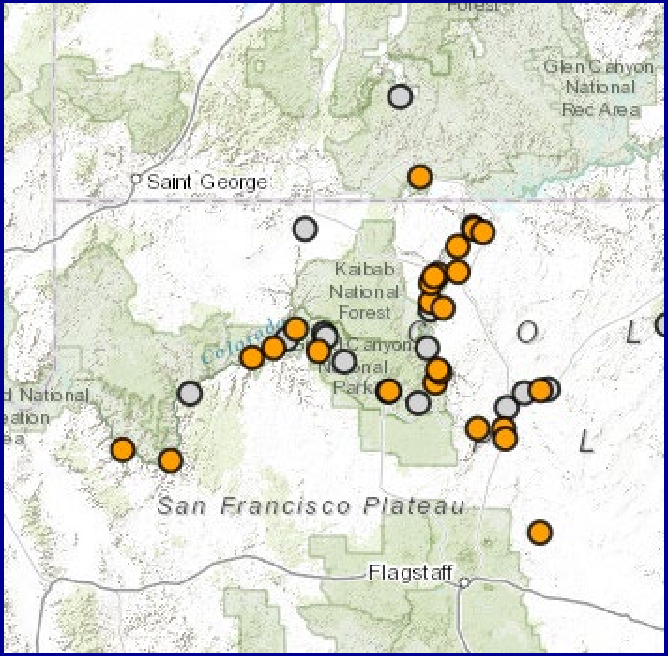
Project A: Streamflow, Water Quality, and Sediment Transport and Budgeting in the Colorado River Ecosystem

Project A collects the physical data that directly link dam operations to all resources in the downstream Colorado River; data inform 10 LTEMP goals; data used to trigger, design, and evaluate HFEs



- Element 1: Stream gaging
  - Stage
  - Discharge
- Element 2: Water quality
  - Water temperature
  - Salinity (specific conductance)
  - Turbidity
  - Dissolved Oxygen
- Element 3: Sediment transport and budgeting
  - Suspended- and bed-sediment data
  - Sediment loads (silt and clay loads and sand loads)
  - User-interactive sand budgets in 6 reaches from Lees Ferry to Lake Mead

- All elements
  - Database and website

Evaluation of LTEMP fine-sediment management

Increase and retain fine sediment [sand, silt, and clay] volume, area, and distribution in the Glen, Marble, and Grand Canyon reaches above the elevation of the average base flow for ecological, cultural, and recreational purposes.

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Basics of sand management

- Sand supply is <5% of natural
- Keep dam releases low for part to much of the year to accumulate sand **OR**

RECLAMATION
Managing Water in the West

Colorado River Ecosystem
Sediment Augmentation
Appraisal Engineering Report

Randle and others (2007)

- Episodic short-duration artificial floods (HFEs) to rebuild sandbars
- Avoid sustained high releases (e.g., equalization) that greatly exceed the sand supply and result in widespread erosion

