Changes in sandbars and campsites during the HFE Protocol

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Overview

- Background on the HFE Protocol
- Background on study sites, methods, and database
- Observations of sandbar response from HFE protocol
- Observations of sandbar response to 1990-2019
- Campsite area response during the HFE protocol
- Summary

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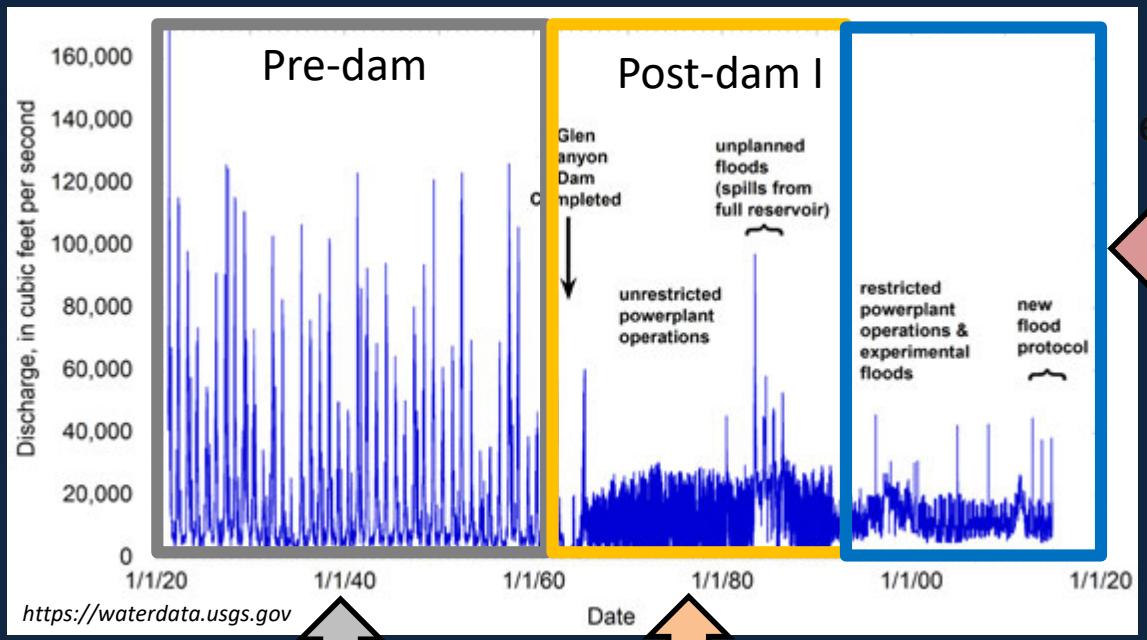

Post-dam II:

- Restricted hydropower operations
- **High Flow Experiments (HFEs)**
  - triggered by sand supply from Paria River

Pre-dam:

- Annual floods
- Abundant sand supply
- Large sandbars

Post-dam I:

- Daily small floods
- Limited sand supply
- Eroding sandbars
- Unplanned floods (spills)

HFE-related Science and Management Questions:

- With frequent HFEs, will sandbars increase in size and abundance?
- Will frequent HFEs cause sand supply in channel to decrease and exacerbate sediment deficit?

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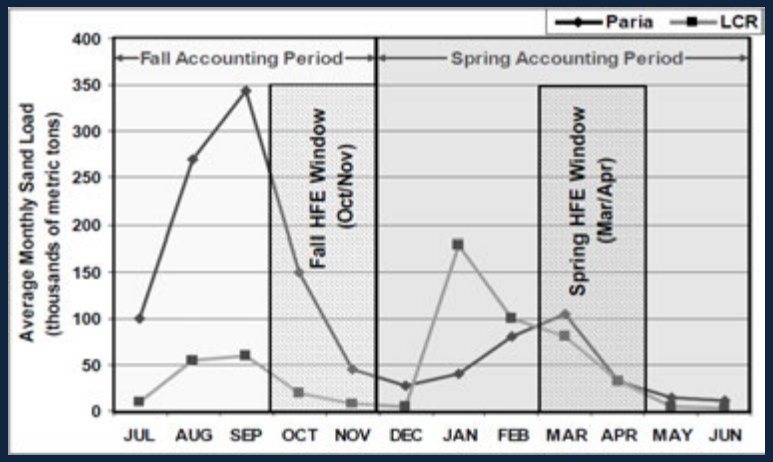
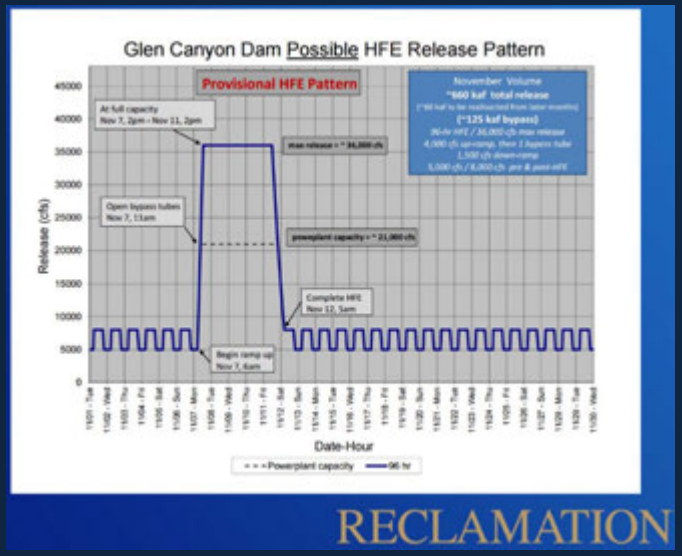
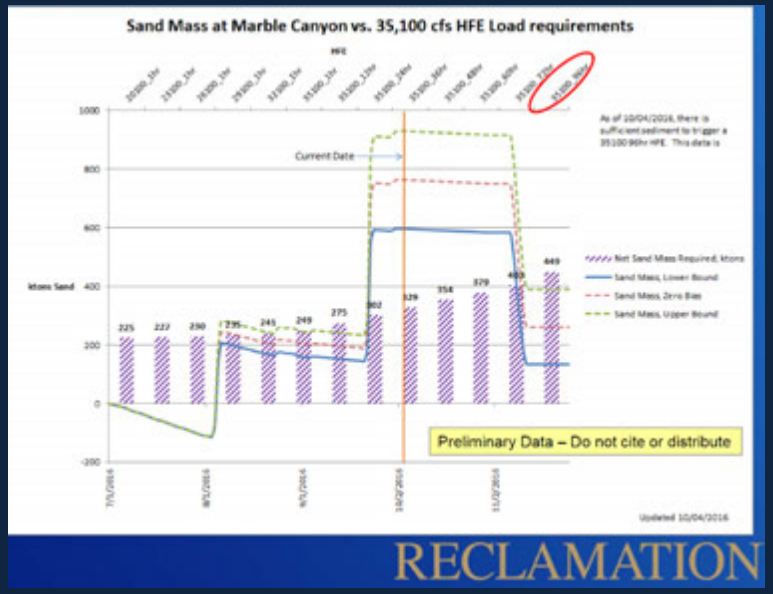
The HFE Protocol:

