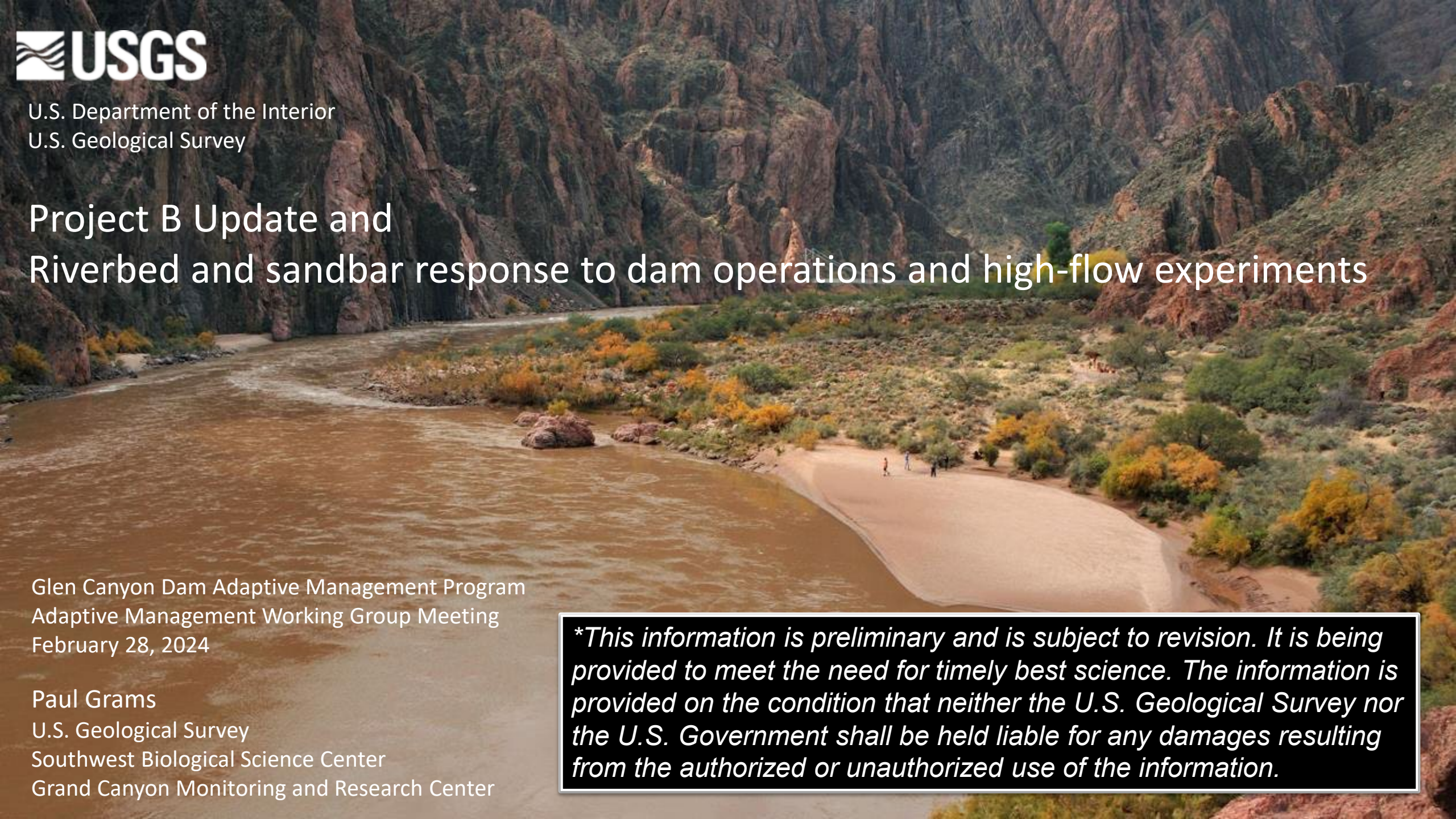


USGS

U.S. Department of the Interior
U.S. Geological Survey

Project B Update and Riverbed and sandbar response to dam operations and high-flow experiments