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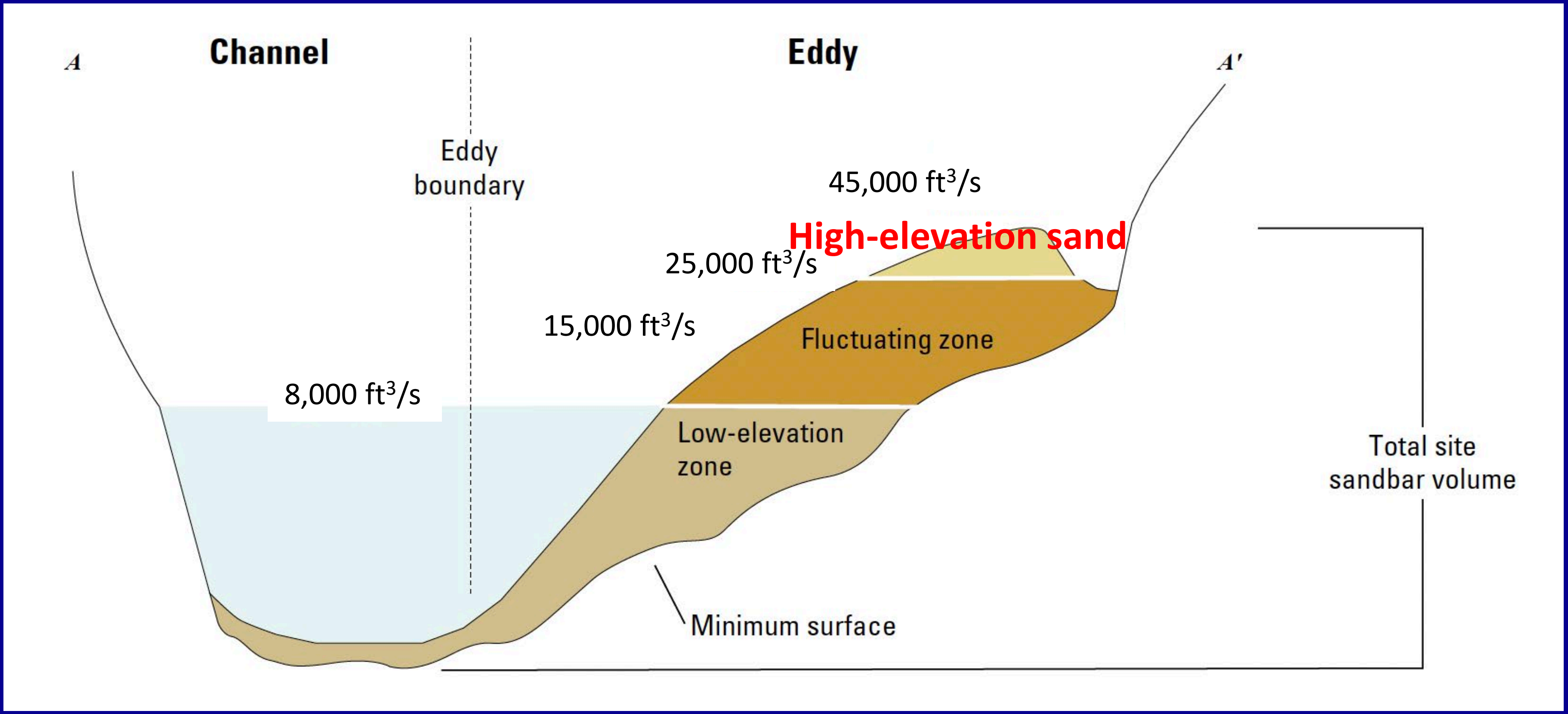


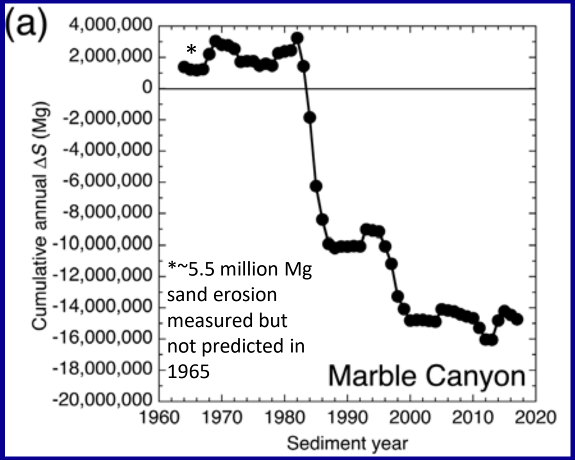
Figure modified from Hazel and others (*USGS-PP*, 2022)

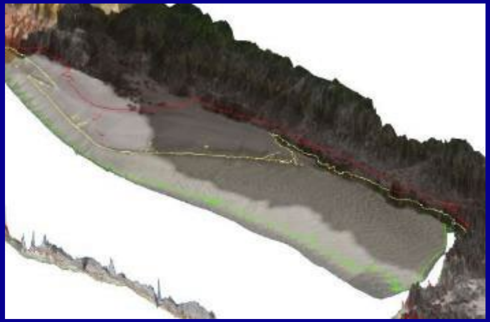
- ~30–50% of the sand stored in sandbars is relict “pre-dam” sand (Chapman and others, *GSA Bulletin*, 2020)
- Stratigraphic and ground-penetrating-radar data indicate pre-dam sand at depth in at least some sandbars (Barnhardt and others, *USGS-OFR*, 2001)
- By suspended-sediment theory, nonlinear lesser amounts of finer grain sizes are required on the bed to support the same amount of sediment in suspension