- Track sand inputs from Paria River and model sand budget during designated accounting periods
  - July 1 – Dec. 1
  - Dec. 1 – Jun. 30
- Find the magnitude and duration of HFE that "fits" the amount of sand available
- Schedule HFE



Wright and Kennedy (2011)





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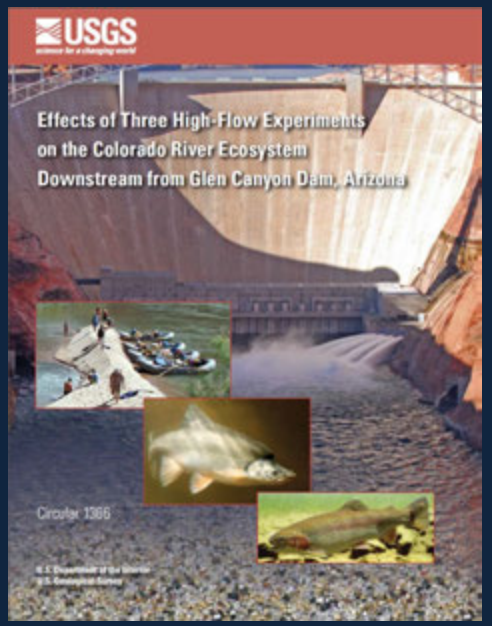
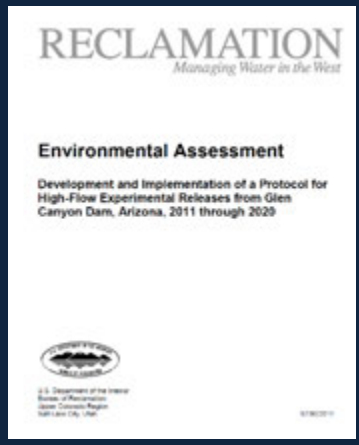
Post-dam Floods and High-flows:
Summary of findings up to start of 2012 HFE Protocol

- Sediment depleted floods scour the bed.
- Sediment-depleted floods can build high-elevation sandbars at expense of erosion from the channel and low-elevation parts of eddies.
- Floods during sediment-enriched conditions build bars without "mining" background sand storage.
- High flows should be timed to best take advantage of recent tributary sand inputs.



→ These findings are basis of the key components of HFE Protocol:

- Tracking sand inputs from Paria River over the summer-fall storm season.
- Scheduling HFEs to follow the series of inputs when sand storage in Upper Marble Canyon is greatest.
- Scaling the size (magnitude and duration) of HFE to "match" the amount of sand accumulation.



Schmidt and Grams (2011); Wright and Kennedy (2011)

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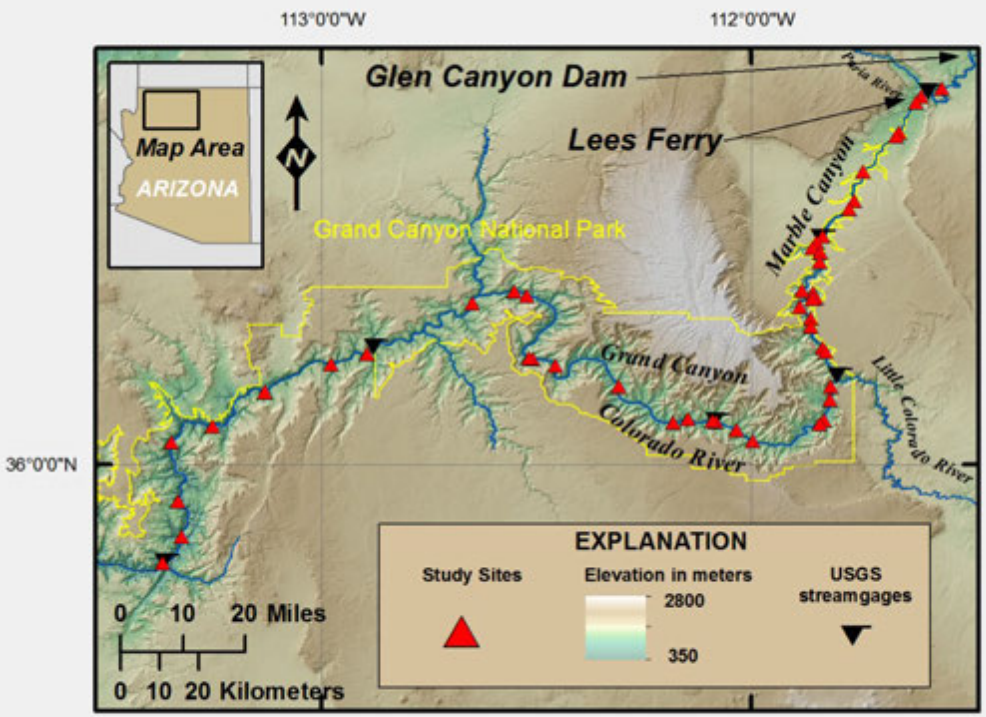
Long-term monitoring (LTM) sites between Lees Ferry and Diamond Creek



- 32 sites established in 1990 by Beus and others (1992)
- Additional sites added in 1993, 1996, 2002, and 2008 for a total of 44 sites
- The percentage of eddies with monitored sandbars is 9% and 7% in Marble and Grand Canyons, respectively
- 37 sites are monitored for campsite area

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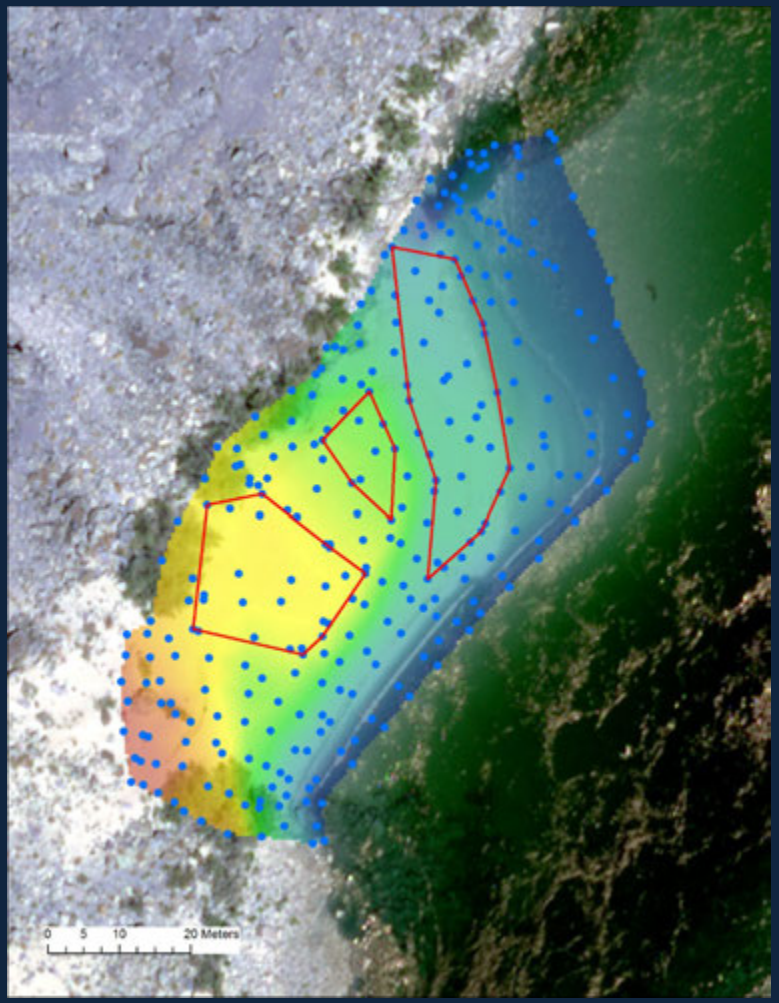
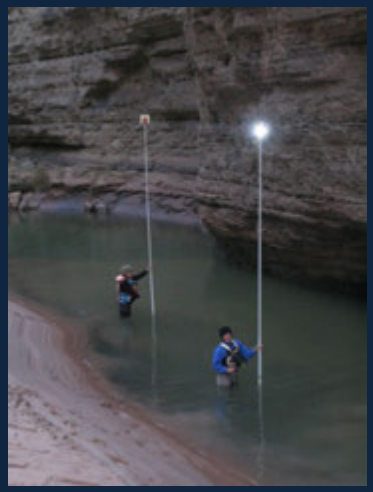
Sandbar and campsite survey methods





