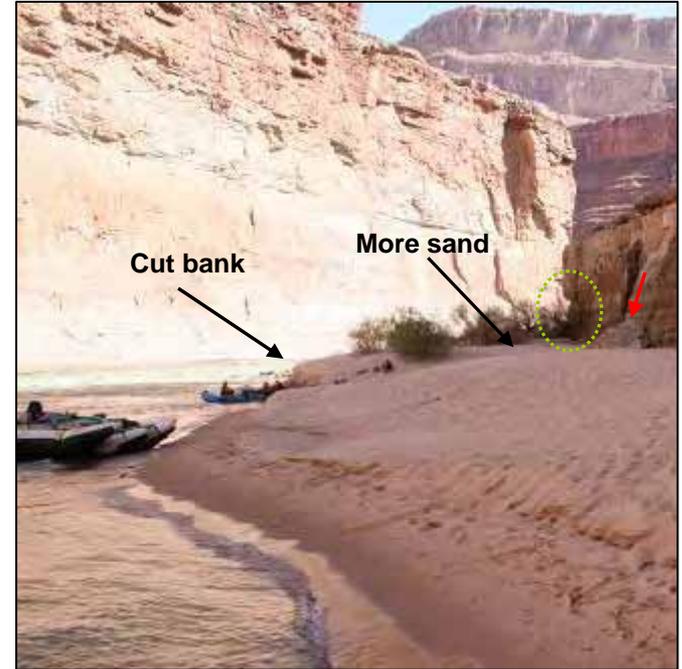


1000 March 30, 2008 (~9,500 ft³/s)

Silver Grotto, Looking upstream, RM 29.5L: 1997-2008 comparison



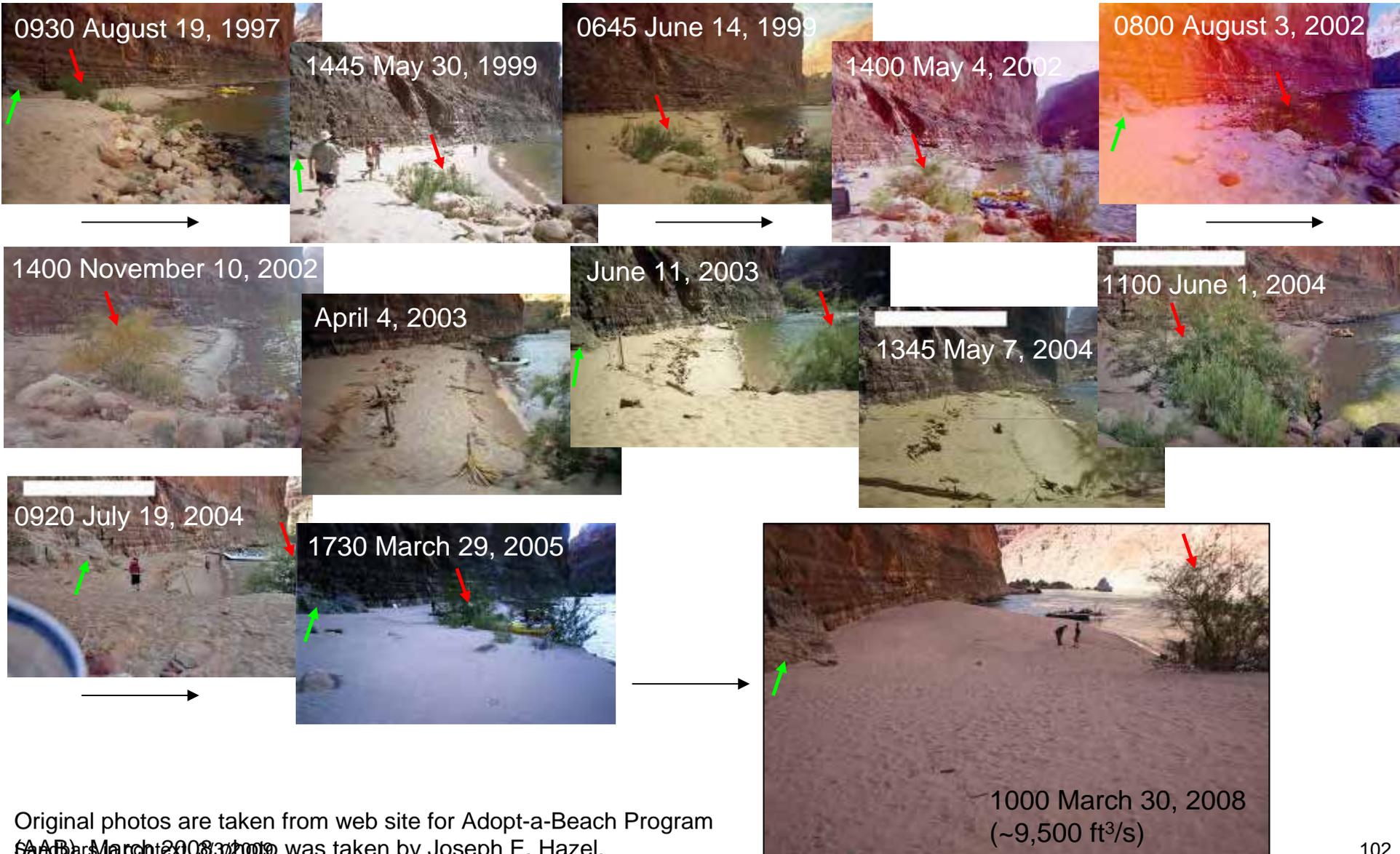
February 1997



1000 March 30, 2008 (~9,500 ft³/s)

There appears to be more sand on the upper surface of the bar in 2008. Some new vegetation growing in 2008 as well. Cut bank caused by fluctuating flow is visible (behind the blue boat) in 2008 photo.

Silver Grotto, RM 29.5L: Adopt a Beach Program and 2008 comparison



Original photos are taken from web site for Adopt-a-Beach Program (AAB) March 2008 photo was taken by Joseph E. Hazel.

Changes in Sand Bars and Vegetation

RM 29.50 R

Year	Discharge (ft ³ /s)	Area of Sand			Vegetation
		Below 25,000 ft ³ /s	25,000-50,000 ft ³ /s	Above 50,000 ft ³ /s	
July 1889	-	Can't tell	Less	Less	Less
1974	-	Can't tell	More	More	More
May 1985	43,500 ft ³ /s	Can't tell	More	More	Same
August 1985	26,500 ft ³ /s				
January 1986	8,500 ft ³ /s	Can't tell	Less	Same	Same
January 1989	8,500 ft ³ /s	Less	Less	Same	Same
February 1993	11,000 ft ³ /s	Can't tell	Less	Less	More
February 1997	-	Can't tell	Less	Less	Can't tell
March 1999	11,000 ft ³ /s	Can't tell	Less	Less	More
March 2008	9,500 ft ³ /s	Can't tell	More	More	More
May 2008	12,700 ft ³ /s	Can't tell	More	More	More