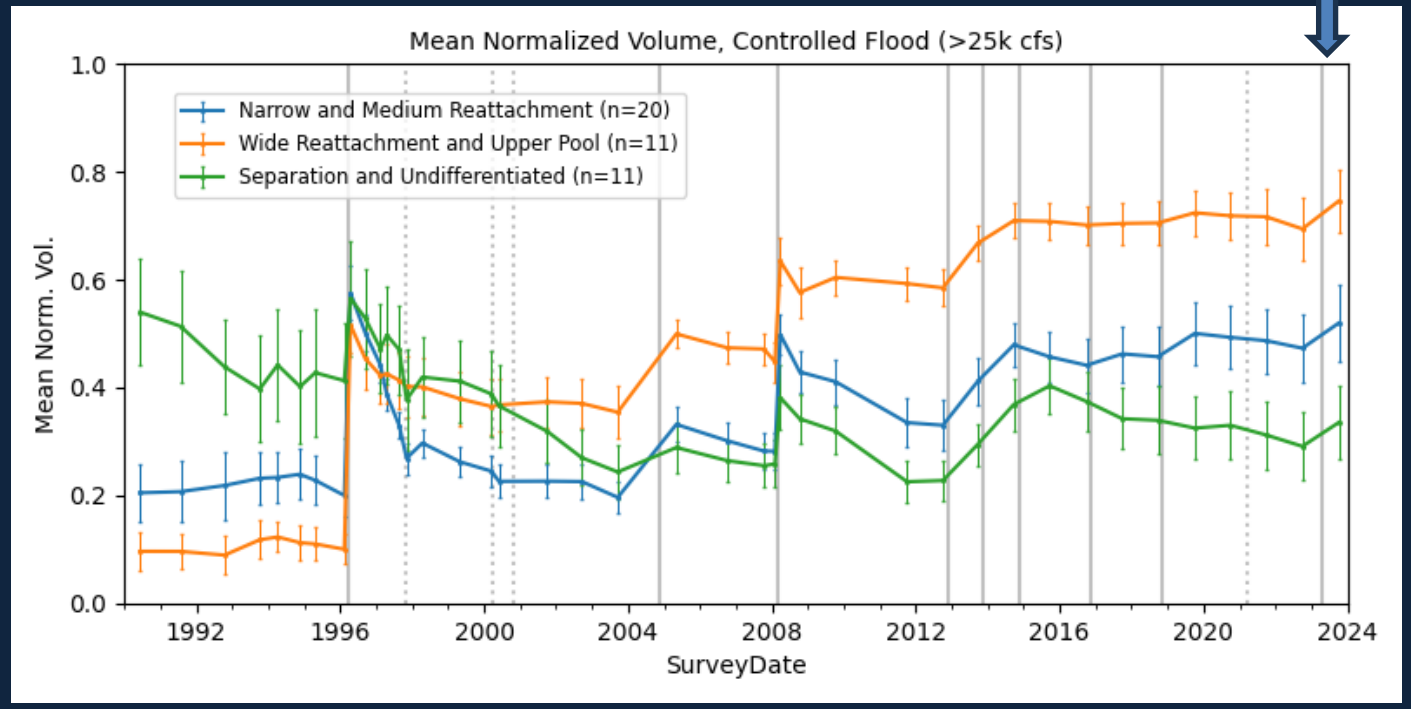
Glen Canyon Dam Adaptive Management Program
Adaptive Management Working Group Meeting
February 28, 2024

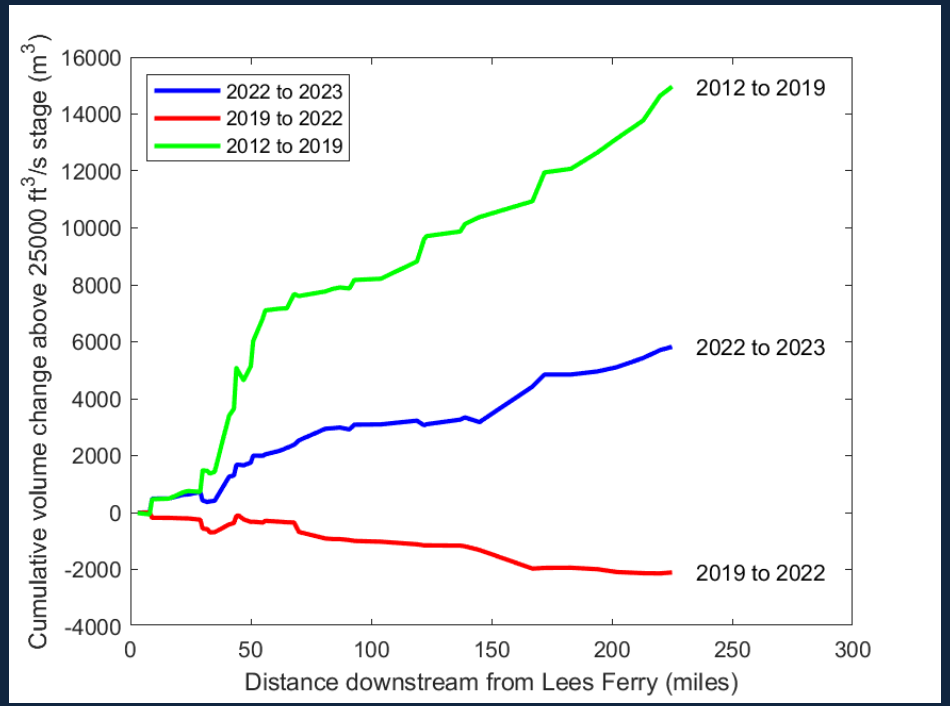
Paul Grams
U.S. Geological Survey
Southwest Biological Science Center
Grand Canyon Monitoring and Research Center

