

**Glen Canyon Dam Adaptive Management Work Group**  
**Agenda Item Information**  
**February 25-26, 2015**

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Agenda Item

Updates from the 2015 Glen Canyon Dam Adaptive Management Program Technical Work Group Annual Reporting Meeting

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Action Requested

Information item only

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Presenters

Scott VanderKooi, Acting Chief, Grand Canyon Monitoring and Research Center  
Paul Grams, Research Hydrologist, Grand Canyon Monitoring and Research Center

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Previous Action Taken

N/A

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Relevant Science

N/A

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Background Information

The January 2015 Annual Reporting meeting was conducted under the auspices of a Technical Work Group meeting. The two-day meeting included presentations by GCMRC staff, cooperators and collaborators, staff of sister federal agencies, and Tribal representatives. Speakers presented summaries of findings from work conducted as part of the FY2013-14 GCDAMP budget and workplan and discussed insights of management significance. Some of the latter are summarized below.

Each of the high flows implemented under the high-flow protocol since July 2012 has resulted in sandbar deposition in Marble and Grand Canyons. Although sandbars have also eroded following each high-flow, the long-term monitoring sites were larger 10 months following each of the high flows than at any other time between 2009 and 2012. Because Paria River sand inputs have been relatively large and annual release volumes from Lake Powell relatively low, there has been maintenance or accumulation of sand in all segments of Marble and Grand Canyons since July 2012.

Project J of the FY2013-14 biennial workplan examined effects of dam operations on cultural sites in Glen and Grand canyons. One key finding is that gully development and the risk of gully erosion can exceed what would occur without river regulation in some locations. However, management actions that increase aeolian deposition of fluvially-sourced (e.g., HFE) sand can limit gully erosion within cultural sites as indicated by a variety of analyses that included lidar change detection, field mapping, air photo interpretation, digital topographic modelling, and site investigations. While HFEs can reduce gully extent in areas with upwind sandbars, sites with the greatest potential to receive windblown HFE sand still undergo gully erosion on seasonal time scales. In Glen Canyon,

lidar monitoring showed that the November 2012 HFE caused erosion of a steep cut bank adjoining one cultural site that is adjacent the river. It is possible that erosion of the cutbank could influence geomorphic processes that occur farther upslope in the cultural site, for example, by shortening the length and consequently steepening the gradient of existing gullies that cross the site.

Riparian vegetation monitoring and the analysis of vegetation data in order to identify vegetation response guilds indicates that most vegetation from sample plots can be placed into seven categories or guilds based on morphological traits and physiological traits including rooting depth (shallow to deep) and drought tolerance (high to low). Grouping species based on shared traits increases the power to detect a direction of vegetation response to changes in a flow regime when compared with evaluating single species responses. Nonetheless, the annual data collection, while informing response guild development, can also be used to track individual species of interest and general trends in species richness among the three river segments (Marble Canyon, Eastern Grand Canyon and Western Grand Canyon).

Annual estimates of spring abundance of humpback chub in the Little Colorado River for fish >150 mm and >200 mm exceed 5,000 in each case, and trends remain stable. Juvenile humpback chub survival estimates in the mainstem Colorado River near the Little Colorado River confluence for the interval from July 2013 to July 2014 were similar to those observed for the July 2012 to July 2013 interval. The estimated total abundance of rainbow trout between Glen Canyon Dam and Lees Ferry in January 2015 was approximately 200,000 fish, which represents a decline in abundance of over 80% since April 2012. In addition to declines in abundance, relative condition of rainbow trout has declined as have growth rates for fish larger than approximately 175 mm. As observed in recent years, the majority of the population of rainbow trout occurs upstream from River Mile 20. In contrast to observations upstream, abundance estimates for rainbow trout near the Little Colorado River confluence have increased, with three of four 2014 estimates exceeding trigger levels identified in the 2011 Biological Opinion for Nonnative Fish Control. No action is warranted at this time since other triggering criteria have not been met.

# January 2015 Annual Reporting Meeting

## Streamflow, Water Quality, and Sediment Transport

David Topping, GCMRC; Ron Griffiths, GCMRC; Nick Voichick, GCMRC; Tom Sabol, GCMRC; Dave Dean, GCMRC; Nancy Hornewer, AZ Water Science Center; Jon Mason, AZ Water Science Center; Brad Garner, AZ Water Science Center; Dave Sibley, CIDA; Megan Hines, CIDA

## Sandbars and Sediment Storage

Paul Grams<sup>1</sup>, Tim Andrews<sup>1</sup>, Daniel Buscombe<sup>1</sup>, Tom Gushue<sup>1</sup>, Dan Hadley<sup>2</sup>, Dan Hamill, Joseph Hazel<sup>2</sup>, Matt Kaplinski<sup>2</sup>, Keith Kohl<sup>1</sup>, Erich Mueller<sup>1</sup>, Robert Ross<sup>1</sup>, Robert Tusso<sup>1</sup>  
<sup>1</sup>U.S. Geological Survey, Grand Canyon Monitoring and Research Center  
<sup>2</sup>Northern Arizona University

## Cultural Resource Monitoring and Research

Amy Draut, Joel Sankey, Helen Fairley, and Brian Collins

## Riparian Vegetation Monitoring and Research

Barb Ralston, Daniel Sarr, Emily Palmquist, David Merritt, and Patrick Shafroth



## Project B: Streamflow, water quality, and sediment transport

- The basic physical data nearly all projects rely upon
- This now mature monitoring program is the result of sustained efforts that began 15 years ago
- **Completion of database and publically accessible website is HUGE accomplishment**
- The data demonstrate that sand evacuation occurs during periods of sustained high releases (equilization flows) and sand accumulation during periods of sustained low releases
  - *To be covered in more detail in HFE workshop*

Inbox (387) - pgram x GCMRC x

www.gcmrc.gov/discharge\_qw\_sediment/?

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- Canyonlands**
  - Monitoring Stations
- Dinosaur**
  - Monitoring Stations
  - Sediment Budget Reaches
- Colorado River Delta**
  - Monitoring Stations
- Big Bend**
  - Monitoring Stations
  - Sediment Budget Reaches

**For Additional Information**

For additional information, please contact

**Project Chief**  
David Topping  

- USGS Southwest Biological Science Center
- Grand Canyon Monitoring Research Center
- Contact [dtopping@usgs.gov](mailto:dtopping@usgs.gov) or (928)556-7396

**Database Designer/Programmer**  
Brad Garner  

- USGS Arizona Water Science Center

**Website Design and Programming**  
USGS Center for Integrated Data Analytics  

- Contact [cika\\_gcmrc@usgs.gov](mailto:cika_gcmrc@usgs.gov)

**Cooperating Agencies and Academic Institutions**

- Bureau of Reclamation
- National Park Service
- Bureau of Land Management
- Commission for Environmental Cooperation
- Utah State University

**Cooperating USGS Water Science Centers**

- Arizona Water Science Center

**Terms of Use**

The data presented in this website are collected and processed using standard USGS protocols and other established peer-reviewed methods, and subject to rigorous quality control. Nevertheless, minor edits of these data are possible. The data are released on the condition that neither the USGS nor the U.S. Government may be held liable for any damages resulting from its authorized or unauthorized use.