Changes in Sand Bars and Vegetation

Sand and margin bars on river right

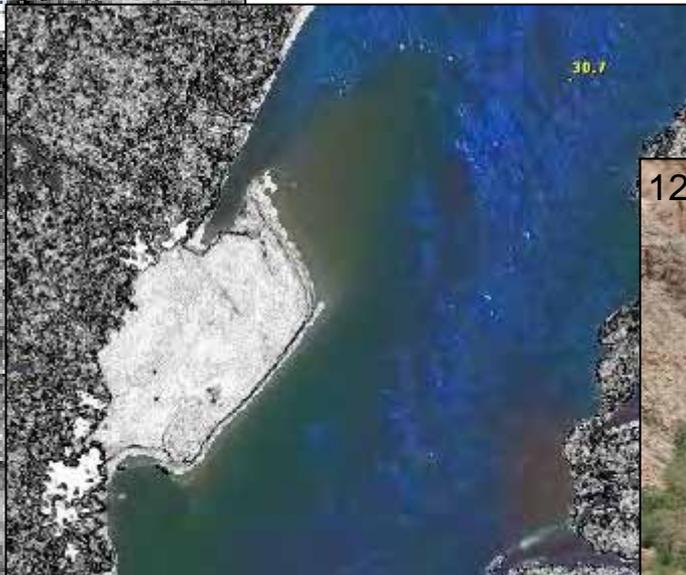
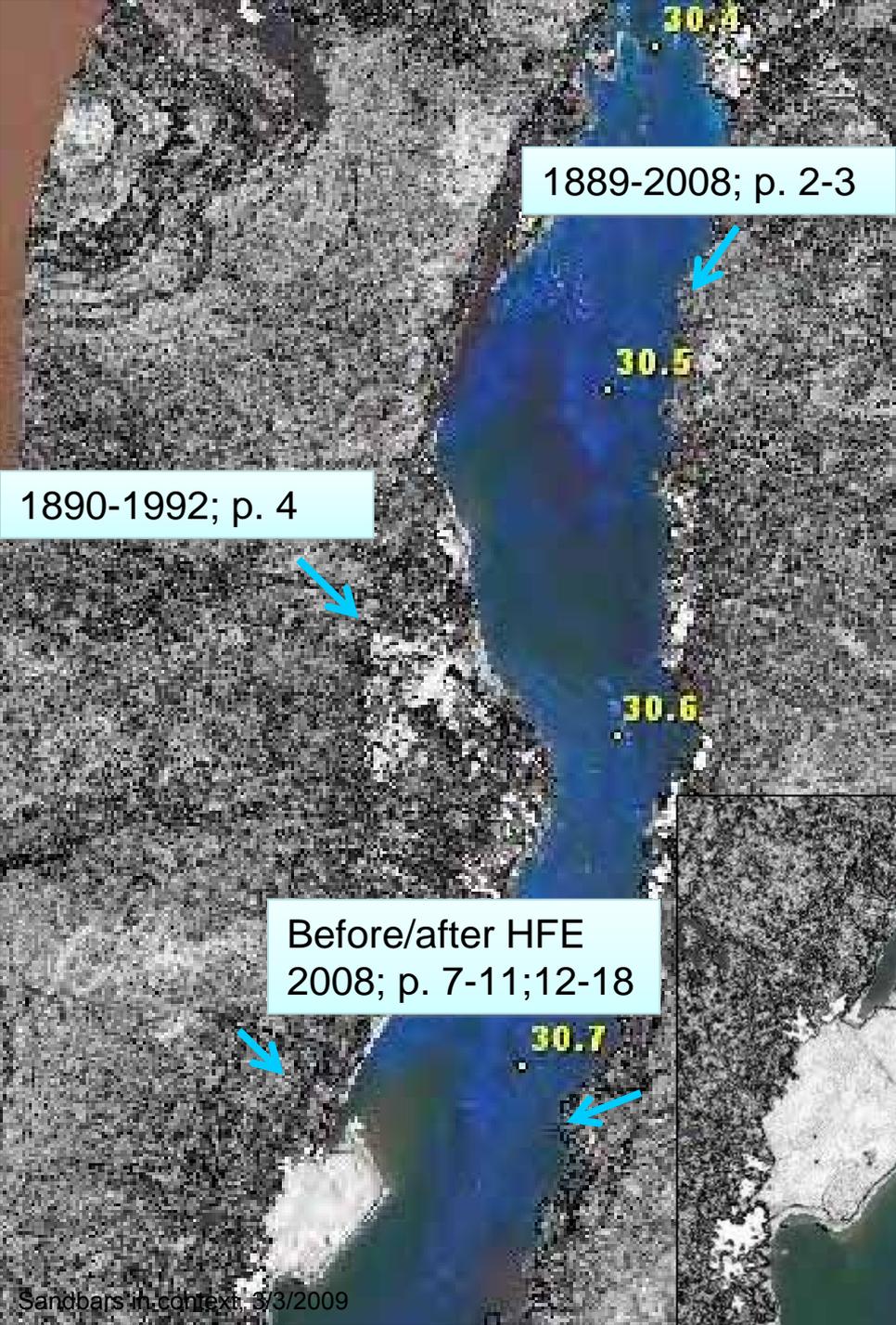
Year	Discharge (ft ³ /s)	Area of Sand			Vegetation
		Below 25,000 ft ³ /s	25,000-50,000 ft ³ /s	Above 50,000 ft ³ /s	
July 1889	-	Can't tell	More	More	Less
1974	-	Can't tell	More	More	Same
August 1985	26,500 ft ³ /s				
January 1989	8,500 ft ³ /s	Can't tell	Less	More	More
May 2008	12,700 ft ³ /s	Can't tell	Less *	Less *	More

* Bar itself has less sand and is in lower elevation, but there new sand deposits at the upstream and downstream end of the original bar