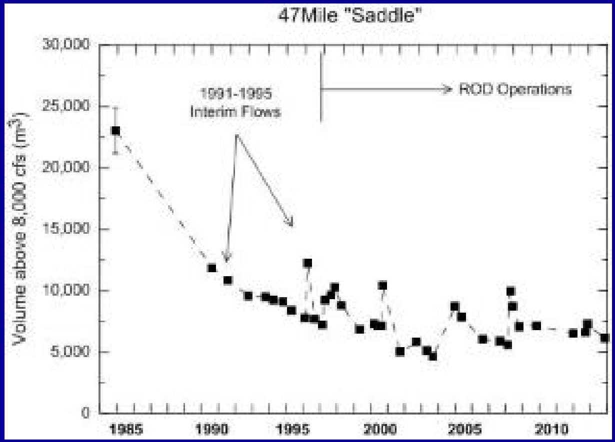
Downward spiral has likely occurred in long-term sand mass balance… and reflected in at least some of the sandbars

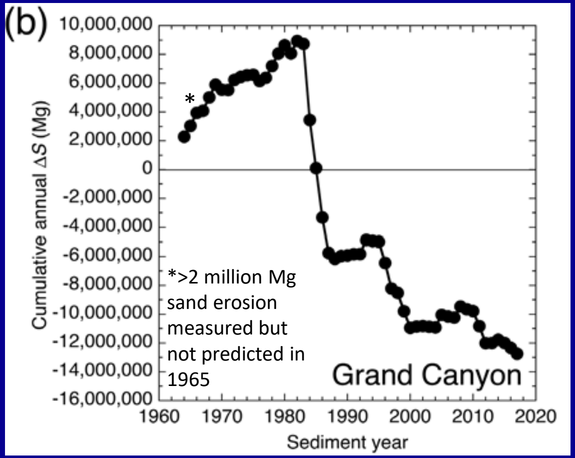
>28 million metric tons of sand eroded since 1963, mostly during 3–4 periods of high dam releases (Topping and others, *JGR*, 2021)

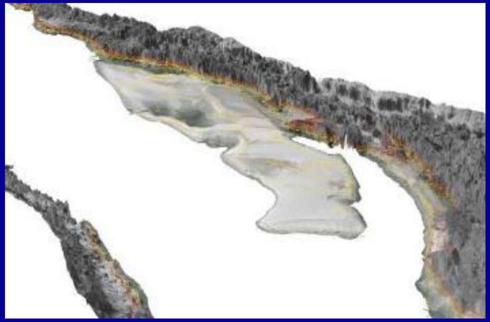
~12 million metric tons eroded in late 1990s alone (6 from Marble and 6 from Grand)

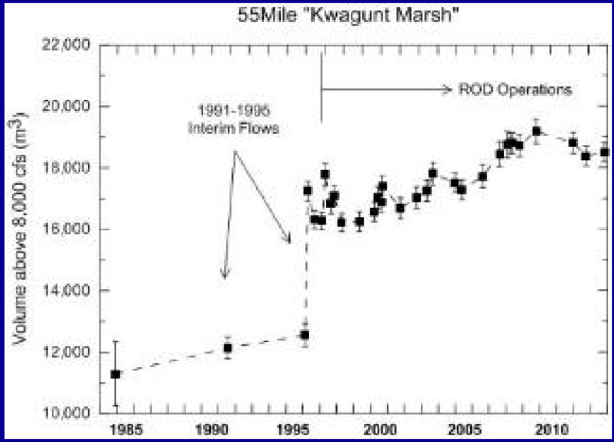










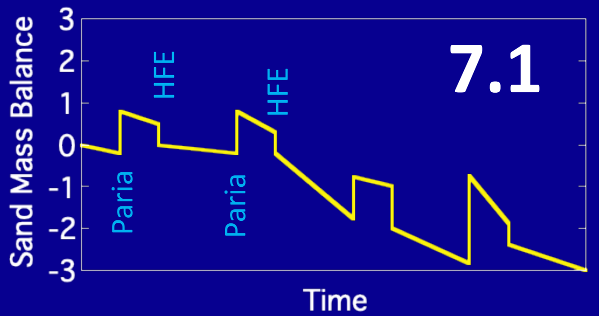


Figures from Topping and others (*JGR*, 2021)