**This information is preliminary and is subject to revision. It is being provided to meet the need for timely best science. The information is provided on the condition that neither the U.S. Geological Survey nor the U.S. Government shall be held liable for any damages resulting from the authorized or unauthorized use of the information.*

Sandbar response to 2023 HFE

2023 HFE





- Reattachment bars and upper pool bars as large or larger compared to 2013-2019
- Separation and undifferentiated bars increased, but not as large as some previous years

- HFE reversed 2019 to 2022 downward trend
- Increases in bar volume at most, but not all, sites

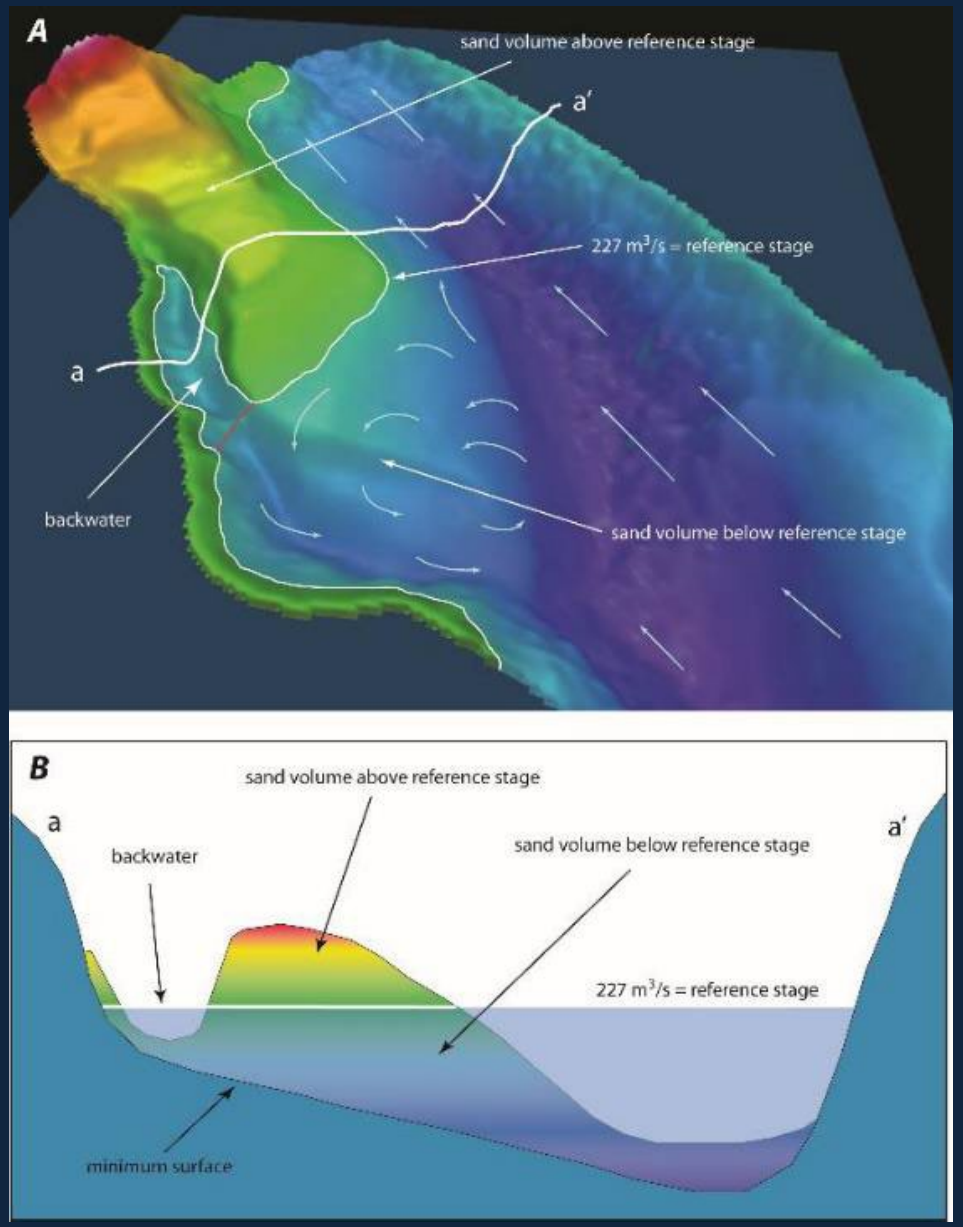
Hazel and others (2022); www.usgs.gov/apps/sandbar

USGS

Why measure sand storage by mapping the riverbed?