Photo comparisons
RM 30.55 and 30.75

30.55R separation bar
30.75R reattachment bar

Changes in sand area and
vegetation for RM 30.55 and
30.75 summarized on table (p.
19) are relative to after HFE 2008
conditions



1215 May 12, 2008 (~10,200 ft³/s)

RM 30.55R: Looking downstream from RL at the bar 1889-1992-2008 comparison



July 16, 1889



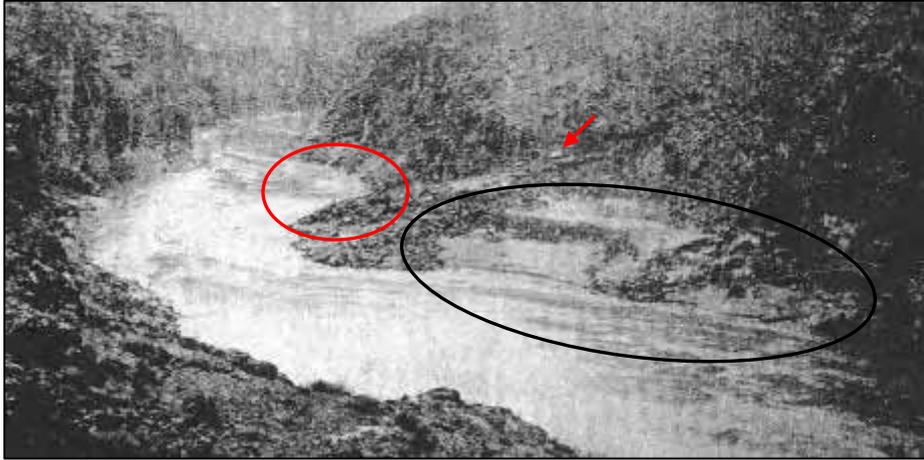
January 2,
1992 (~daily
max 15,900
ft³/s; min
9,900 ft³/s;
mean 13,100
ft³/s); photo
by Robert H.
Webb