Total Station Surveys of Sandbar Topography, Campsite Area* (vegetation survey plots), and Daily Imagery

***Campsite Area** = a smooth substrate (preferably sand) with no more than eight degrees of slope with little or no vegetation

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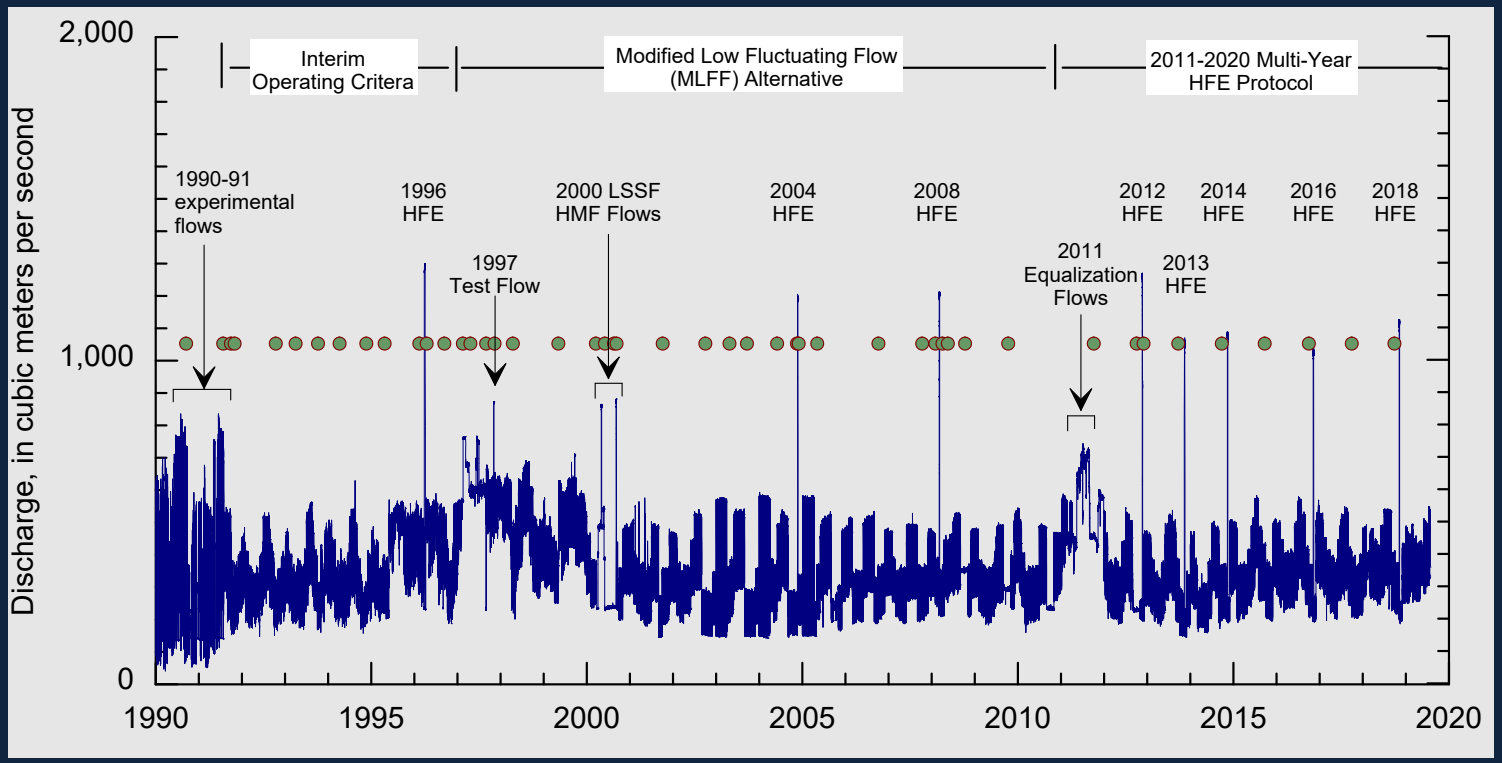
Flow regimes, high-flow experiments, and sandbar surveys



- 11 HFEs between 1996 and November 2018, including lower magnitude HMFs in 1997 and 2000
- ~1,750 surveys collected between 1990 and 2019
- The original LTM sites have as many as 50 repeat surveys
- Sandbar surveys during the HFE protocol are made ~11 months following each HFE

Hazel and others, in prep

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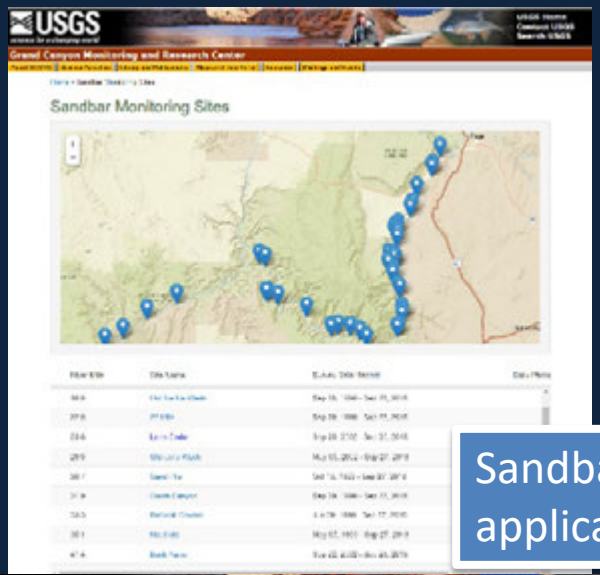
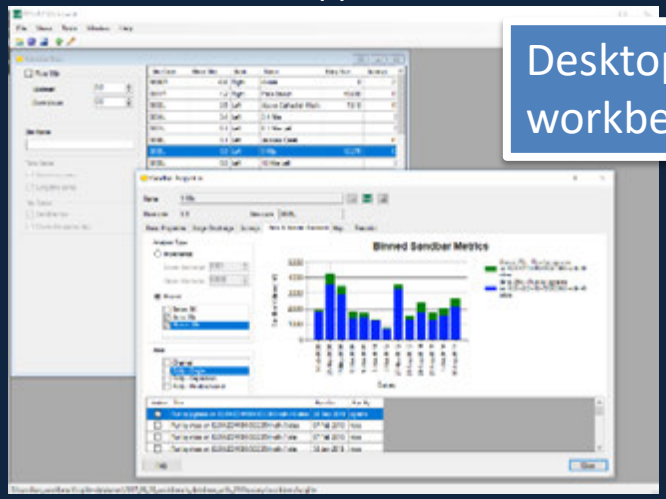
Sandbar database and web application