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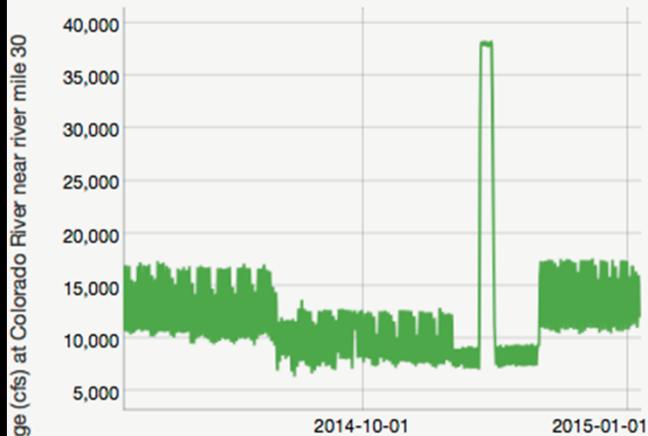
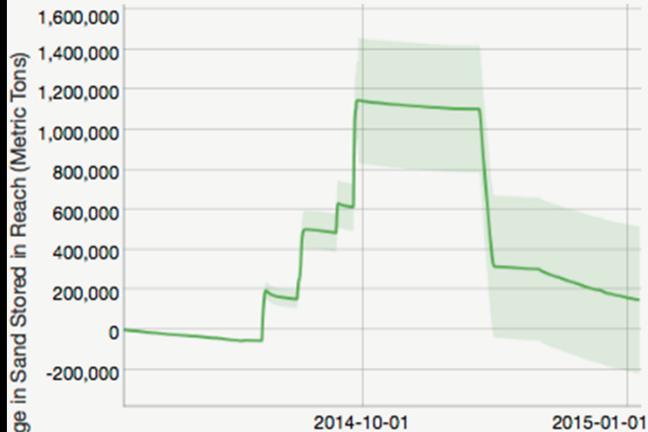
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[http://www.gcmrc.gov/discharge\\_qw\\_sediment/](http://www.gcmrc.gov/discharge_qw_sediment/)



## Change in Sand Mass

- Zero Bias Value: 150,000 Metric Tons
- Upper Uncertainty Bound: 520,000 Metric Tons
- Lower Uncertainty Bound: -220,000 Metric Tons



**This project collects  
and processes  
the data used to  
trigger HFEs**

**Upper Marble Canyon  
sand budget**

**July 1, 2014 to  
January 5, 2015**

[http://www.gcmrc.gov/discharge\\_qw\\_sediment/](http://www.gcmrc.gov/discharge_qw_sediment/)

# Project A: Sandbar Monitoring and Sediment Storage Dynamics

- Sandbar monitoring
  - *HFE response by network of remote cameras*
  - *Annual sandbar monitoring by topographic surveys*
  - *Development of new sandbar monitoring database and website*
- Sand budget
  - Effect of equalization flows
  - Effect of HFEs since 2012
- Modeling, Methods for bed texture classification, Sandbar geochemistry, interactions between bed sediment and suspended sediment (won't get to these)

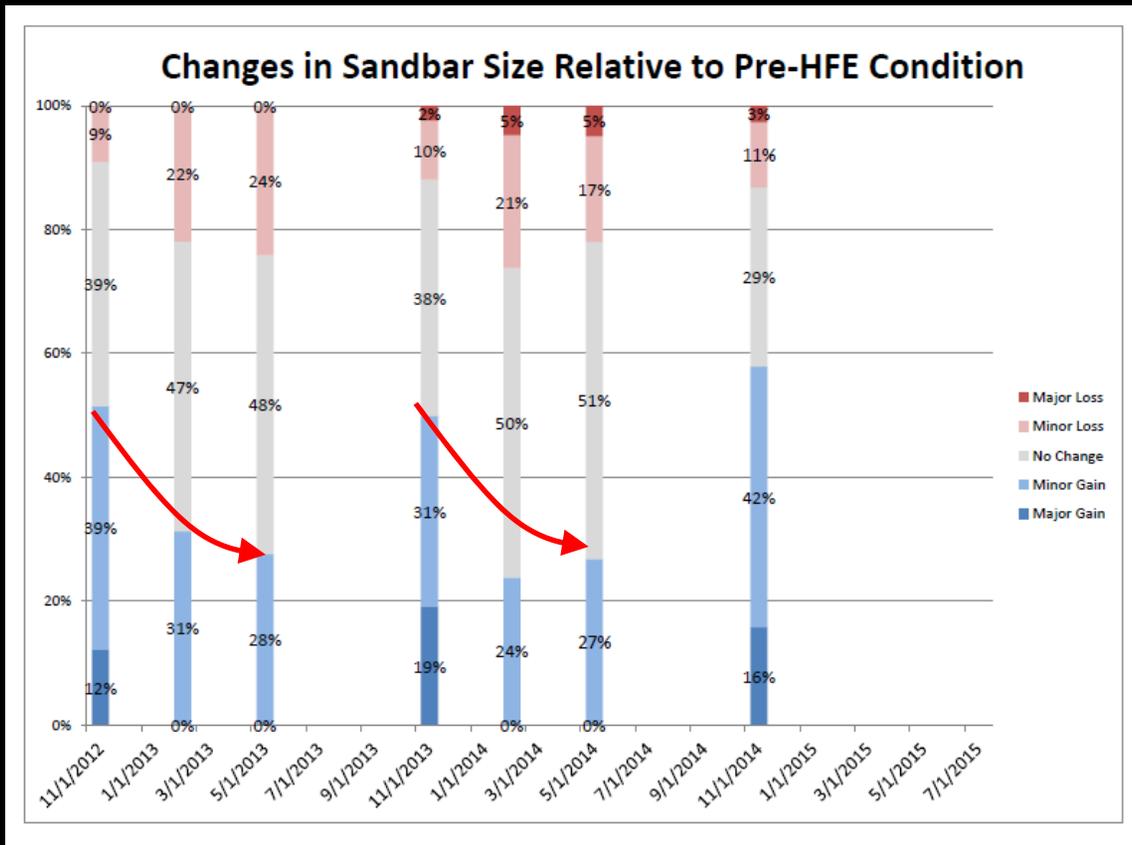


## 2014 HFE

- 22 sites (58%) larger
- 11 sites (29%) no change
- 5 sites (13%) smaller

# Response to HFE Protocol

- Each of the HFEs in the past 3 years has resulted in sandbar deposition
  - They continue to erode in following 6 to 12 months