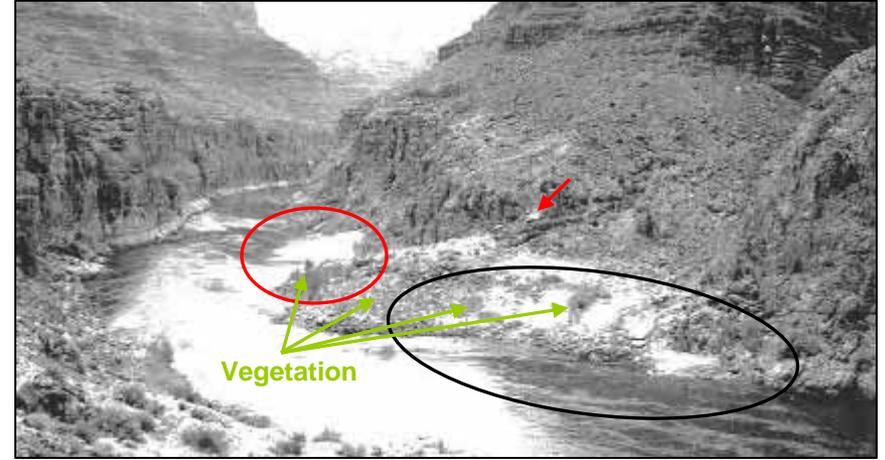
1615 March 11, 2008 (~ 10,600 ft³/s)

Detail photos continue on the next page

RM 30.55R: 1889-1992-2008 comparison



July 16, 1889



January 2, 1992 (~daily max 15,900 ft³/s; min 9,900 ft³/s; mean 13,100 ft³/s); photo by Robert H. Webb



1615 March 11, 2008 (~ 10,600 ft³/s)

There seems to be less sand in 1992 than in 1889 on the main beach itself. The new vegetation is starting to be visible. There is a small reattachment bar visible on 1992 photo (red ellipse); although, flow is smaller so it is hard to compare the existence of this bar.

There is new sand on the main beach in 2008. It seems that sand is in higher elevation, now being eroded and forming cut bank (downstream end of black ellipse). New vegetation, with more established trees, is growing on the entire site. Downstream reattachment bar looks bigger in 2008.

RM 30.55R: 1890-1992 comparison



January 14, 1890



January 2, 1992; photo by Steve Tharnstrom
(Stake 2525a-1992)

Reattachment Bar at RM 30.75R: 2004-2005



November 26, 2004 (~8,000 ft³/s)



January 3, 2005 (~6,000-10,000 ft³/s)



December 4, 2004 (~8,000 ft³/s)



March 9, 2005
(~6,000-10,000
ft³/s)



Reattachment Bar at RM 30.75R: Before and during HFE



1244 March 4,
2008
(~8,200 ft³/s)



1242
March 5,
2008
(~23,200
ft³/s)

1241 March 6,
2008
(~42,500 ft³/s)



1240
March 7,
2008
(~42,700
ft³/s)

Reattachment Bar at RM 30.75R:

View from river left During and after HFE



1238 March 8,
2008
(~42,700 ft³/s)



1237
March 9,
2008
(~21,800
ft³/s)



1238 March 10,
2008
(~8,200 ft³/s)



1235
March 11,
2008
(~8,300
ft³/s)

Reattachment Bar at RM 30.75R: View from river left After HFE



Wind erosion

1228 March 18,
2008
(~8,500 ft³/s)



Cut bank

1146
April 22,
2008
(~10,500
ft³/s)



1133 May 3,
2008
(~10,400 ft³/s)



1124
May 12,
2008
(~10,500
ft³/s)

Reattachment Bar at RM 30.75R: View from river left After HFE



1100 June 3,
2008
(~11,400 ft³/s)



1059
June 4,
2008
(~11,200
ft³/s)



1053 June 10,
2008
(~11,300 ft³/s)



1046
June 16,
2008
(~11,400
ft³/s)

Reattachment Bar at RM 30.75R: View from river left Before and after HFE 2008

Before HFE:



1244 March 4, 2008 (~8,200 ft³/s)

After HFE:



1235 March 11, 2008 (~8,300 ft³/s)

3 months after HFE:



1046 June 16, 2008 (~11,400 ft³/s)

Lines in June 2008 photo represent the size of the sand bar before and right after the HFE. Red dotted line represents conditions before HFE and black dashed line represents conditions right after HFE. Lines are following the water level line - ~8,300 ft³/s for both days.