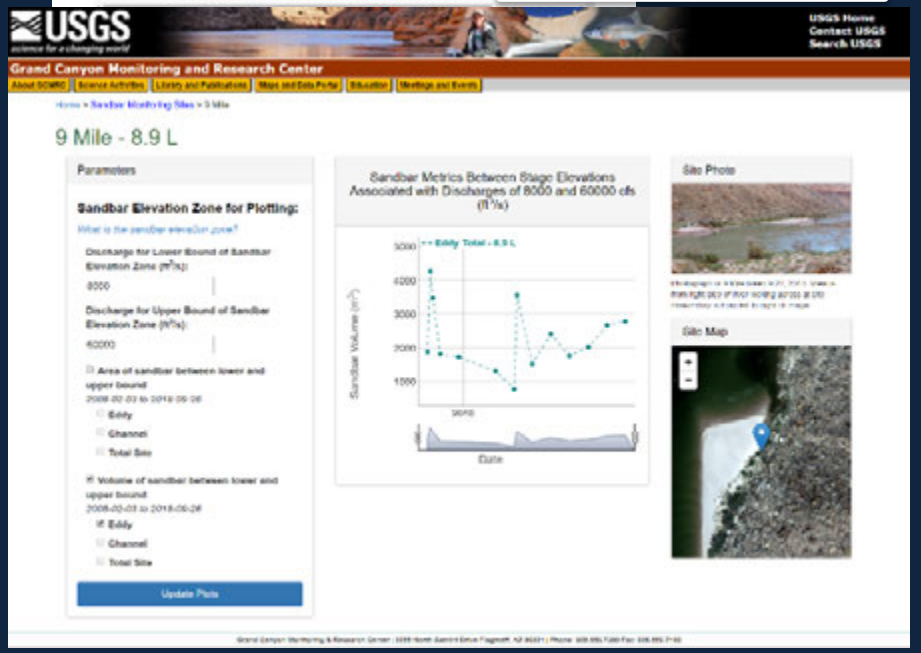
- In development since 2014
  - Started as a javascript app supported by oracle database
  - Now mainly in python and supported by a sql database (free and open source)
- Includes a desktop “workbench” for loading, processing and viewing data
- Web application for public access to data
- Series of python scripts for generating summary plots
  - Next step is to incorporate those in workbench and web application



Sandbar web application



Desktop sandbar workbench



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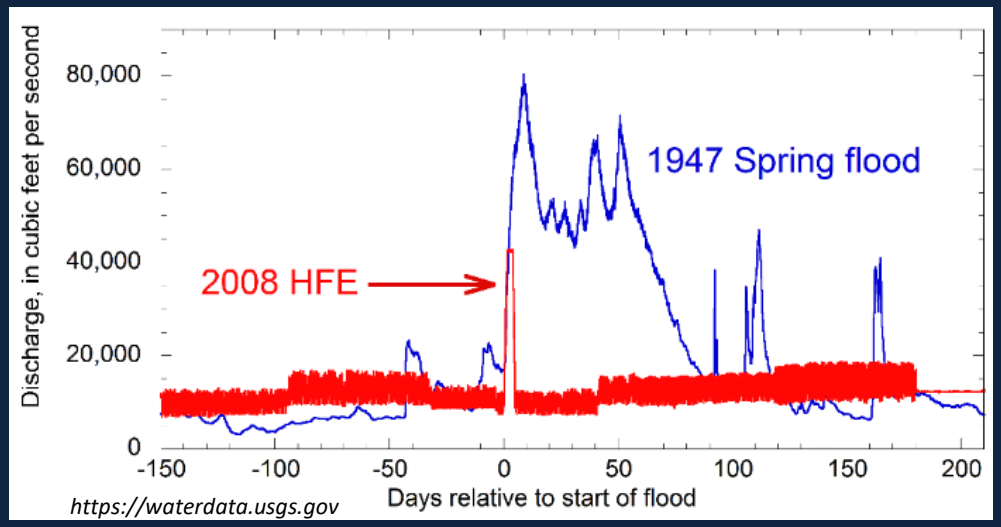
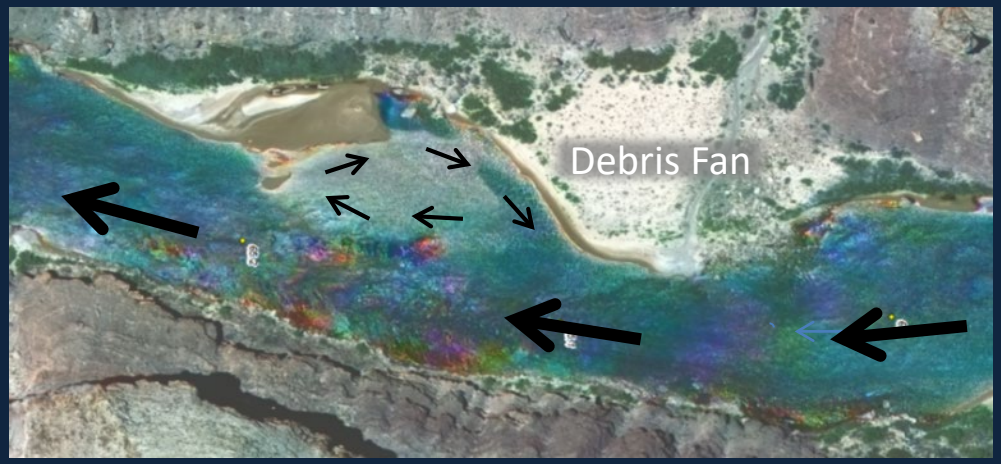
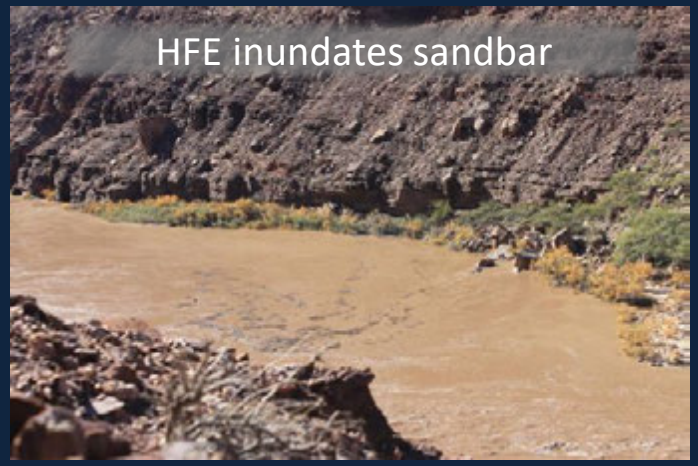
www.gcmrc.gov/sandbar OR www.usgs.gov/apps/sandbar

What are the high-flow experiments (HFEs) doing?