2012 HFE

2013 HFE

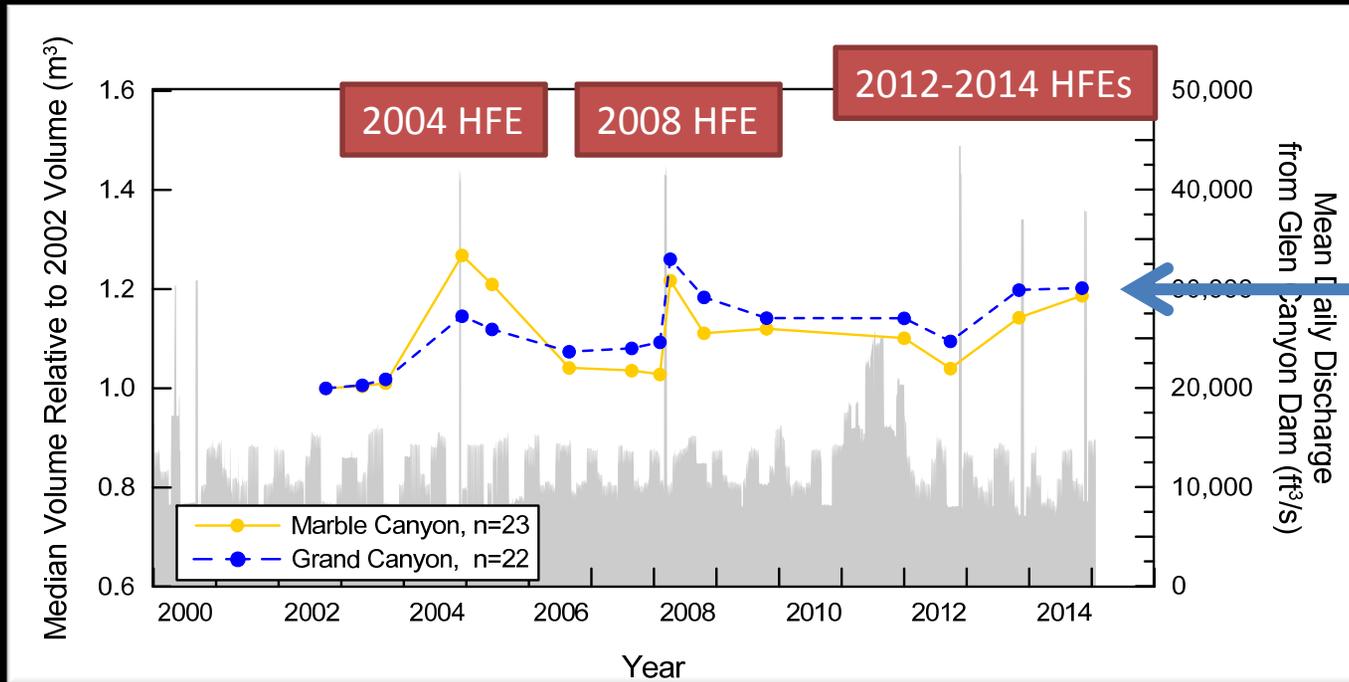
2014 HFE

Photos at [www.gcmrc.gov/sandbar/](http://www.gcmrc.gov/sandbar/)



Preliminary results, subject to review and revision – do not cite

# Sandbars: 2002-present



~10 months after HFEs, bars still larger than before start of protocol

- Increase in volume in both Marble Canyon and Grand Canyon at long-term monitoring sites
  - Deposition by HFEs
  - Bars erode following HFEs, but not quite to pre-flood size
- Frequent HFEs = consistently larger bars
- Cumulative effect? No evidence yet that bars will get progressively larger.
- 2013 and 2014 HFEs were smaller than 2012 and earlier.
- **Data now on website!!** *Preliminary results, subject to review and revision – do not cite*



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## Grand Canyon Sandbar Monitoring

### Introduction

Since the completion of Glen Canyon Dam in 1963, the amount of sand supplied to Grand Canyon National Park has been reduced by more than 90 percent. The Paria River, a tributary to the Colorado River 15 miles downstream from the dam, is now the single most important supplier of sand to the Colorado River within the Park. This large reduction in sand supply has resulted in substantial decrease in the number and size of sandbars. Sandbars are important because they serve as campsites for river runner and hikers, provide important aquatic and riparian habitats, and are the source of sand that may help protect archaeological sites. The information collected by this project will be used to determine whether dam operations, including short-duration artificial floods, cause increases or decreases in sandbars and associated campsites in Grand Canyon National Park.

### For Additional Information

For additional information, please contact

**Project Chief**  
 Paul Grams  
 • USGS Southwest Biological Science Center  
 • Grand Canyon Monitoring Research Center  
 • Contact [pgrams@usgs.gov](mailto:pgrams@usgs.gov) or (928)556-7365

**Database Designer/Programmer**  
 Kathryn Schoephoester  
 • USGS Center for Integrated Data Analytics

**Website Design and Programming**  
 USGS Center for Integrated Data Analytics

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The data are released on the condition that neither the USGS nor the U.S. Government may be held liable for any damages resulting from its authorized or unauthorized use.

### The Sandbar Monitoring Data

Currently, topographic maps are made at a set of monitoring sites annually using conventional survey equipment. These surveys are used to calculate the size of each sandbar in terms of the area of exposed sand and the volume of sand contained in the bar. Both of these calculations are relative to an elevation of interest.




### View Sandbar Monitoring Data



**Sandbar Surveys**

- [Survey Data](#)

**Photos**

- [Photos showing results of 2012 high-flow](#)
- [Photos showing results of 2013 high-flow](#)
- [Photos showing results of 2014 high-flow](#)

**References**

**Methods**

- Hazel, J.E., Jr., Grams, P.E., Schmidt, J.C., and Kapinski, M., 2010. Sandbar response in Marble and Grand Canyons, Arizona, following the 2009 high-flow experiment on the Colorado River. U.S. Geological Survey Scientific Investigations Report 2010-5015, 62 p. <http://pubs.usgs.gov/sir/2010/5015/>

**Recent Publications**

- Grams P. E., 2013. A sand budget for Marble Canyon, Arizona – implications for long-term monitoring of sand storage change. U.S. Geological Survey Fact Sheet 2013-3074, 4p. <http://pubs.usgs.gov/fsw/2013/3074>
- Grams P. E., D. J. Topping, J. C. Schmidt, J. E. Hazel Jr., and M. Kapinski, 2013. Linking morphodynamic response with sediment mass balance on the Colorado River in Marble Canyon: Issues of scale, geomorphic setting, and sampling design. J. Geophys. Res. Earth Surf., 118, 361–381. doi:10.1002/jgrf.20050. <http://onlinelibrary.wiley.com/doi/10.1002/jgrf.20050/full>

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### Cooperating Agencies and Academic Institutions

Bureau of Reclamation  
 National Park Service  
 Northern Arizona University



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### Sandbar Monitoring Sites



River Mile	Site Name	Survey Data Record	Daily Photo Record
-6.6	<a href="#">-6-mile</a>	None - None	
2.5	<a href="#">Cathedral Wash</a>	Sept. 28, 1990 - Sept. 21, 2013	
8.1	<a href="#">Jackass Camp</a>	Sept. 29, 1990 - Sept. 21, 2013	
8.9	<a href="#">9-Mile</a>	Feb. 3, 2008 - Sept. 21, 2013	
16.6	<a href="#">Hot Na Na Wash</a>	Sept. 29, 1990 - Sept. 22, 2013	
22.05	<a href="#">22-Mile</a>	Sept. 30, 1990 - Sept. 22, 2013	
23.5	<a href="#">Lone Cedar (Harry McDonald)</a>	Sept. 21, 2002 - Sept. 23, 2013	
29.5	<a href="#">Shinumo Wash (Silver Grotto)</a>	Sept. 22, 2002 - Sept. 23, 2013	
30.7	<a href="#">Sand Flat (30-Mile)</a>	Oct. 14, 1990 - Sept. 23, 2013	

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## 22-Mile - 22.05 R

**Parameters**

**Sandbar Elevation Zone for Plotting:**

What is the sandbar elevation zone?

Discharge for Lower Bound of Sandbar Elevation Zone (ft<sup>3</sup>/s):

Discharge for Upper Bound of Sandbar Elevation Zone (ft<sup>3</sup>/s):

Area of sandbar between lower and upper bound  
 1990-09-30 to 2013-09-22  
 Eddy  
 Channel  
 Total Site

Volume of sandbar between lower and upper bound  
 1990-09-30 to 2013-09-22  
 Eddy  
 Channel  
 Total Site

**Streamflow and Sediment Data:**

Discharge for Colorado River at Lees Ferry, AZ  
 1921-05-08 to 2015-02-25

Cumulative Suspended-Sand Load for Colorado River near river mile 30  
 2002-08-11 to 2015-02-25

[Update Plots](#)

[Download Sandbar Data](#)

Sandbar Metrics Between Stage Elevations Associated with Discharges of 8000 and 60000 cfs (ft<sup>3</sup>/s)

**Site Photo**

Photograph of 22-Mile taken September 22, 2015. View is from left side of river looking across at site. Streamflow is low right in photograph.