Reattachment Bar at RM 30.75R: View from river left 2005 and before-after HFE 2008



March 9, 2005 (~6,000-10,000 ft³/s)



1244 March 4, 2008 (~8,200 ft³/s)



1235 March 11, 2008 (~8,300 ft³/s)



1046 June 16, 2008 (~11,400 ft³/s)

Photos are compared to June 2008 photo.

Sand bar looks bigger and higher in elevation in 2005. Sand bar was re-built during 2008 HFE but portion of it was eroded by fluctuating flow later in 2008. Vegetation is about the same for both years.

Reattachment Bar at RM 30.75R:

View from river right Before and during HFE



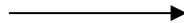
1428 February
4, 2008
(~9,500 ft³/s)



1356
March 4,
2008
(~8,400
ft³/s)



1156 March 5,
2008
(~22,100 ft³/s)



1155
March 6,
2008
(~42,600
ft³/s)

Reattachment Bar at RM 30.75R:

View from river right During and after HFE



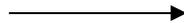
1155 March 7,
2008
(~42,800 ft³/s)



1155
March 9,
2008
(~22,800
ft³/s)



1155 March 10,
2008
(~8,400 ft³/s)



1155
March 11,
2008
(~8,400
ft³/s)

Reattachment Bar at RM 30.75R: View from river right After HFE



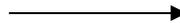
1155 March 18,
2008
(~8,600 ft³/s)



1156
April 22,
2008
(~10,500
ft³/s)



1155 May 3,
2008
(~10,200 ft³/s)



1155
May 12,
2008
(~10,300
ft³/s)

Reattachment Bar at RM 30.75R: View from river right After HFE



1154 June 3,
2008
(~11,100 ft³/s)



0754
June 4,
2008
(~13,500
ft³/s)



1153 June 10,
2008
(~11,000 ft³/s)



0953
June 16,
2008
(~11,800
ft³/s)

Reattachment Bar at RM 30.75R: View from river right After HFE



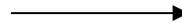
1552 June 30,
2008
(~12,500 ft³/s)



1552 July
8, 2008
(~22,800
ft³/s)



1752 July 15,
2008
(~13,900 ft³/s)



1551 July
27, 2008
(~11,400
ft³/s)

Reattachment Bar at RM 30.75R: View from river right After HFE



0751 August 7,
2008
(~16,900 ft³/s)



1350
August
13, 2008
(~11,000
ft³/s)



0750 August
20, 2008
(~16,600 ft³/s)



1350
August
22, 2008
(~11,700
ft³/s)



Reattachment Bar at RM 30.75R: View from river right Before and after HFE 2008

Before HFE:



1428 February 4, 2008 (~9,500 ft³/s)

After HFE:



1155 March 11, 2008 (~8,400 ft³/s)

5 months after HFE:



1350 August 22, 2008 (~11,700 ft³/s)

Lines in August 2008 photo represent the size of the sand bar before and right after the HFE. Red dotted line represents conditions before HFE and black dashed line represents conditions right after HFE. Lines are following the water level line - ~8,400-9,500 ft³/s for both days.

Changes in Sand Bars and Vegetation

RM 30.55 R

Year	Discharge (ft ³ /s)	Area of Sand			Vegetation
		Below 25,000 ft ³ /s	25,000-50,000 ft ³ /s	Above 50,000 ft ³ /s	
July 1889	-	Less	Less	Same	Less
January 1890	-	Can't tell	Can't tell	Can't tell	Less
January 1992	13,100 ft ³ /s (mean)	Less	Less	Same	Same
March 2008	10,600 ft ³ /s				

RM 30.75 R

Year	Discharge (ft ³ /s)	Area of Sand			Vegetation
		Below 25,000 ft ³ /s	25,000-50,000 ft ³ /s	Above 50,000 ft ³ /s *	
November 2004	8,000 ft ³ /s	More	More	-	Same
December 2004	8,000 ft ³ /s	More	More	-	Same
January 2005	6,000-10,000 ft ³ /s	More	More	-	Same
March 2005	6,000-10,000 ft ³ /s	More	More	-	Same
Before HFE 2008 (March)	8,200 ft ³ /s	More	More	-	Same
Right after HFE 2008 (March)	8,300 ft ³ /s	More (a lot more)	More	-	Same
Later after HFE 2008	11,400-11,700 ft ³ /s				