HFEs transfer sand from channel and low-elevation parts of eddies to sandbars along channel margins



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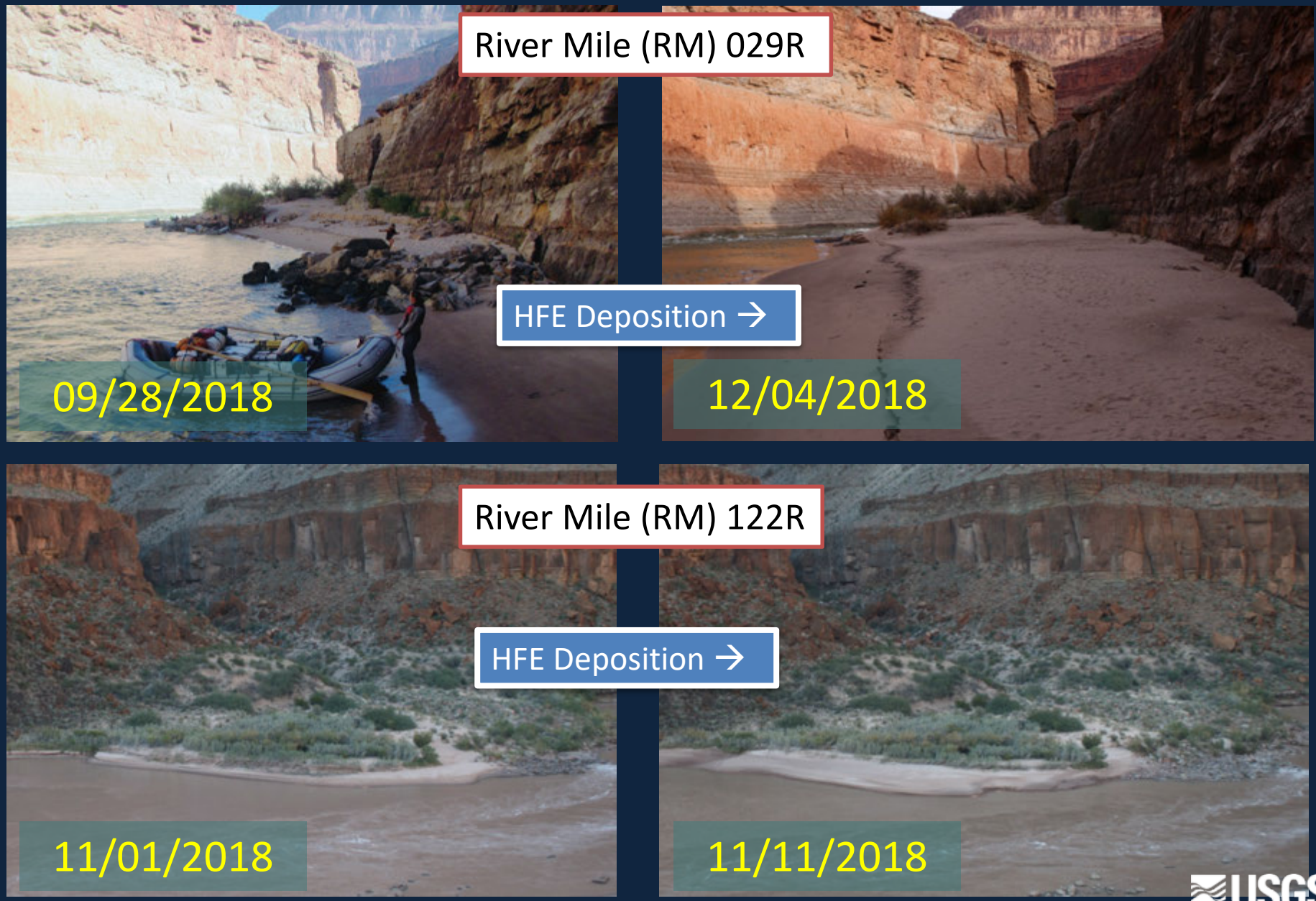
November 2018 High-flow Experiment Deposition-1



November 2016 High-flow Experiment Sandbar Deposition-2

River Mile (RM) 23L

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Rebuilding of sandbars and campsites affected by tributary floods

- Flash flood and debris flow at 220-mile in 2018 eroded and wiped out middle camp (a long-term monitoring site)
- Also eroded gully through upper camp
- Both partially rebuilt by 2018 HFE

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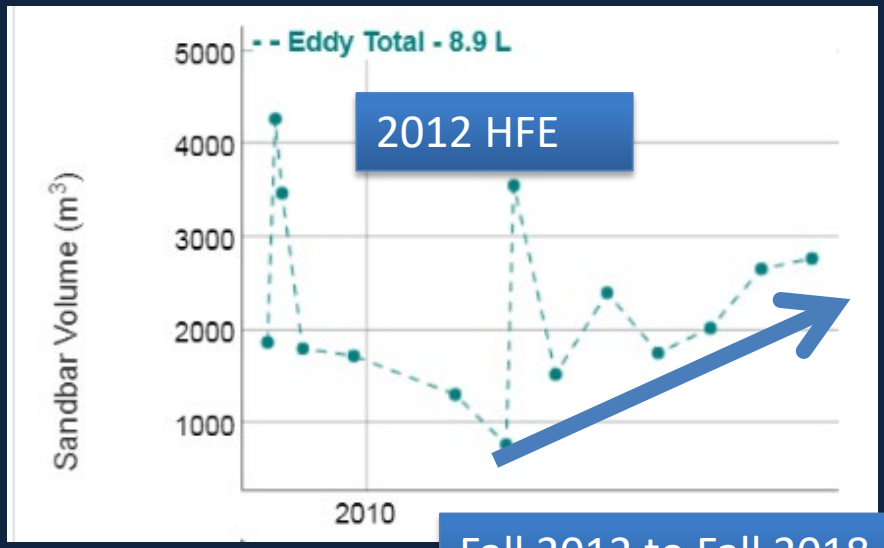
Cumulative increases in sand volume at some sites