Preliminary figures from Gushue, Weber, Grams, Hazel (do not cite)

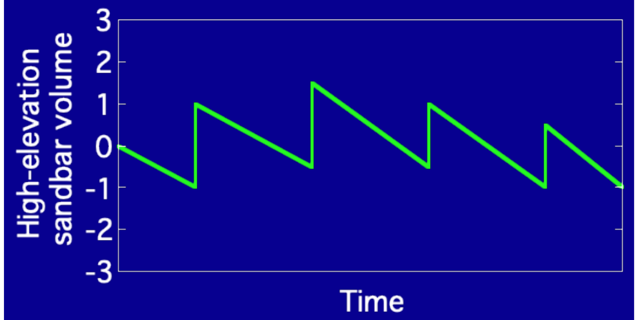
Sustainable management of sand under the LTEMP sediment goal thus requires neutral to positive trends in both **METRIC 1**, the sand supply (i.e., the sand mass balance bank account) and **METRIC 7.2.1**, the high-elevation sandbar volume (i.e., your expenditures) over multiple years

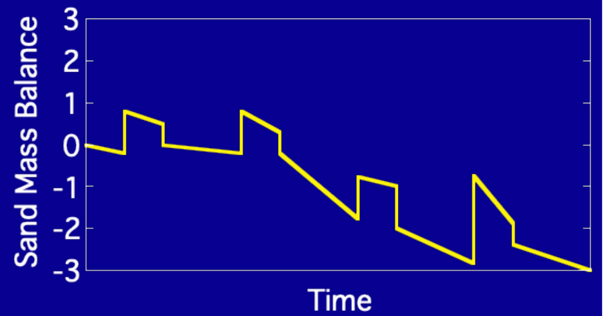
Scenario 1



Not sustainable

Scenario 2



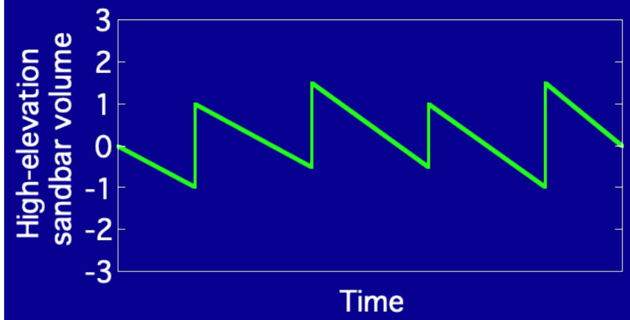


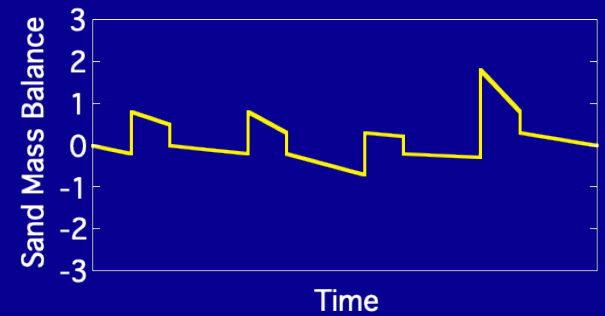
Not sustainable

Bank account mined to deposit sandbars

"Living on credit"