* Entire sand bar is under water around 45,000 ft³/s

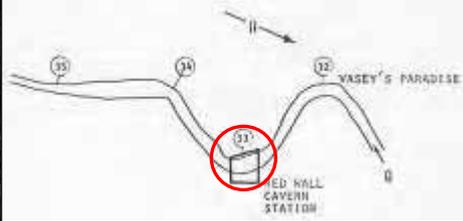


Photo comparisons
RM 33.30L

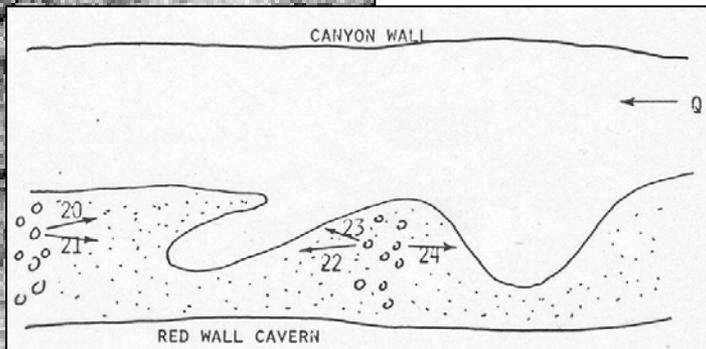
33.30L

Changes in sand area and vegetation for RM 33.30L summarized on table (p. 9) are relative to 1999 conditions

Redwall Cavern Area

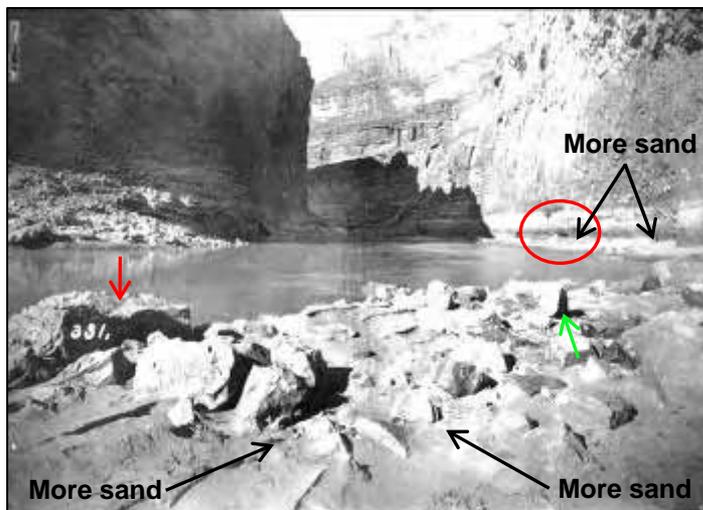
Sketch from
E. M. Laursen and
E. Silverston,
December 1976

1500 October 13, 2008
(~12,400 ft³/s)



Redwall Cavern RM 33.30L

Upstream view from the site



January 15, 1890; Stanton expedition



January 3, 1992; Robert H. Webb (~daily max
↓ 16,000 ft³/s, min 10,000 ft³/s, mean 13,400 ft³/s)

There is more sand in 1890 than 1999 (~0.5 ft). Sand on upper terrace between boulders has presence of ripples. There is more sand in far background as well. Amount of sand is about the same for 1992 and 1999 photos. There is less vegetation in 1890 and 1992 than in 1999.

March 30, 1999 (~daily max 16,000 ft³/s,
min 10,300 ft³/s, mean 13,600 ft³/s)



Redwall Cavern RM 33.30L



July 14, 1951 (~daily
mean 20,400 ft³/s);
Tad Nichols



August 1992



Unknown year

<http://freelargephotos.com/?fetch=000040.xml&title=View%20upstream%20from%20Redwall%20Cavern%20in%20Marble%20Gorge>.

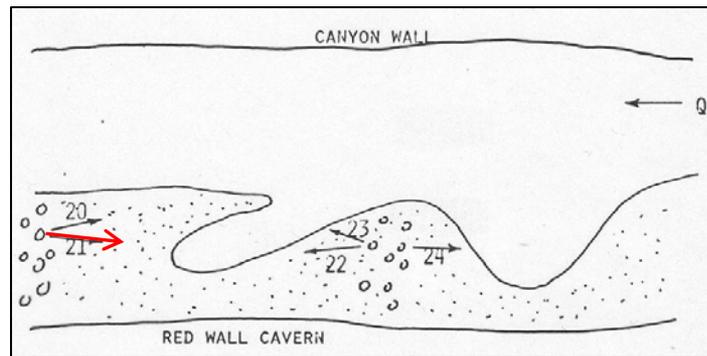
Redwall Cavern RM 33.30L



August 6, 1976; E. M. Laursen (~daily mean 8,500 ft³/s)