- Sandbar replenishment controlled by:
  - Flow (need high flows to build large bars)
  - Sand supply (if supply in the channel is low, a net loss from eddy sandbars is risked)
- Sand supply is controlled by:
  - Dam releases (annual volume and release pattern)
  - Inputs from tributaries

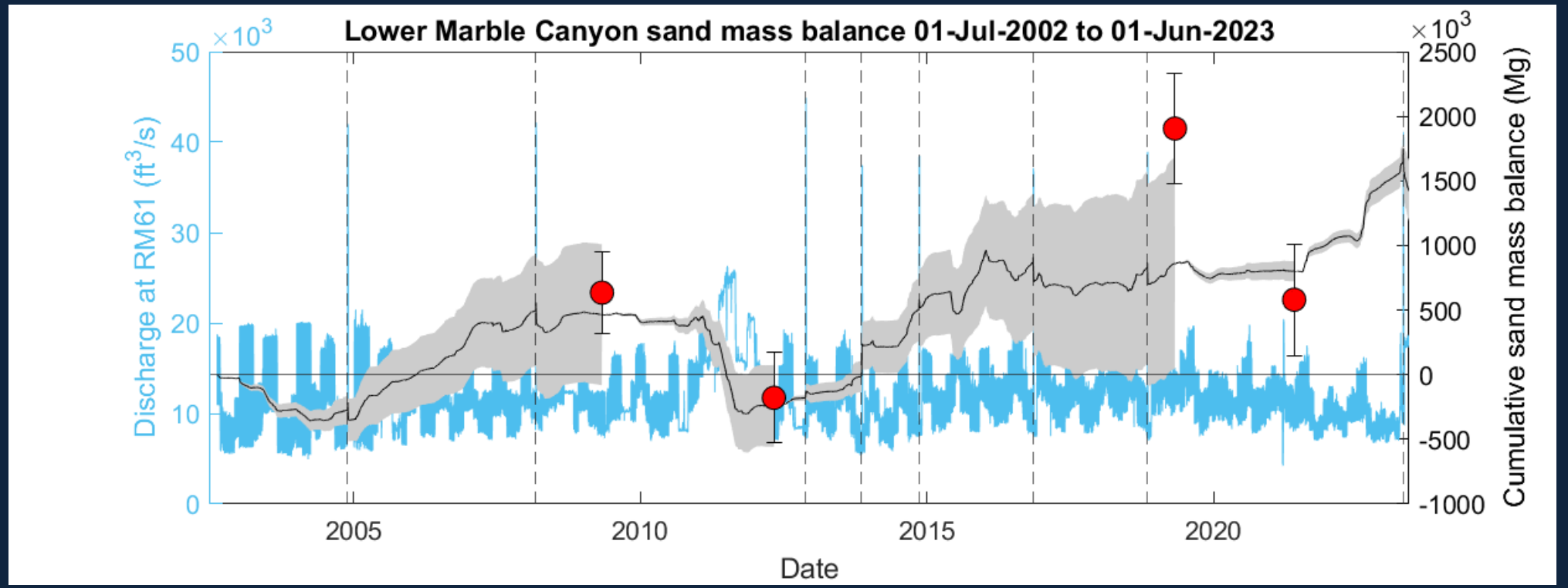
- The sand that builds sandbars is stored on the bed of the river and understanding the sand supply is critical to understanding and predicting sandbar response



Adapted from Hazel and others (2010)

USGS

Repeat channel mapping in Lower Marble Canyon



- Repeat measurements of channel bed (red points) verify mass balance sand budget (black line with gray uncertainty band)
- Sand budget has trended upward with the exception of periods of high dam release volumes (equalization and reservoir balancing flows)

www.gcmrc.gov/discharge_qw_sediment; Grams et al., 2018; and Preliminary results. Do not cite.

USGS

How are channel mapping data used to evaluate the effects of dam operations?

"high-elevation sandbar"

gain

loss

Mining sand from storage to build sandbars	Accumulating sand and building sandbars
Mining sand and losing sandbars	Accumulating sand, but not building sandbars.

loss ⟷ gain

"total sand storage in channel and eddies"