RM 9 L



Fall 2012 to Fall 2018 increase

Preliminary results, subject to review, do not cite

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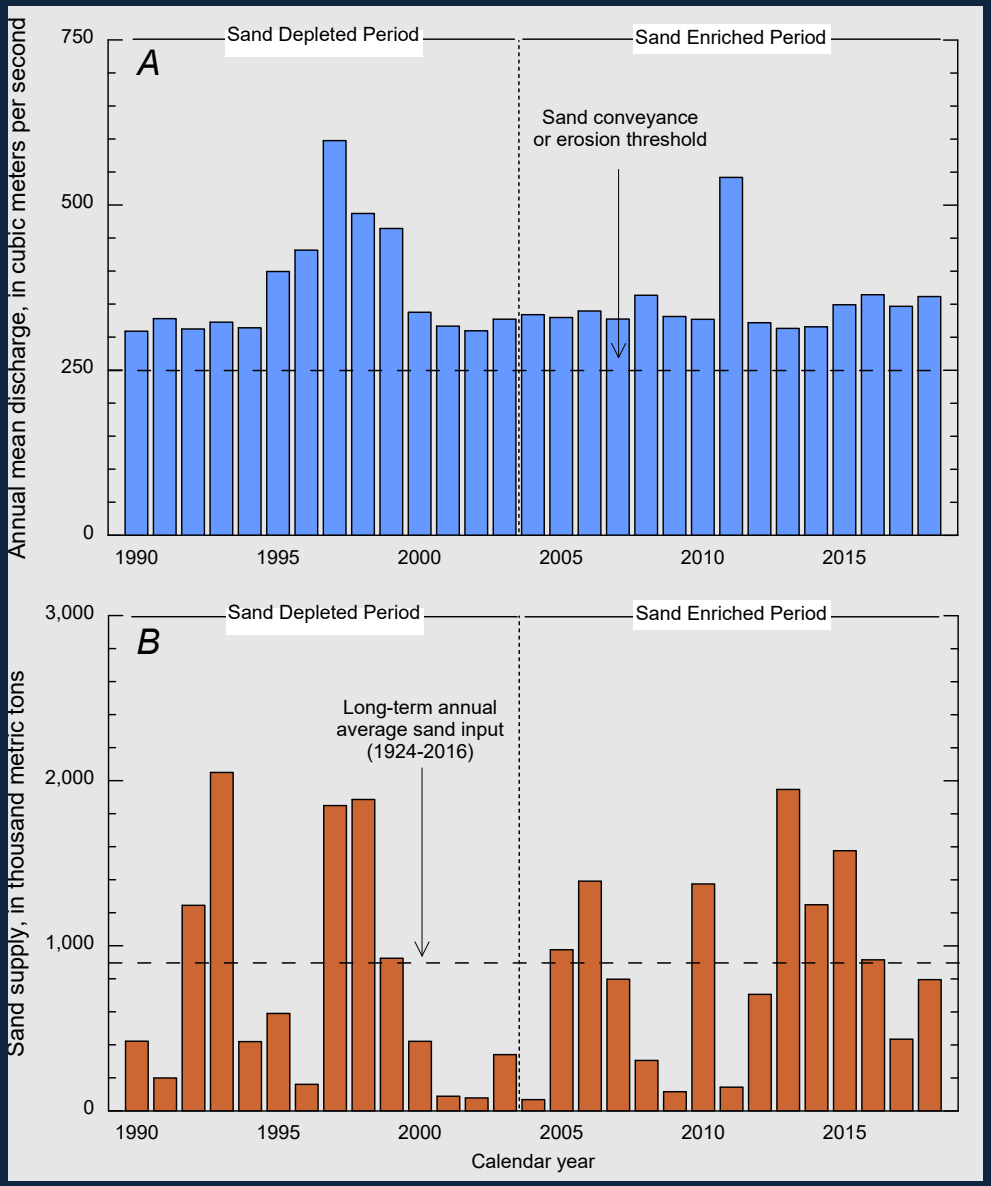
Two analysis periods between 1990 and 2019



- Sand depleted period (1990-2003)
  - Median discharge ~351 m^3/s
  - Sand conveyance threshold exceeded 78% of the time
  - Paria sand supply was average or above average in only 5 years during the 14-year period
- Sand enriched period (2004-present)
  - Median discharge ~332 m^3/s
  - Sand conveyance threshold exceeded 80% of the time
  - Paria sand supply was average or above average in 9 years during the 15-year period
  - 7 HFEs were timed to occur before inputs were conveyed through the system
  - The difference? Large inputs and only one year with high releases

Hazel and others, in prep

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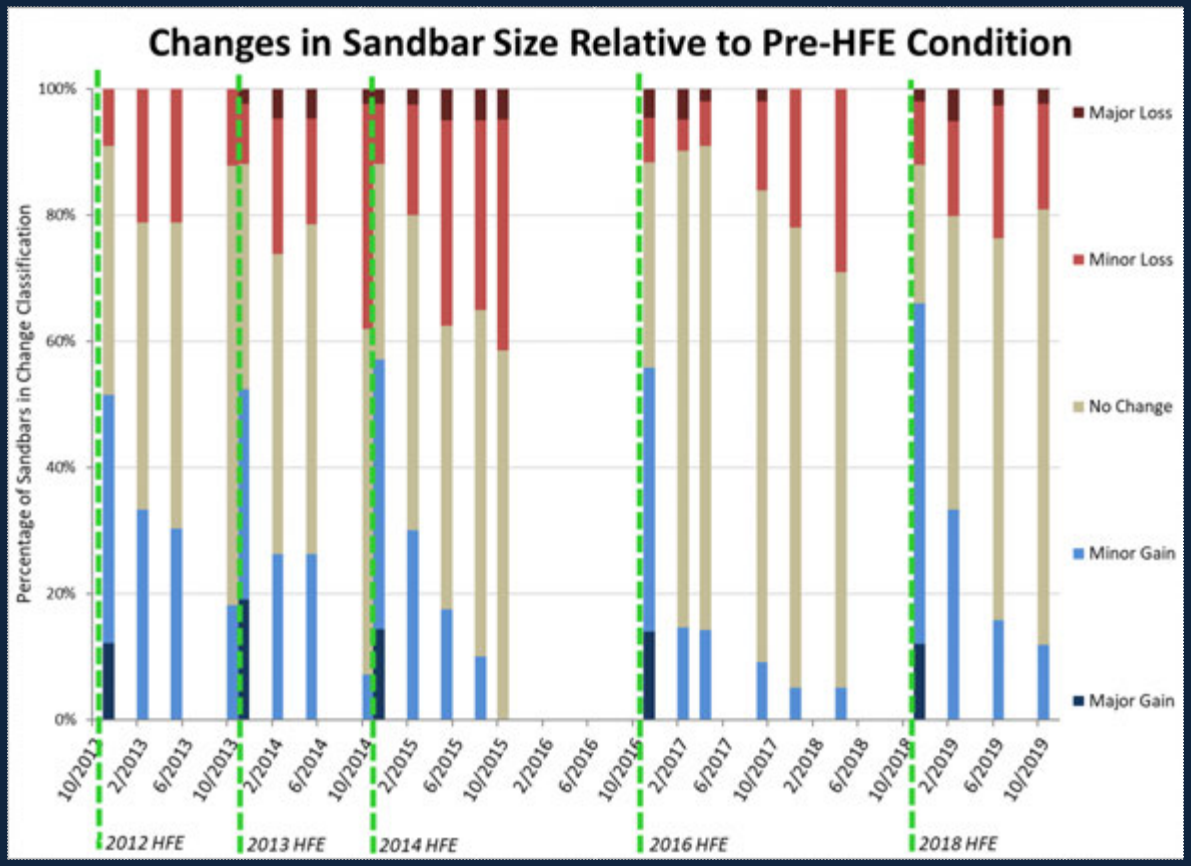
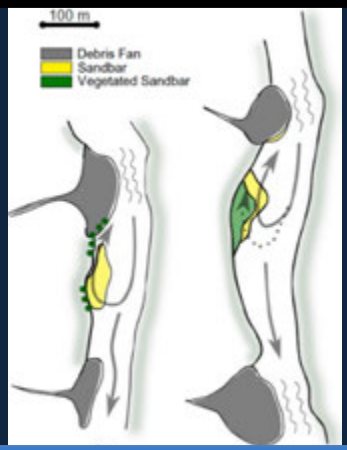
Photographic analyses of the HFE protocol