March 30, 1999
 (~daily max
 16,000 ft³/s,
 min 10,300 ft³/s,
 mean 13,600 ft³/s)



Sketch from E. M. Laursen and
 E. Silverston, December 1976

Redwall Cavern RM 33.30L



August 8, 1923; E. C. LaRue (~daily mean 19,000 ft³/s)

The 1923 photo shows less sand at higher elevation than the 1911 photo. Rocks at both the downstream and upstream ends of the bar are exposed about the same amount in the 1923 photo as they were in 1999. The thickness of low-elevation sand has been more variable. There was between 0.6 and 1.5 m more in 1923 than in 1999.



March 30, 1999 (~daily max 16,000 ft³/s, min 10,300 ft³/s, mean 13,600 ft³/s)



November 13, 1911; Kolb

Redwall Cavern RM 33.30L



July 1951; Tad Nichols



September 10, 1994; Robert H. Webb
 (~daily max 12,600 ft³/s,
 min 8,100 ft³/s, mean 10,000 ft³/s)



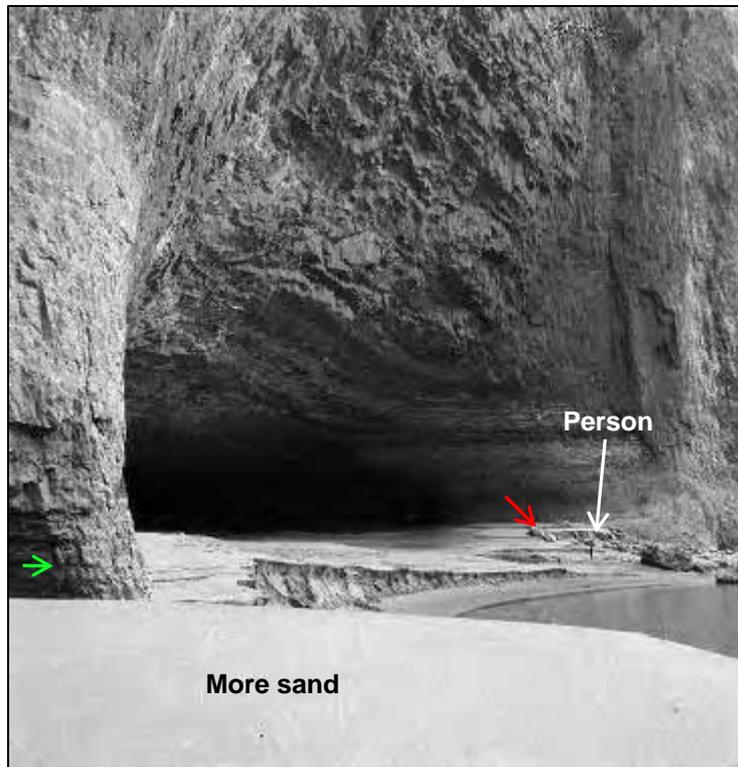
March 30, 1999 (~daily max 16,000
 ft³/s, min 10,300 ft³/s, mean 13,600 ft³/s)



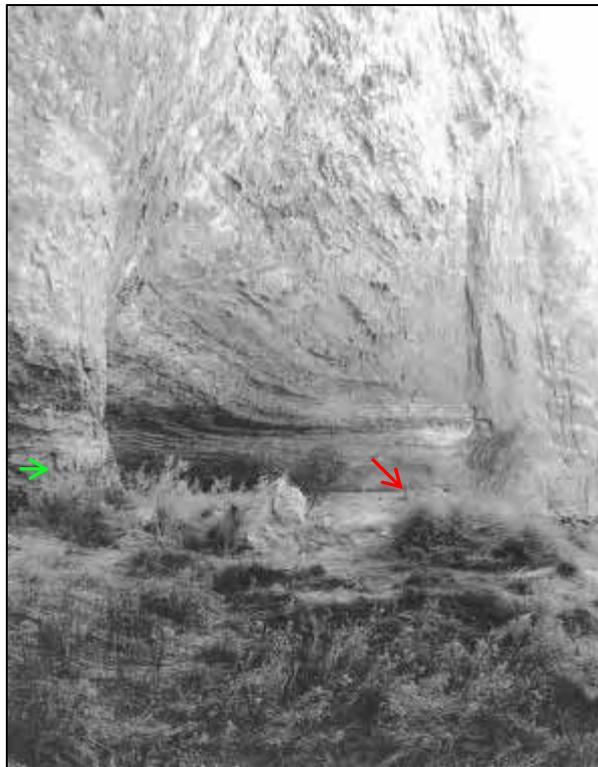
Unknown year

There is slightly less sand in higher elevation in 1951 than 1999. Sand slopes more gently towards the river in 1951. There is less vegetation in 1951 than in 1994 but about the same as for 1999. When comparing 1994 and 1999, there is more high elevation sand and more vegetation in 1994. Sand slopes more gently towards the river in 1994. Amount of low elevated sand is about the same for both years with little bit more sand in the green ellipse.