USGS

Repeat channel mapping: Implications for high flows and dam management

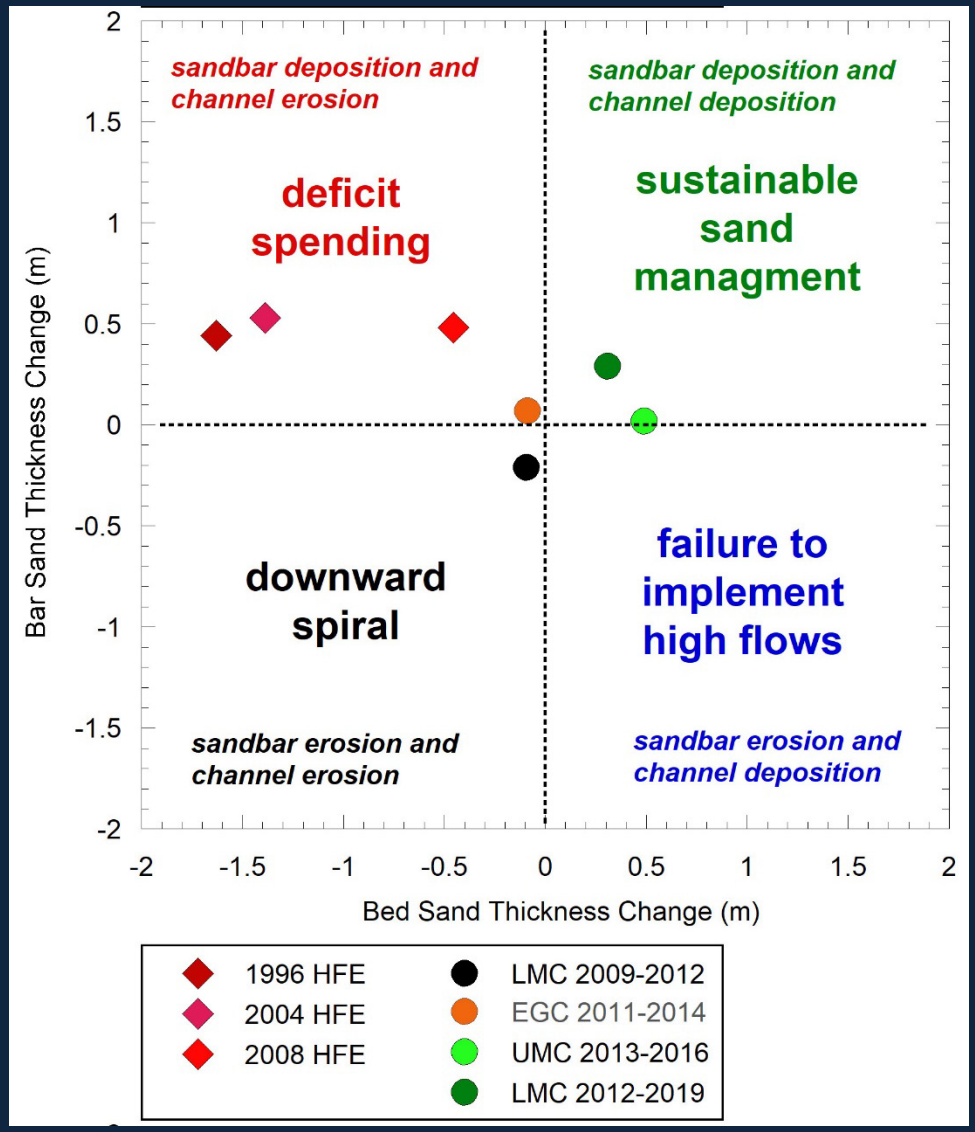
Repeat measurements during HFEs (diamonds)

- HFEs are "deficit spending"
- Need to mobilize all the sand to build sandbars and a large fraction is exported
- But a short-term negative that can be recovered from

Repeat measurements over many years (circles)

- Downward spiral: Equalization flows and no HFEs
- Deficit spending: Equalization flows and HFEs
- Sustainable: No equalization flows and HFEs

The 2004 and 2008 HFEs demonstrated sandbar building under conditions of greater sand enrichment was most effective with less erosion of sand from storage in eddies and channel (Hazel and others, 2010; Schmidt and Grams, 2011).