Scenario 3

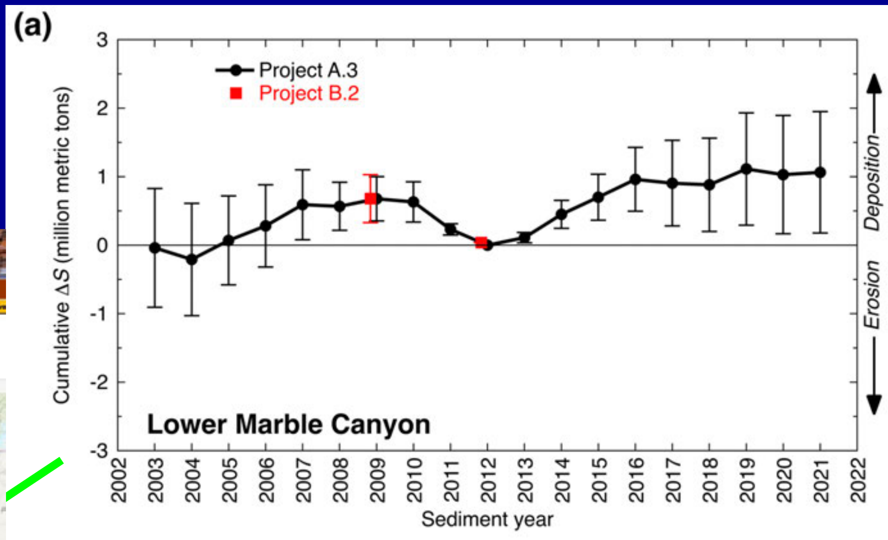


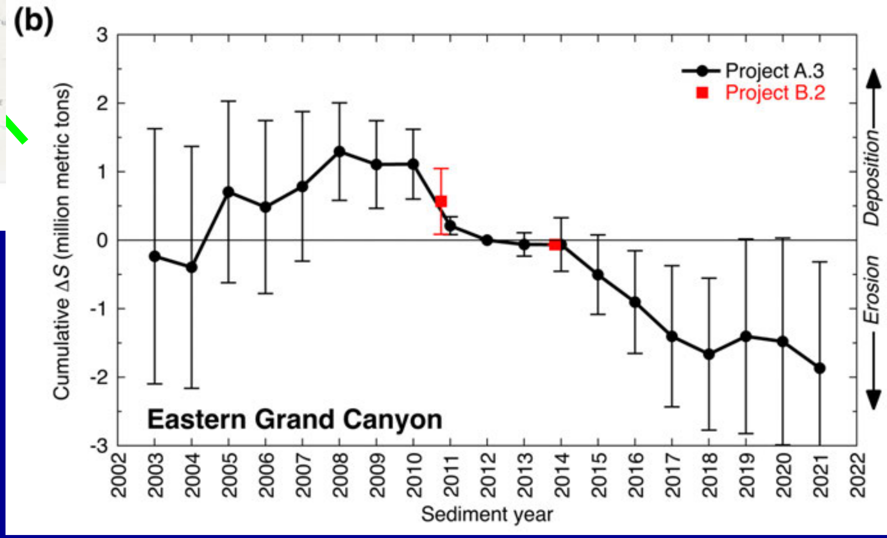


Sustainable

"Living within your means"