Redwall Cavern RM 33.30L



November 13, 1911;
Ellsworth and Emery Kolb



→ February 23, 1995
(~daily max 14,100 ft³/s,
min 11,100 ft³/s, mean 12,700 ft³/s)



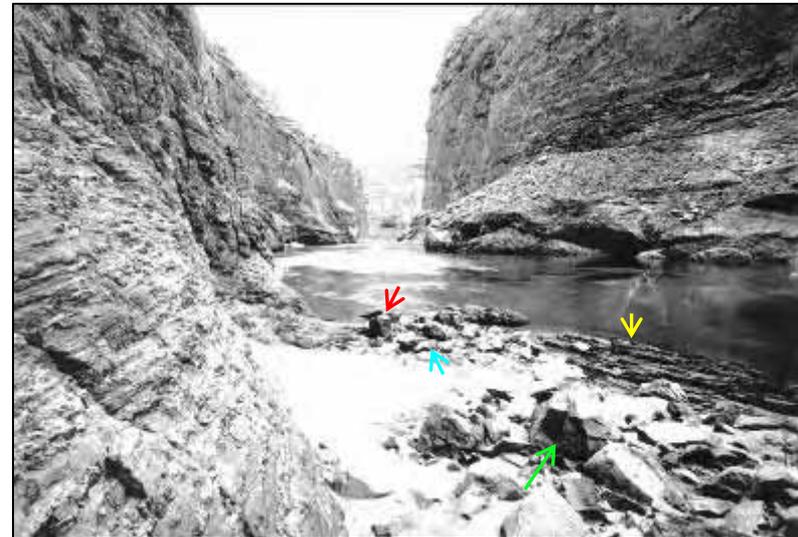
→ March 30, 1999
(~daily max 16,000 ft³/s,
min 10,300 ft³/s,
mean 13,600 ft³/s)

There is sand covering rocks in 1911 photo at the higher elevation parts of the bar. These rocks are exposed (~0.5m above the surface of the sand bar) in 1995 and 1999 photos. Vegetation growth occurred after 1911 and became more established by 1999.

Below Redwall Cavern RM 33.50L Downstream view from the site



January 15, 1890; Stanton expedition



January 3, 1992; Robert H. Webb (~daily max 16,000 ft³/s, min 10,000 ft³/s, mean 13,400 ft³/s)



March 30, 1999 (~daily max 16,000 ft³/s, min 10,300 ft³/s, mean 13,600 ft³/s)

Changes in Sand Bars and Vegetation

RM 33.30L

Year	Discharge (ft ³ /s)	Area of Sand			Vegetation
		Below 25,000 ft ³ /s	25,000-50,000 ft ³ /s	Above 50,000 ft ³ /s	
January 1890	-	More	More	More	Less
November 1911	-	More	More	More	Less
August 1923	19,000 ft ³ /s (daily mean)	More	Same	Same	Can't tell
July 1951	20,400 ft ³ /s (daily mean)	Same	Less	Less	Same
August 1976	8,500 ft ³ /s (daily mean)	More	More	More	Same
January 1992	13,400 ft ³ /s (daily mean)	Same	Same	Can't tell	Less
August 1992	-	Can't tell	Can't tell	Can't tell	Can't tell
September 1994	10,000 ft ³ /s (daily mean)	More	More	More	More
February 1995	12,700 ft ³ /s (daily mean)	Can't tell	Can't tell	Can't tell	Same
March 1999	13,600 ft ³ /s				

In summary, the elevation of sand on the upper parts of the bar has decreased by up to 0.5 m since 1911. Presence of high-elevation sand in 1976 indicates most of this erosion probably occurred between 1976 and 1994. The thickness of low-elevation sand has been more variable. There was between 0.6 and 1.5 m more in 1923 than in 1999. But in 1951 the level of low-elevation sand was about the same as in 1999, indicating pre-dam variability in this deposit. In 1976 there was at least 1.0 m more low-elevation sand than in 1999, indicating post-dam deposition at low-elevations. Post-dam erosion is indicated by the presence of between 0.2 and 0.7 m more sand in 1994 than in 1999.

Wind ripples and dunes were present in some of the old photos and have been observed in the field at Redwall Cavern. It is possible that some or much of the variation in bar elevation is due to eolian processes in addition to fluvial processes.