**Site Map**

Grand Canyon Monitoring & Research Center | 2205 North Gemini Drive Flagstaff, AZ 86001 | Phone: 928.696.7398 Fax: 928.696.7100

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 Channel  
 Total Site

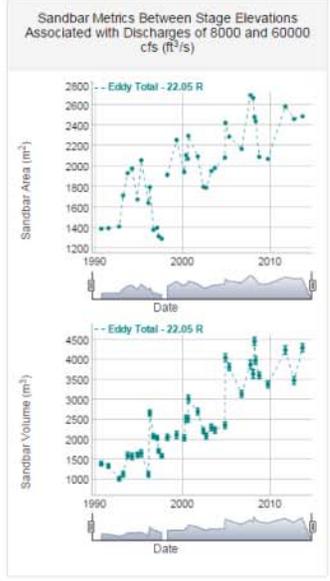
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Cumulative Suspended-Sand Load for Colorado River near river mile 30  
 2002-08-11 to 2015-02-05

[Update Plots](#)

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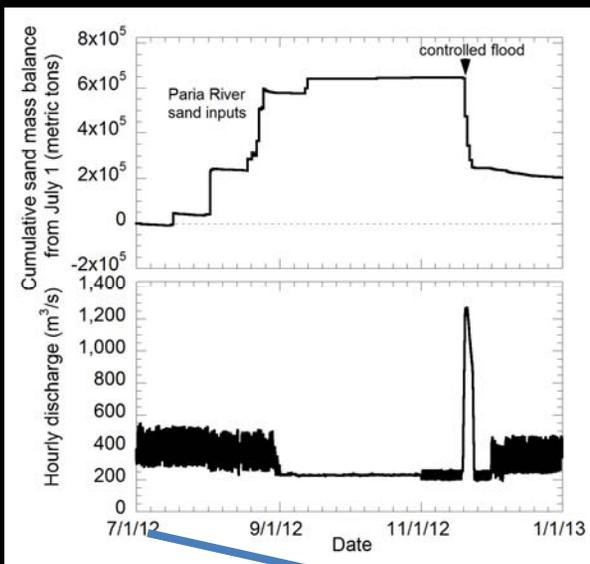
**Site Photo**

Photograph of 22-Mile taken September 22, 2013. View is from left side of river crossing across site. Streamflow is from right to left in image.

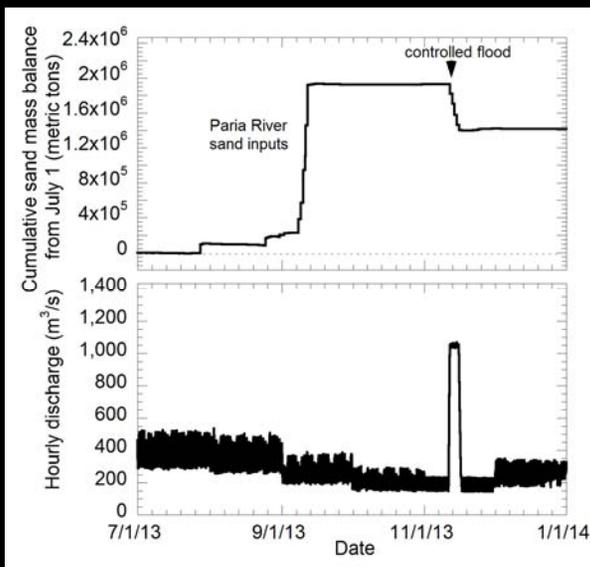
**Site Map**



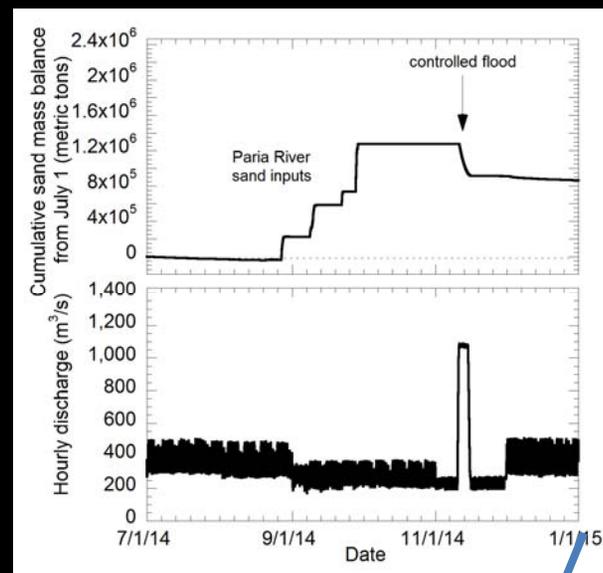
# Sand Storage in Marble Canyon During HFE Protocol



2012 HFE

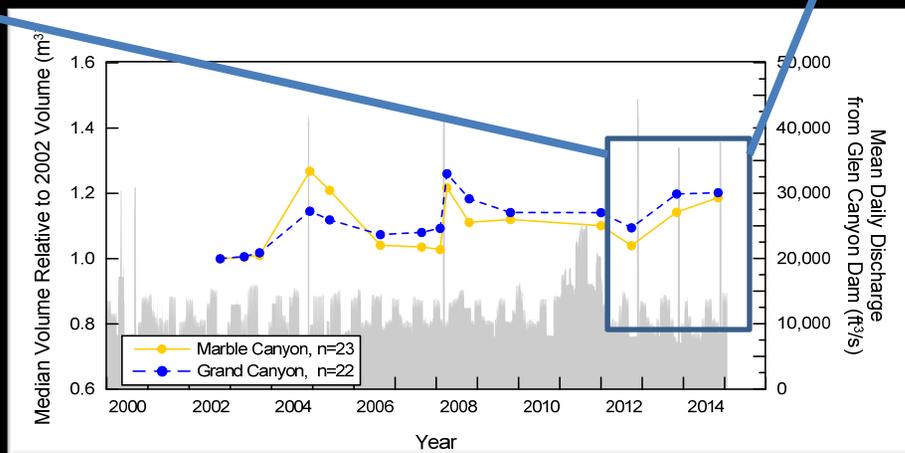


2013 HFE



2014 HFE

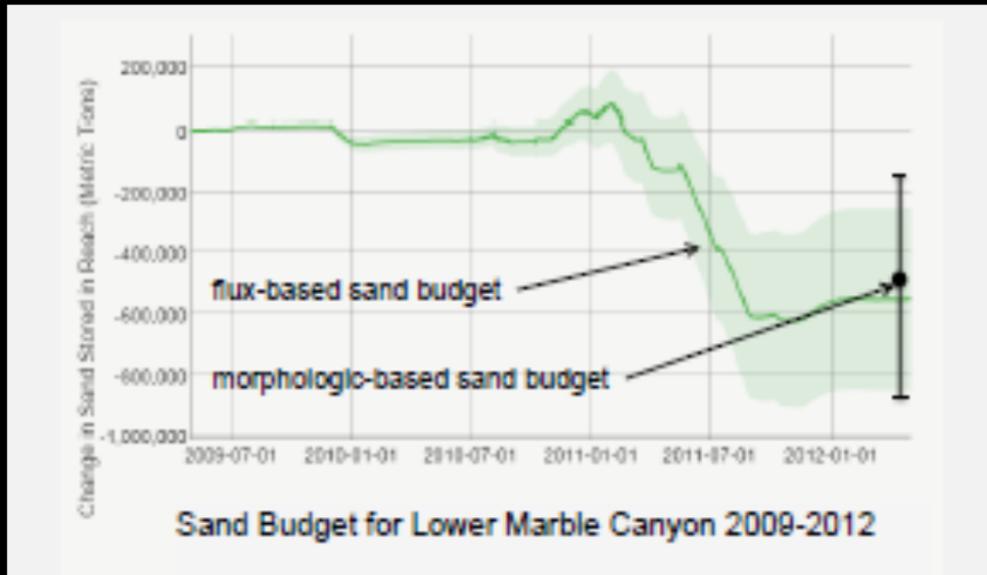
- Since 2012, each year has had enough sand accumulation to have a controlled flood and have sand accumulation
- Accumulation has more than replaced “evacuation” that occurred in 2011