Metrics Example: 7.1



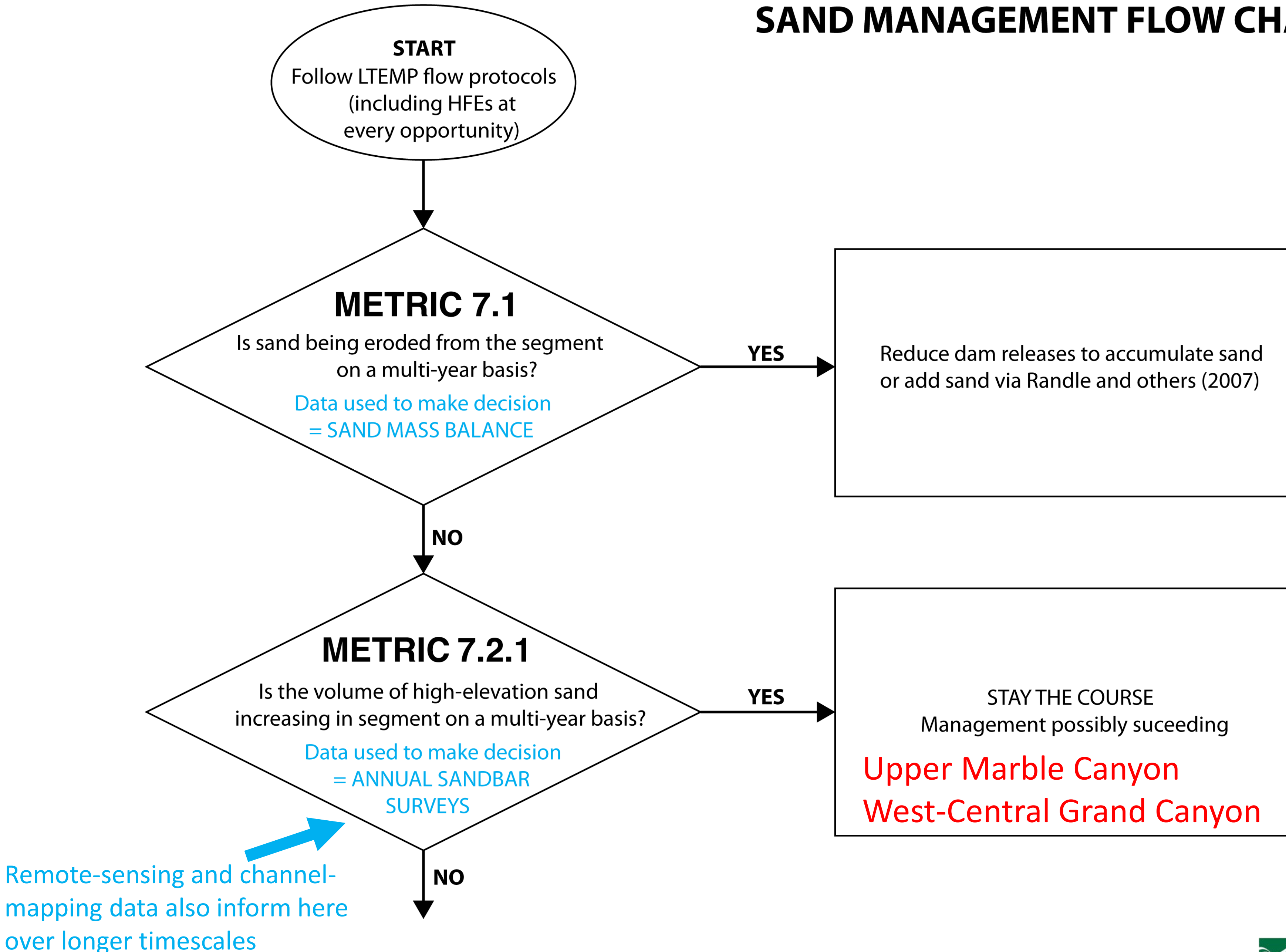


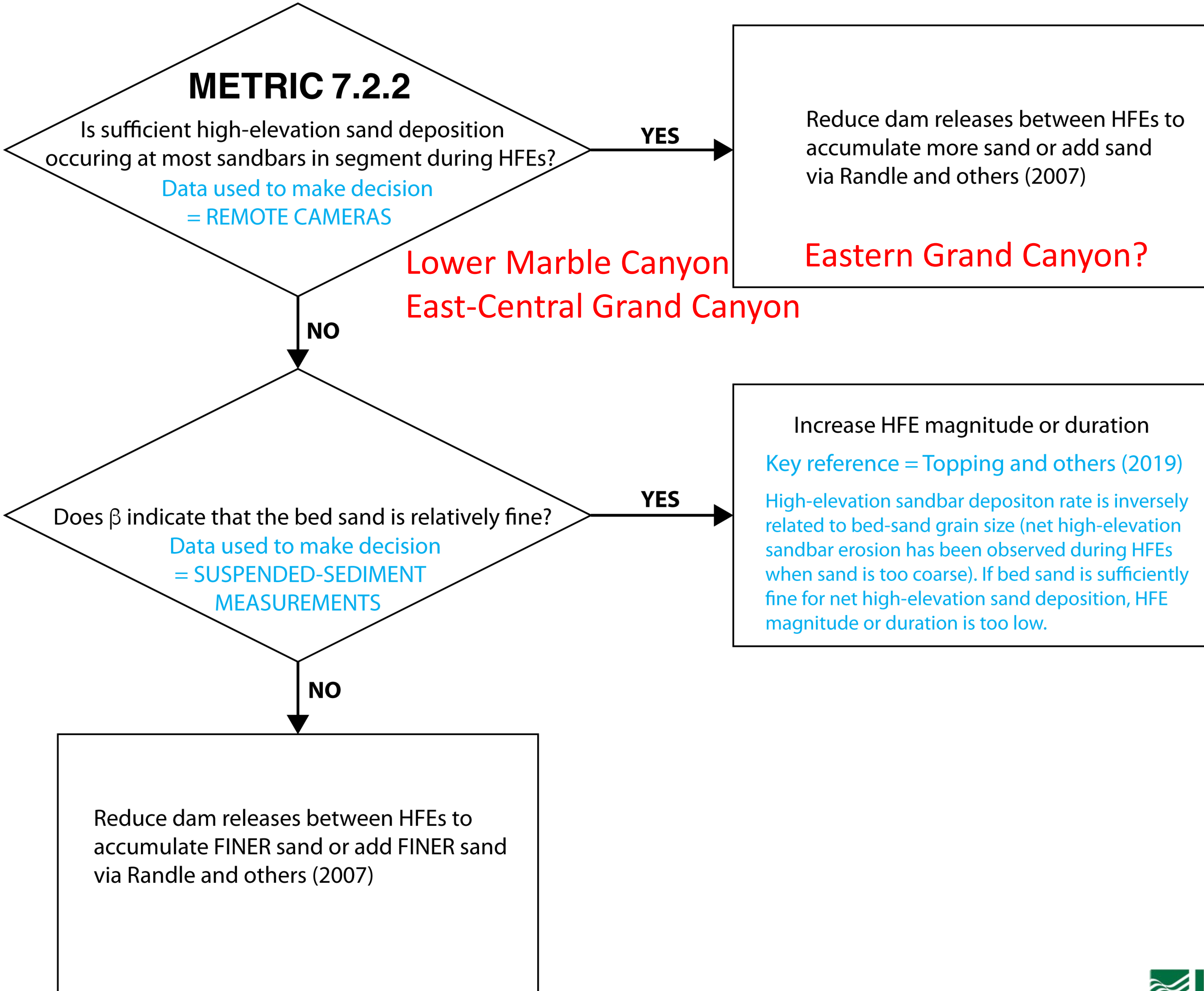
POSSIBLE SUCCESS! Sustainable in Lower Marble Canyon if high-elevation sandbar volume is positive during this period.

POSSIBLE FAILURE Not sustainable in Eastern Grand Canyon regardless of whether high-elevation sandbar volume is positive during this period.

Data from Topping and others (*JGR*, 2021); USGS (2025a)