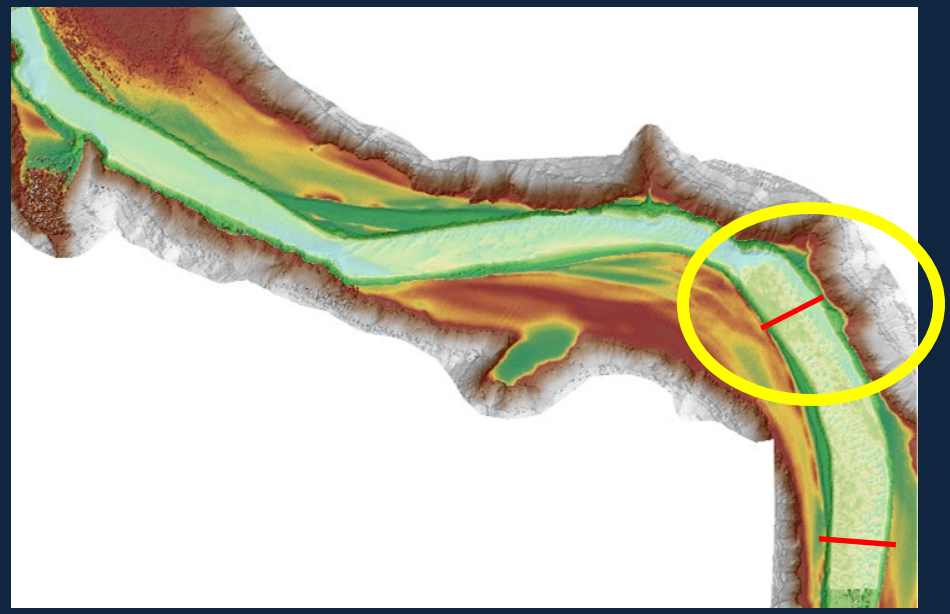


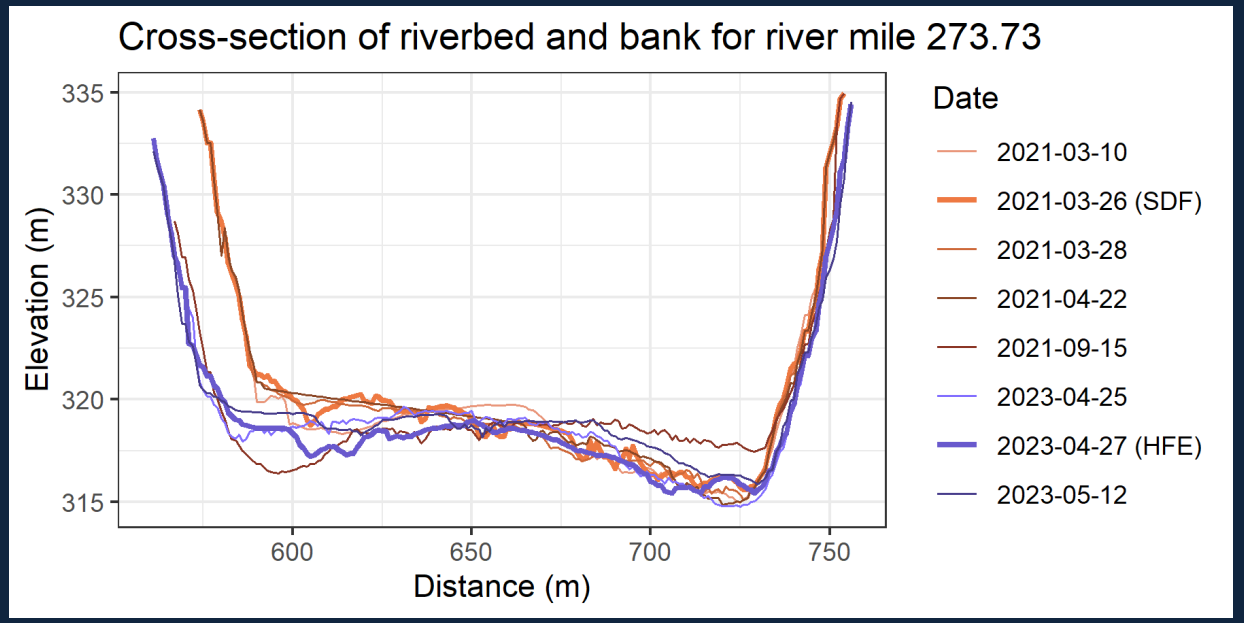
Schmidt and Grams, 2011; Grams et al. 2018; and Preliminary results. Do not cite.

USGS

Project B: Channel Response to High Flows in Western Grand Canyon

- The bed in the reach is dynamic
  - 2 to 3 m of scour and fill in scour holes during high flows (SDF and HFE)
  - ~ 0.5 m of bed variability in dune fields across all flows
  - Slight aggradation of dunes during high flows, but followed by slight erosion after high flows
  - No systematic correlation between bar heights and discharge.
- Mean condition of the channel is relatively stable
  - Likely controlled by downstream Pearce Ferry Rapid
- Banks are eroding but erosion rate does not appear to be accelerated by HFEs