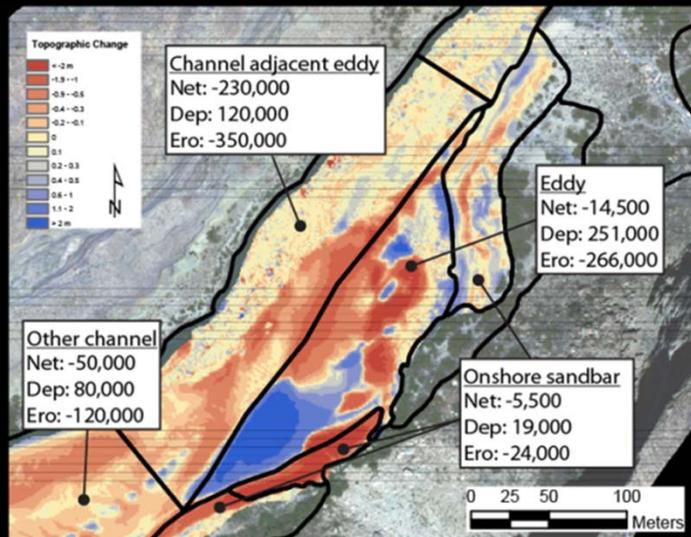
*Preliminary results, subject to review and revision – do not cite*



# Sand Storage in Lower Marble Canyon: 2009-2012



- Sand loss during equalization flows
  - Over short (3-year) period have similar uncertainty to flux measurements
  - Over long (10-20 year) period have much less uncertainty than flux measurements

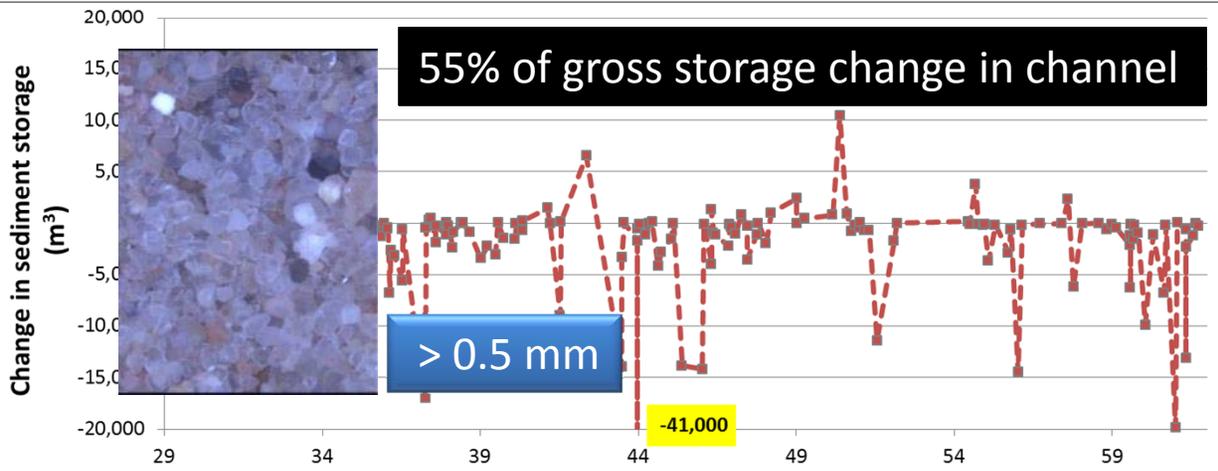
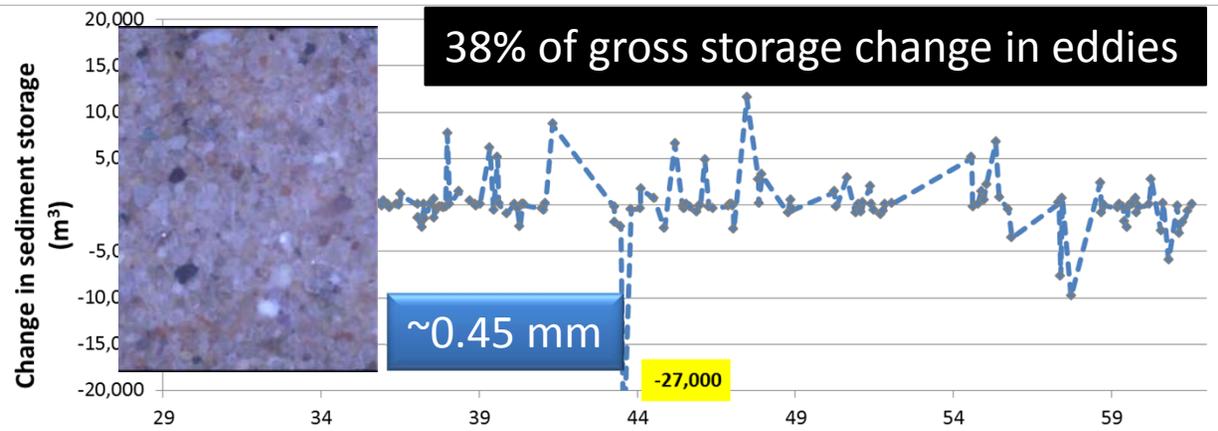
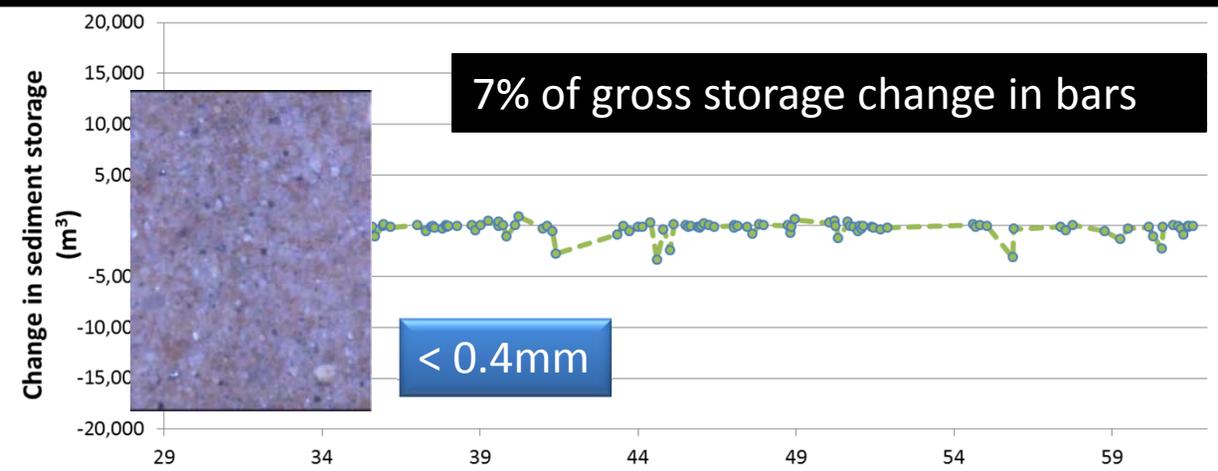


- Most erosion from channel
  - Erosion of high-elevation bars (above 8,000 cfs stage)
  - **No net loss from eddies**