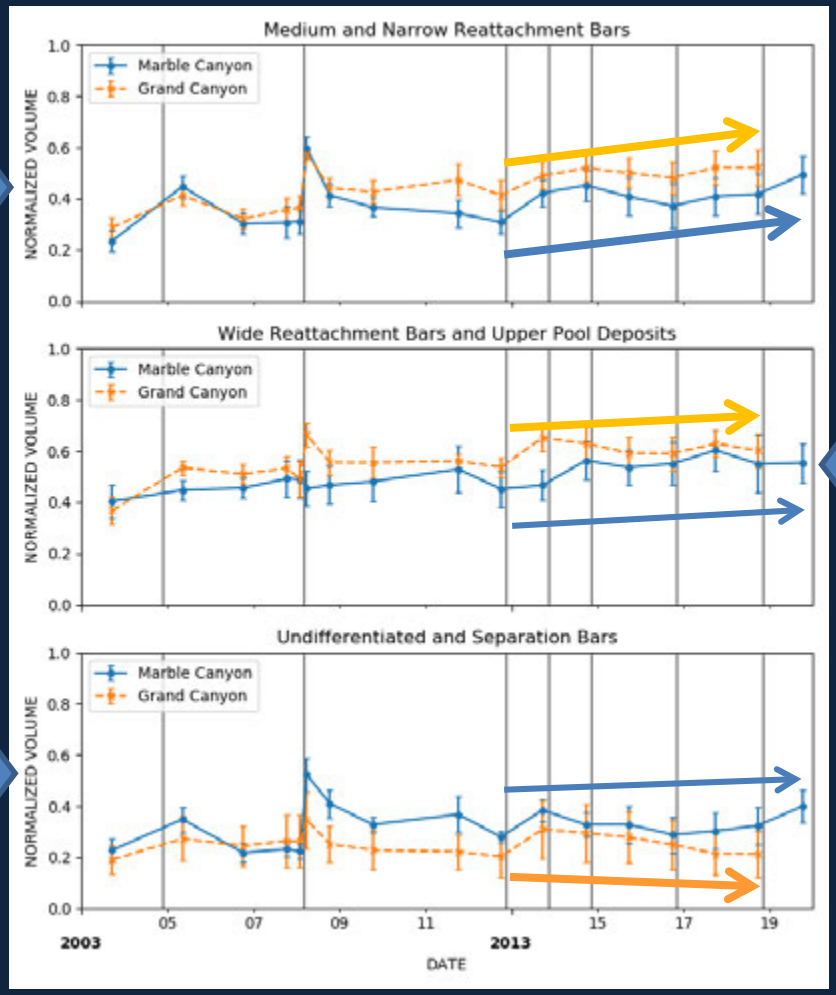


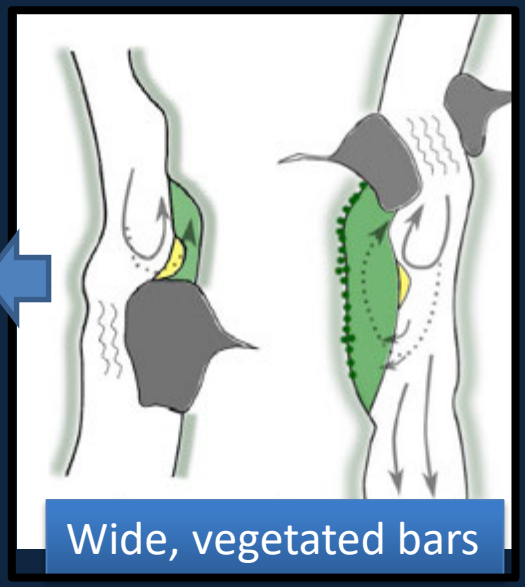
Results of 2018 HFE on par with previous HFEs

Sandbar size during the HFE protocol period

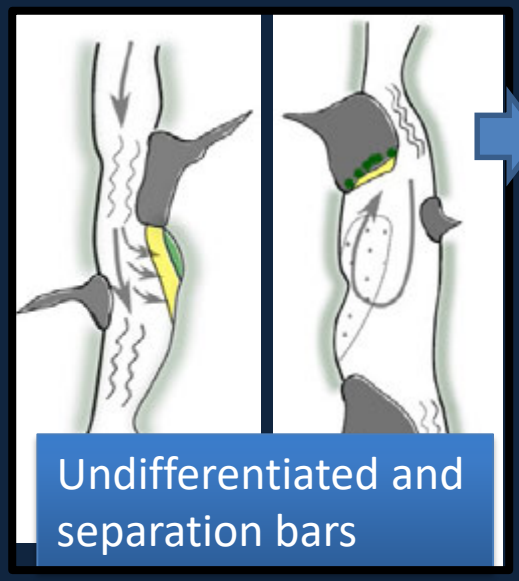


Narrow to medium reattachment bars





Wide, vegetated bars



Undifferentiated and separation bars

- Positive trends in most bar types and in both Marble and Grand Canyon
- Increases in sandbar volume off-set sandbar erosion that occurred between HFEs