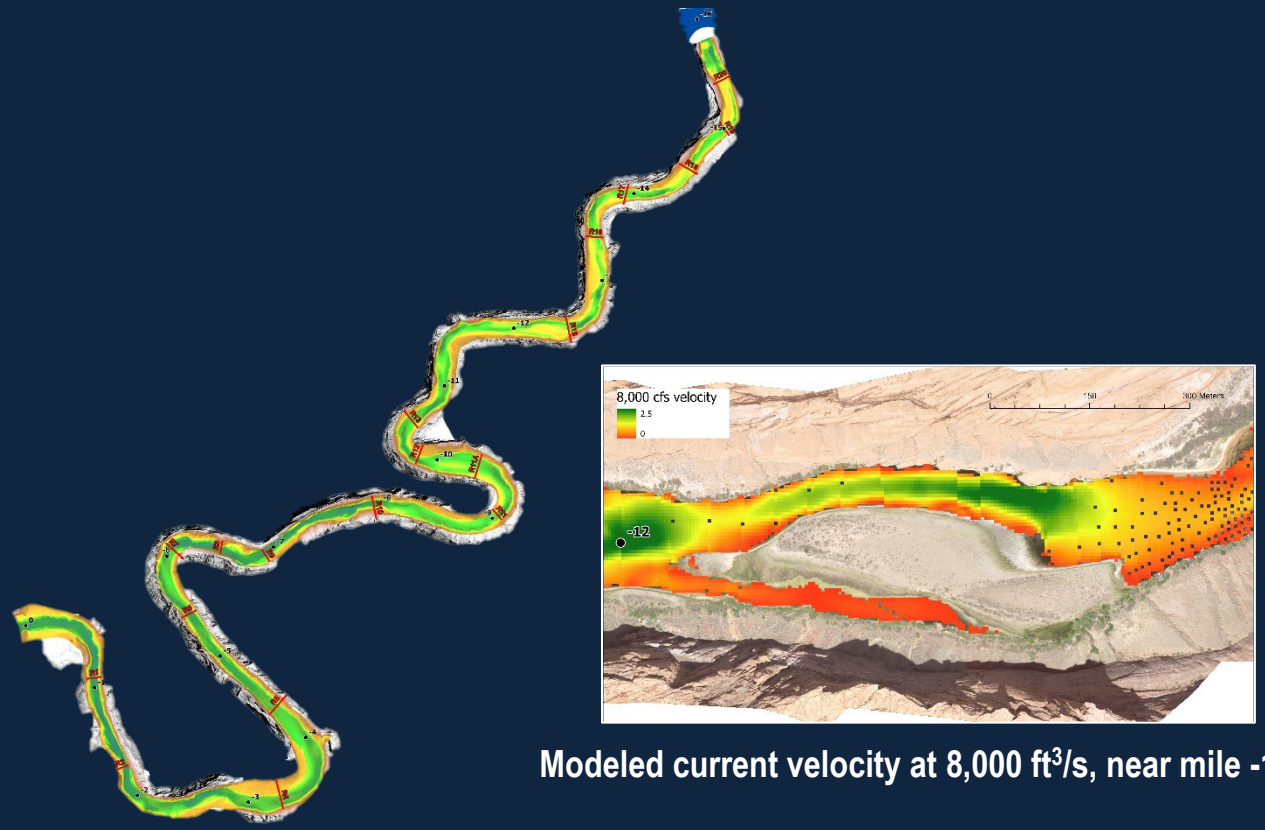




USGS

Project B: Modeling

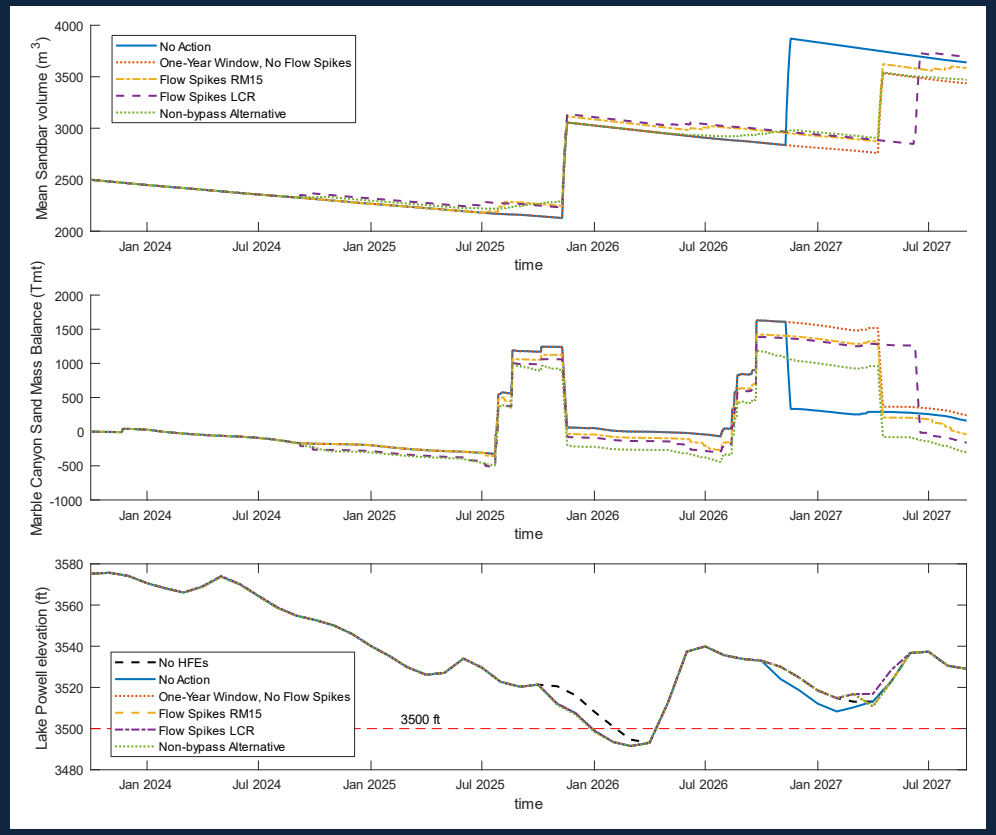
Two-dimensional hydrodynamic model for Glen Canyon