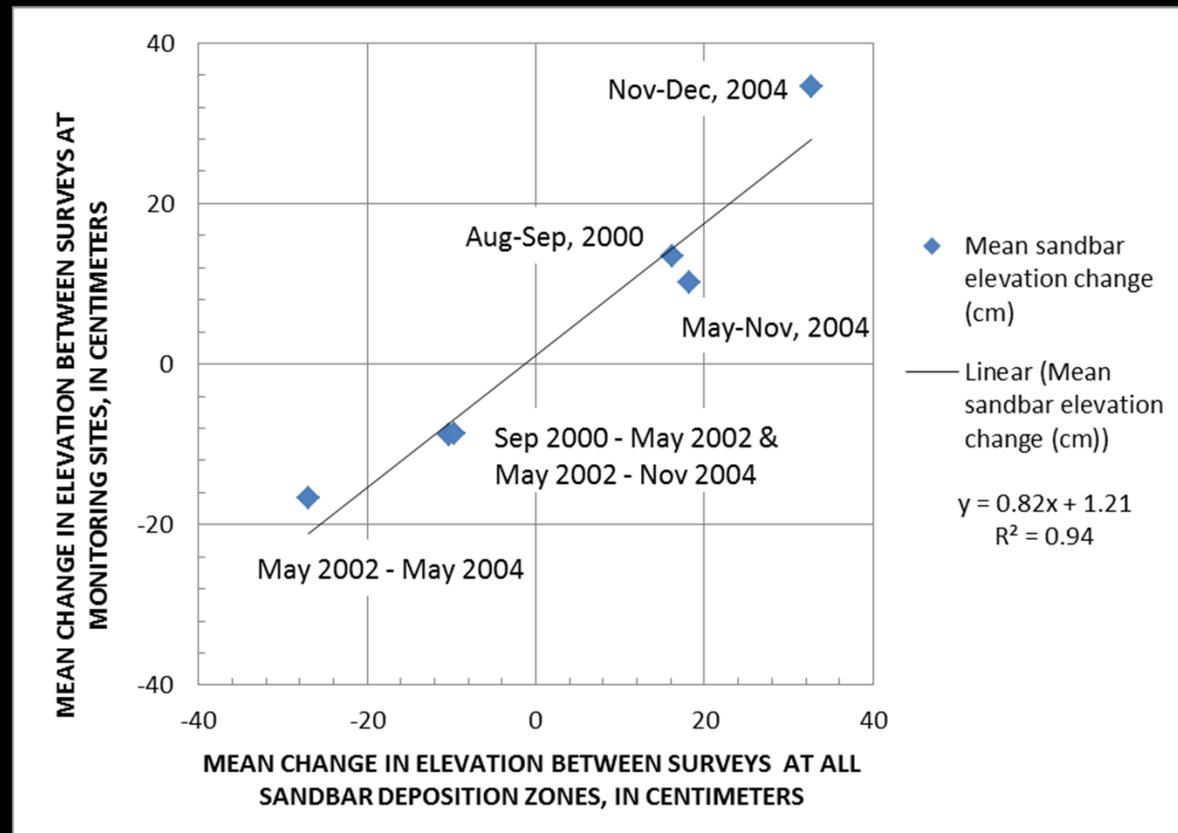


Grams et al. (2015)



# Sandbar Monitoring Sites Compared to all Sandbars in 6 Short Reaches

Positive correlation between response at monitoring sites and response for encompassing 2-mi reach (between RM 0 and 87)

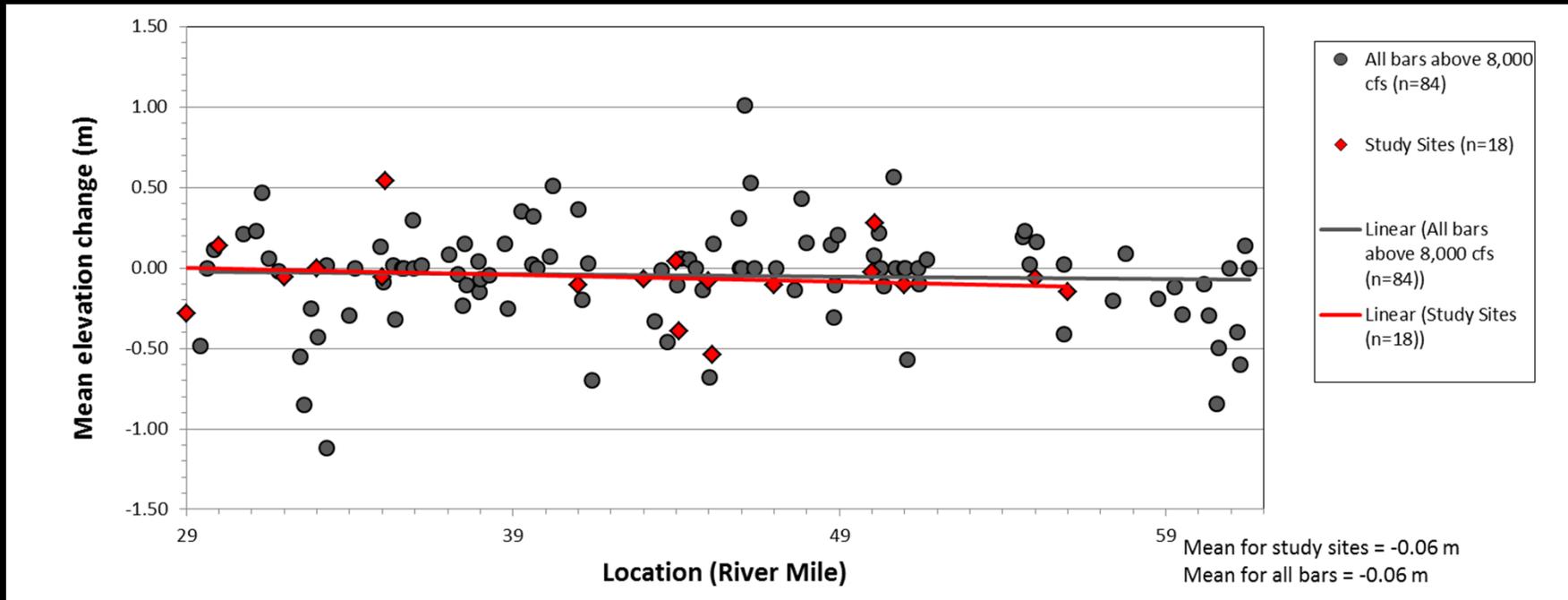


**Conclusion:** *Monitoring sites provide a good representation of both sandbar erosion and sandbar deposition at relatively large eddy sandbars above the 8,000 cfs stage when averaged over long reaches.*



*Preliminary results, subject to review and revision – do not cite*

# Comparison with Long-term Sandbar Monitoring (NAU) Sites – Only for changes above 8,000 ft<sup>3</sup>/s stage elevation



	Mean Change	Maximum Deposition	Maximum Erosion	Standard Deviation
Monitoring Sites	-0.06 m	0.54 m	-0.54 m	0.23 m
All Bars above 8,000 ft <sup>3</sup> /s elevation	-0.06 m	1.01 m	-1.12 m	0.35 m

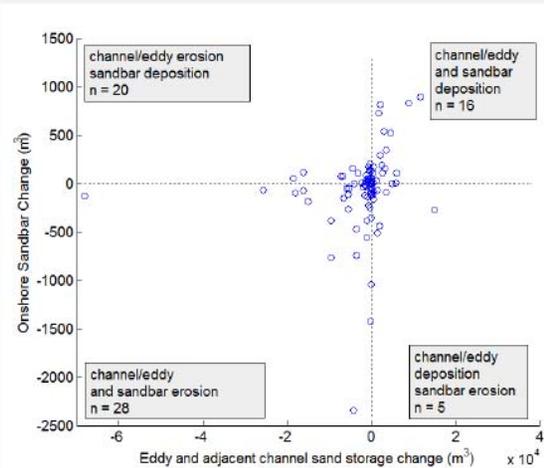
# What is the relation between sand storage in the channel and sandbar response?