Preliminary results, subject to review, do not cite

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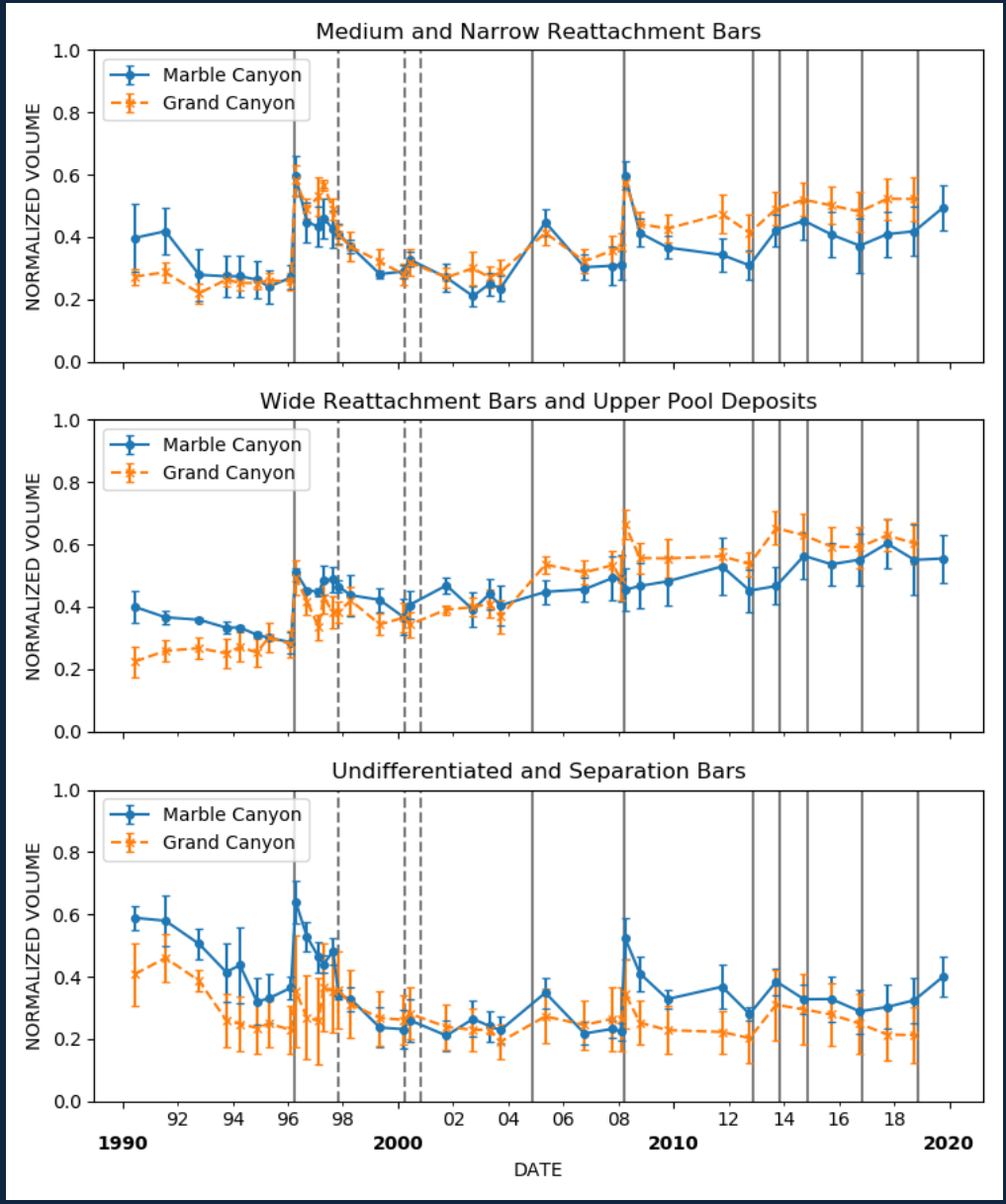
Long-term sandbar response size during the HFE protocol period

- Increased HFE frequency is maintaining sandbars at a majority of the sites
- HFE protocol is off-setting erosion characteristic of the 1990-2003 sand depleted period for most bar types
- Trends for separation and undifferentiated eddy bars show a slight decline in Grand Canyon
- Trends are markedly similar for both Marble and Grand Canyons



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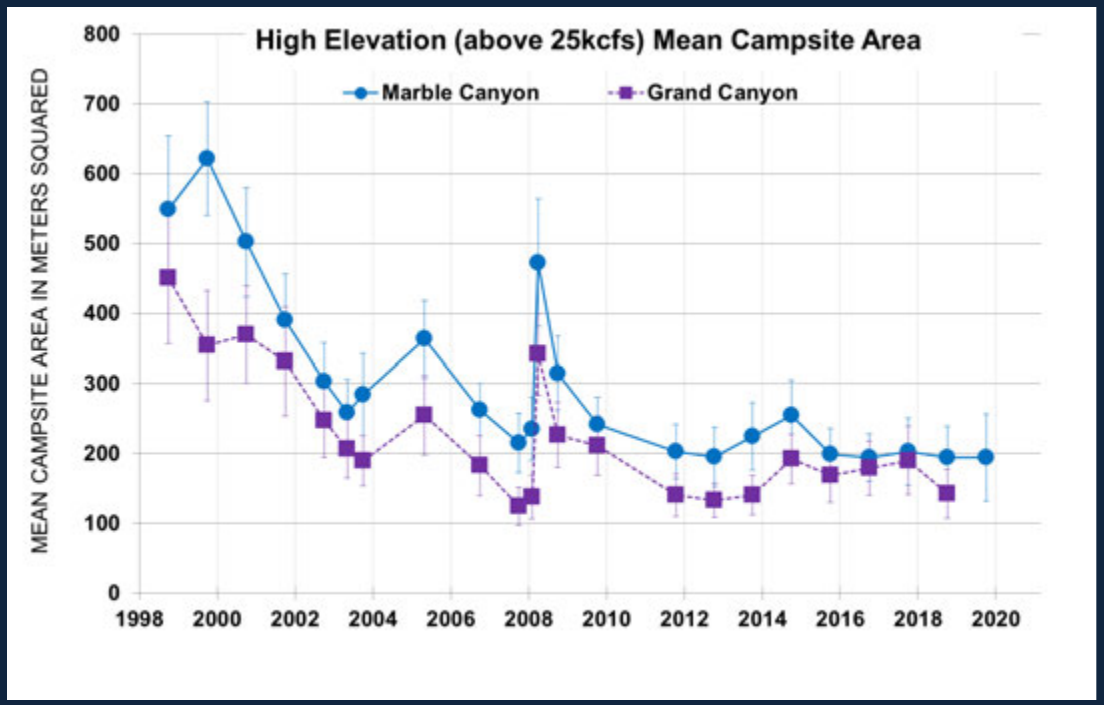
Campsite area in Marble and Grand Canyons



- HFEs increase and maintain campsite area
- Decreases are primarily due to vegetation expansion
- Campsite area declines in years without HFEs
- Trends are similar for both Marble and Grand Canyons

RM 194 L

Summary

- Each HFE since 2012 has resulted in sandbar deposition
- Increases in sandbar size occur at 50% or more of monitoring sites
- There is no difference in site response in different parts of the canyon
  - Marble and Grand Canyon show similar trends
- Although bars erode, they are larger than they would be without HFEs
- HFEs do not scour or remove vegetation
  - Erosion and vegetation encroachment decrease campsite area during the intervening periods between HFEs
- There is evidence for cumulative increases in bar size at some sites whereas others continue to decrease
- The majority of sandbars are those that reliably aggrade during HFEs

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Acknowledgements

Erich Mueller, Daniel Buscombe, Thomas Gushue, Daniel Hamill, James Hensleigh, Robert Ross, Keith Kohl, Jack Schmidt, Laura Kennedy, David Topping, Rod Parnell, Bryan Cooperrider, Karen Koestner, Emily Thompson, Daniel Hadley, Katie Chapman …

In Memoriam: Greg Sponenburgh and Frank Protiva