Modeled current velocity at 8,000 ft^3/s, near mile -12.

Wright, S.A., Kaplinski, M., and Grams, P.E., 2024, Hydrodynamic model of the Colorado River, Glen Canyon Dam to Lees Ferry in Glen Canyon National Recreation Area, Arizona: tables of model results and accuracy assessment: U.S. Geological Survey data release, https://doi.org/10.5066/P1QTRNEB.

Sand mass balance and sandbar modeling for Reclamation compliance (IG SEIS and LTEMP SEIS)



Salter and Grams, in review, do not cite.

Project B References

- Grams, P. E., Topping, D. J., Schmidt, J. C., Hazel, J. E., & Kaplinski, M. (2013). Linking morphodynamic response with sediment mass balance on the Colorado River in Marble Canyon: Issues of scale, geomorphic setting, and sampling design. Journal of Geophysical Research, 118, 21. https://doi.org/doi:10.1002/jgrf.20050
- Grams, P. E., Buscombe, D., Topping, D. J., Kaplinski, M., & Hazel, J. E. (2018). How many measurements are required to construct an accurate sand budget in a large river? Insights from analyses of signal and noise. *Earth Surface Processes and Landforms*, *44*(1), 160 178. https://doi.org/10.1002/esp.4489
- Hazel Jr., J. E., Grams, P. E., Schmidt, J. C., & Kaplinski, M. (2010). Sandbar response following the 2008 high flow experiment on the Colorado River in Marble and Grand Canyons. U.S. Geological Survey Scientific Investigations Report 2010 5015, 52 p. http://pubs.usgs.gov/sir/2010/5015
- Hazel, J.E., Jr., Kaplinski, M.A., Hamill, D., Buscombe, D., Mueller, E.R., Ross, R.P., Kohl, K., and Grams, P.E., 2022, Multi decadal sandbar response to flow management downstream from a large dam The Glen Canyon Dam on the Colorado River in Marble and Grand Canyons, Arizona: U.S. Geological Survey Professional Paper 1873, https://doi.org/10.3133/pp1873
- Mueller, E.R., and Grams, P.E., 2021, A morphodynamic model to evaluate long term sandbar rebuilding using controlled floods in the Grand Canyon: Geophysical Research Letters, v. 48, no. 9, e2021GL093007, https://doi.org/10.1029/2021GL093007.
- Schmidt, J. C., & Grams, P. E. (2011). The high flows physical science results. In T. S. Melis (Ed.), Effects of three high flow experiments on the Colorado River ecosystem downstream from Glen Canyon Dam, Arizona, U.S. Geological Survey Circular 1366 (pp. 53 91). https://pubs.usgs.gov/circ/1366/
- Topping, D. J., Rubin, D. M., & Vierra, L. E. (2000). Colorado River sediment transport 1. Natural sediment supply limitation and the influence of Glen Canyon Dam. Water Resources Research, 36(2), 515 542. https://doi.org/10.1029/1999WR900285
- Wiele, S.M., Andrews, E.D., and Griffin, E.R., 1999, The effect of sand concentration on depositional rate, magnitude, and location in the Colorado River below the Little Colorado River, in Webb, R.H., Schmidt, J.C., Marzolf, G.R., and Valdez, R.A., eds., The controlled flood in Grand Canyon: Washington, D.C., American Geophysical Union, Geophysical Monograph Series, v. 110, p. 131 145.
- Wright, S.A., Topping, D.J., Rubin, D.M., and Melis, T.S., 2010, An approach for modeling sediment budgets in supply limited rivers: Water Resources Research, v. 46, p. 1 18, doi:10.1029/2009WR008600.
- U.S. Department of the Interior, 1996, Record of Decision, Operation of Glen Canyon Dam Final Environmental Impact Statement.
- U.S. Department of the Interior, 2016, Record of Decision for the Glen Canyon Dam Long Term Experimental and Management Plan Final Environmental Impact Statement, https://ltempeis.anl.gov/

USGS