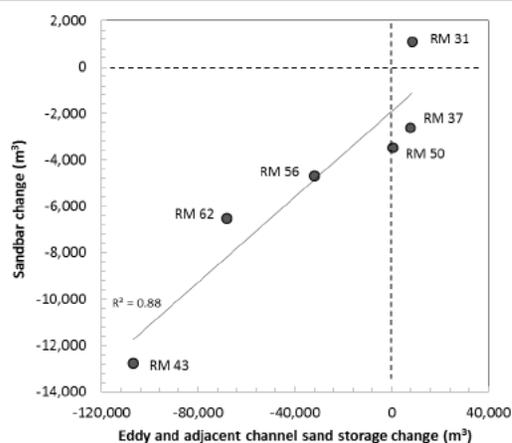
- Building sandbars requires a sand supply
- Although the Paria River is the source of the sand, it has to travel through the river channel to get to a sandbar



# What is the relation between sand storage in the channel and sandbar response?



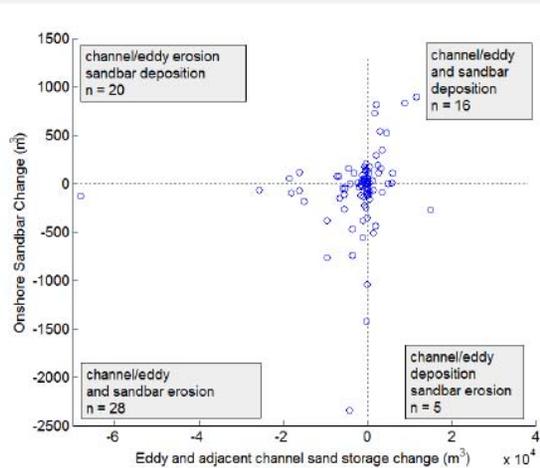
Change in onshore sandbar volume as function of change in channel and eddy storage for the corresponding eddy.



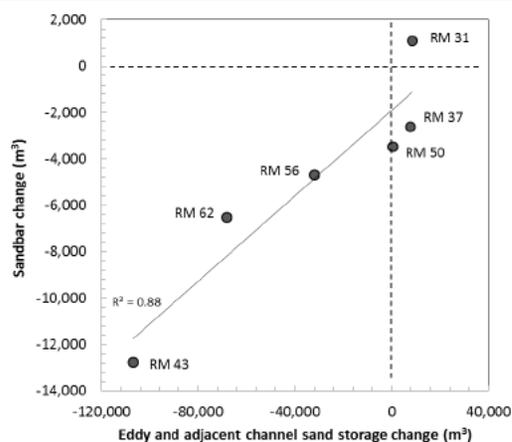
Correlation between sandbar change and eddy/adjacent channel change for 10km segments of study reach.

- At scale of individual eddies, sandbar response not predictable based on change in sand storage in adjacent eddy and channel
- Sandbar response is predictable based on change in sand storage in adjacent eddy and channel when averaged over a 10 km reach

# What is the relation between sand storage in the channel and sandbar response?



Change in onshore sandbar volume as function of change in channel and eddy storage for the corresponding eddy.



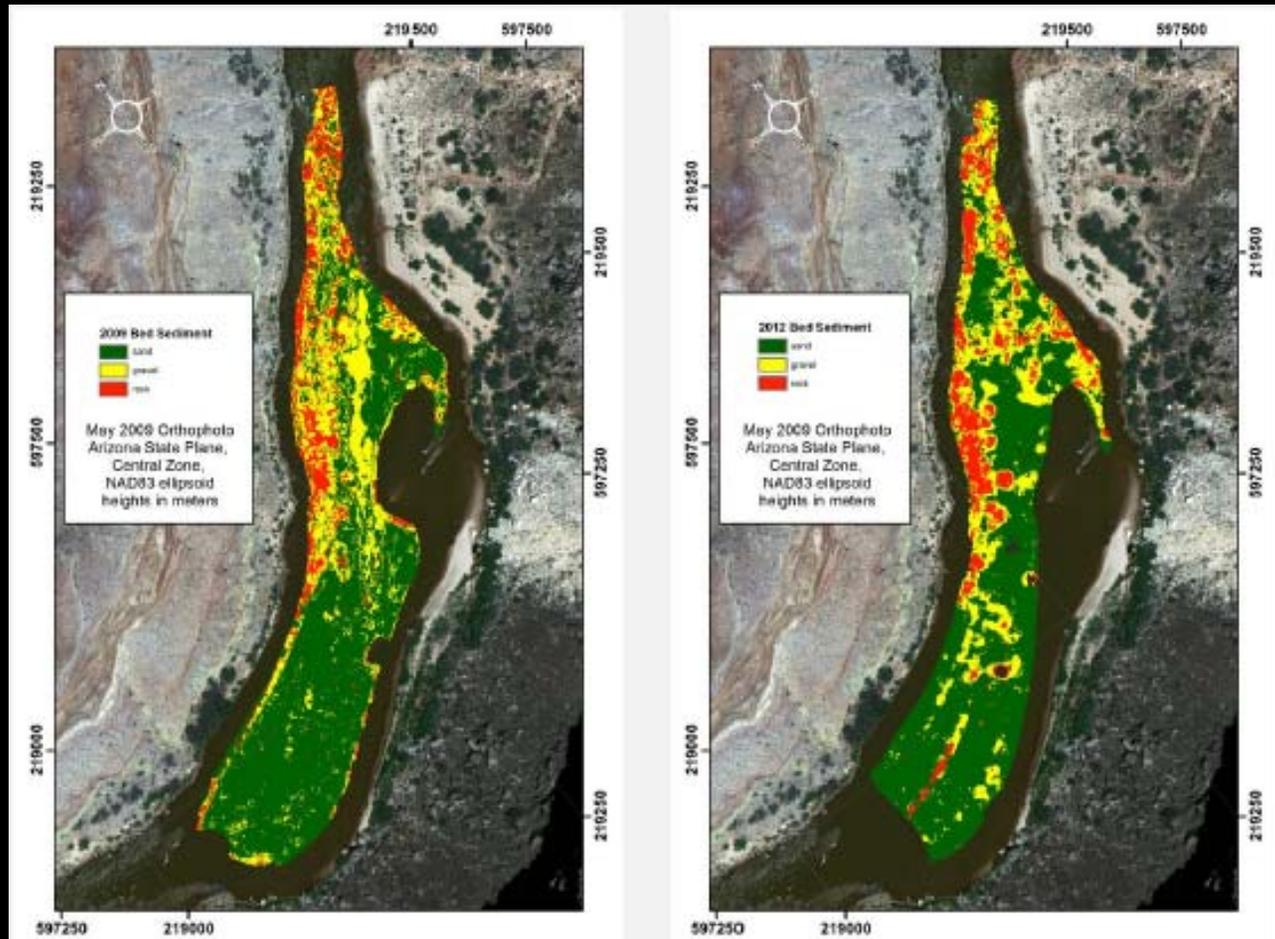
Correlation between sandbar change and eddy/adjacent channel change for 10km segments of study reach.

- At scale of individual eddies, sandbar response not predictable based on change in sand storage in adjacent eddy and channel

- Sandbar response is predictable based on change in sand storage in adjacent eddy and channel when averaged over a 10 km reach

Positive sand budget = larger sandbars  
Negative sand budget = smaller bars

# Advances in Mapping Bed Texture



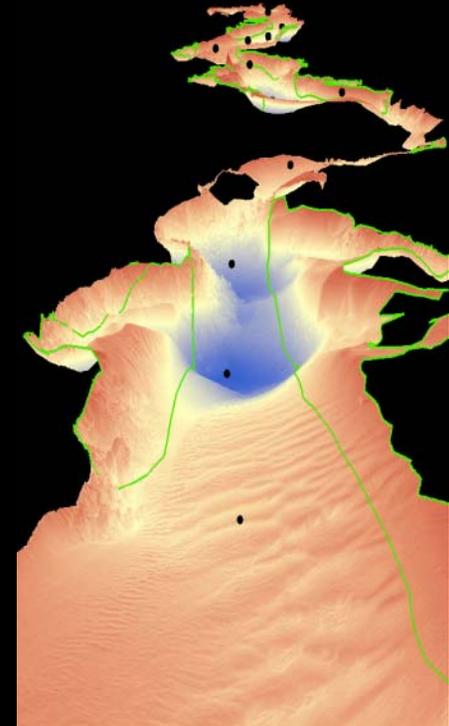
- Maps of bed texture based on acoustic properties
- Automated methods for applying classification to entire river segments
- Extending the methods for use with data collected by simple and inexpensive equipment for studying aquatic habitat

Buscombe et al. (2014)



# Summary

- Sandbar Trends: 2002 to 2014
  - Based on looking at lots of sandbars on air photos, bar area about the same, but variable depending on when you're looking (how long since most recent HFE)
  - Based on looking at NAU long-term monitoring sites (45 sites in Marble and Grand Canyons), bar volume larger now than 2002
- Equalization flows cause sand evacuation
  - The eddies appear to provide a large buffer during periods of evacuation
- First three years of HFE protocol has been a period of low annual release volumes and good tributary sand supply
  - Bar deposition without depleting sand from storage
  - Sand has accumulated in Marble Canyon, replenishing sand evacuated during 2011 equalization



*Preliminary results, subject to review and revision – do not cite*

# Cultural Resource Monitoring and Research: FY 2013-2014

## Summary of Findings

- Topographic changes occurred between 2013 and 2014 at all sites monitored by lidar.
- HFE-deposited sand, subsequently transported to upland locations by wind, temporarily fills some gullies.
- Although gullies runoff generated by seasonal rains may still cause erosion, gully infilling provides a self-regulating mechanism ("annealing") that has the potential to slow or arrest progressive erosion.
- The November 2012 HFE caused erosion along a steep cut bank that is adjacent the river and adjoins a cultural site.

*More at HFE workshop*



*Preliminary results, subject to review and revision – do not cite*

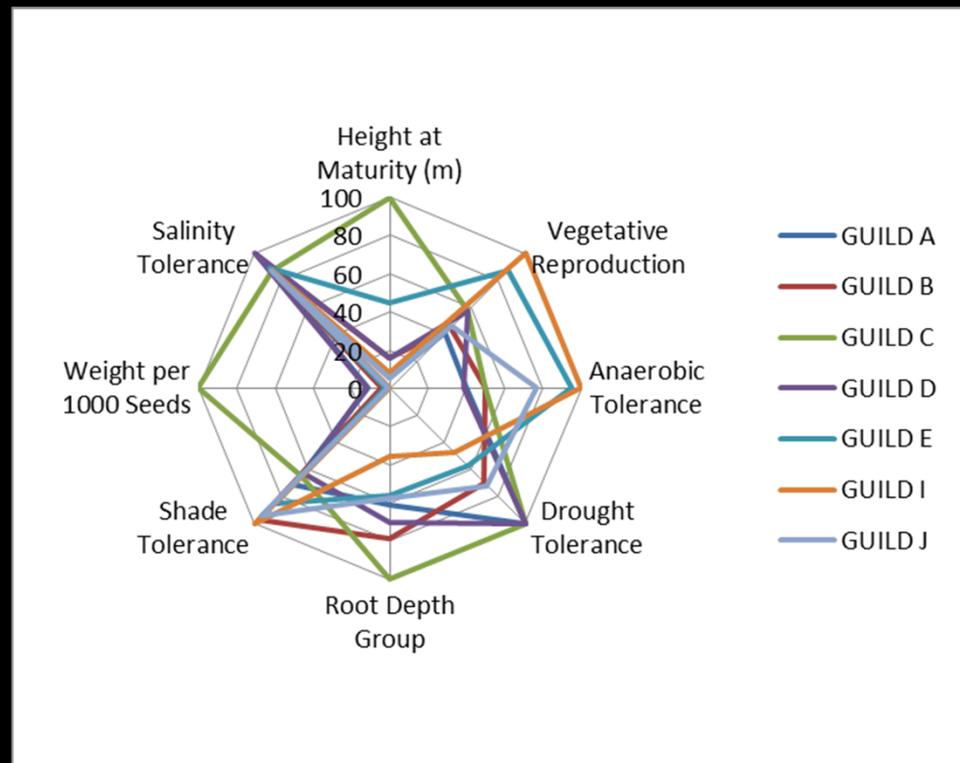
# Riparian Vegetation Monitoring and Research

- Over past 3 years, we have developed and implemented a riparian vegetation monitoring program that is based on protocols consistent with those being used throughout the Colorado River Basin
  - Annual sampling in July-September
  - Mix of random and fixed sites between dam and RM 240
  - Fixed sites co-located with annual sandbar monitoring sites



# Riparian Vegetation Monitoring and Research

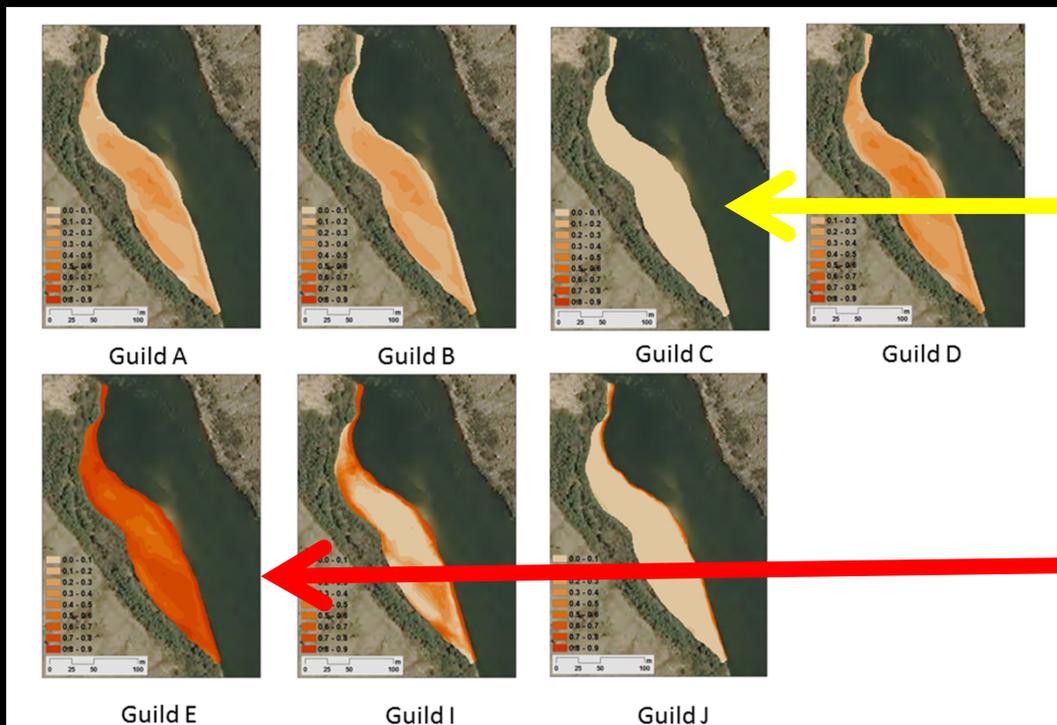
- Most vegetation from sample plots can be placed into 7 categories or guilds based on morphological and physiological traits using hierarchical cluster analysis
- Traits include:
  - rooting depth (shallow to deep) and
  - drought tolerance (high to low).



*Preliminary results, subject to review and revision – do not cite*

# Riparian Vegetation Monitoring and Research

- Grouping species based on shared traits increases the power to detect a direction of vegetation response to changes in a flow regime
- Monitoring also tracks individual species of interest and general trends in species richness



Modeled probabilities of occurrence for the guilds A-J.

**Guild C (includes hackberry) has lowest probability**

**Guild E (includes Phragmites, coyote willow) has highest probability.**

*Merritt et al. (preliminary results)*