SAND MANAGEMENT FLOW CHART





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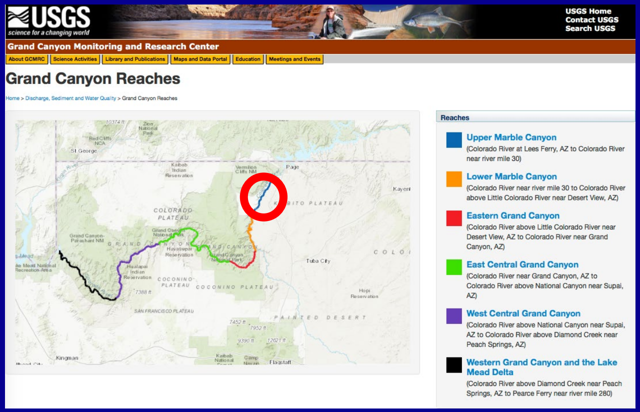
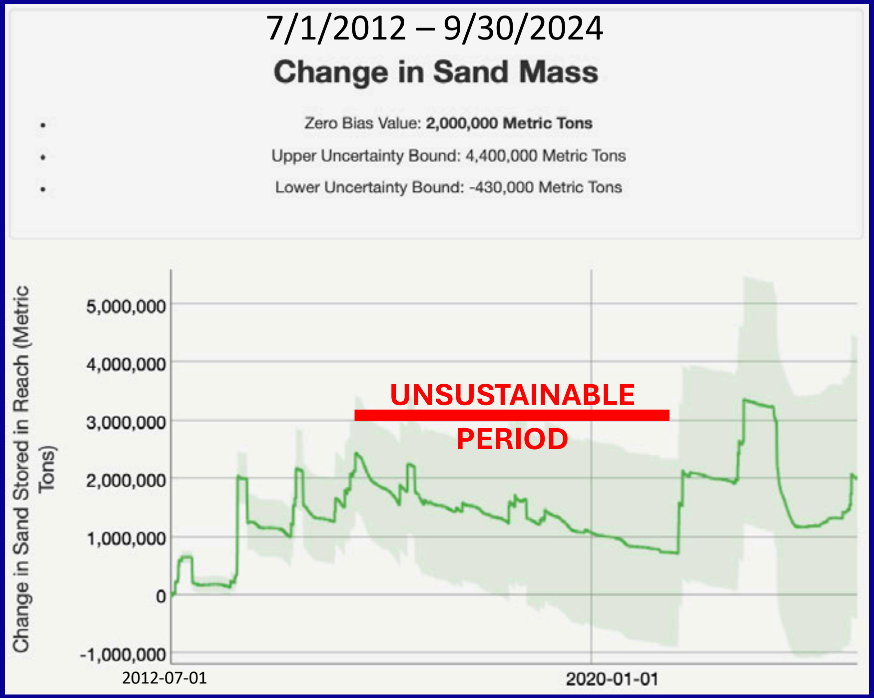
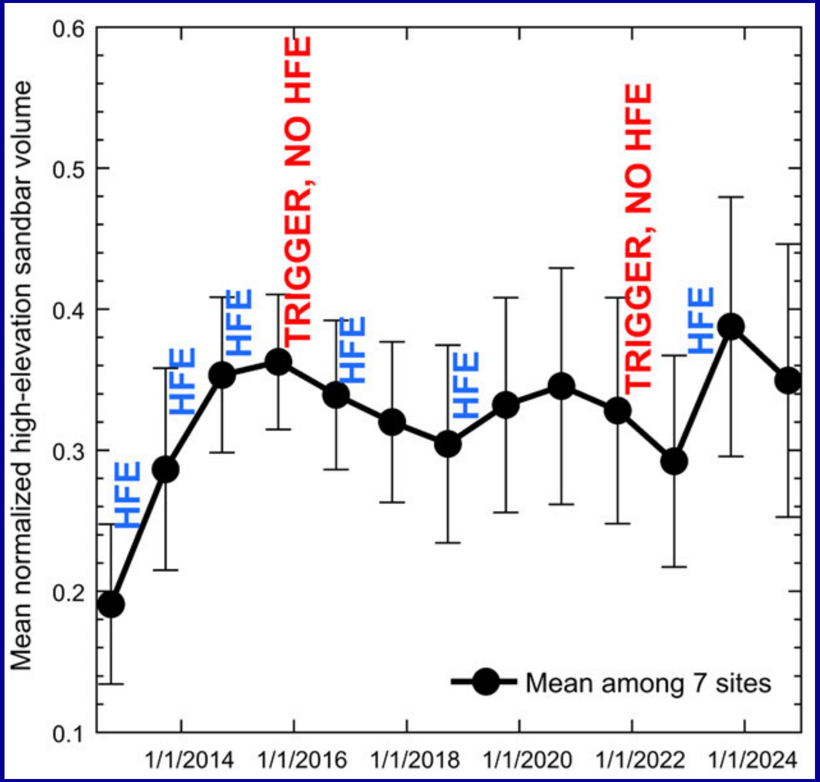
HFE-Protocol/LTEMP Period
Upper Marble Canyon





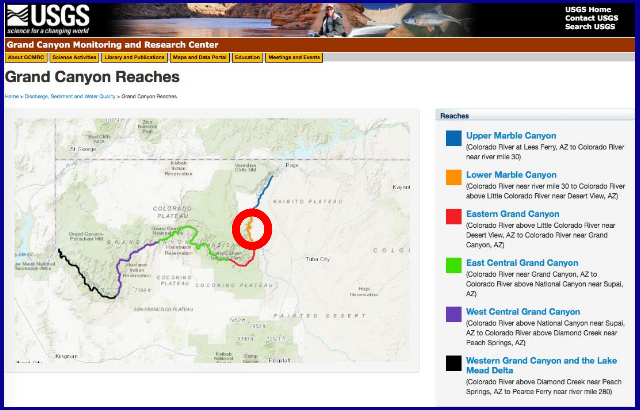


POSITIVE

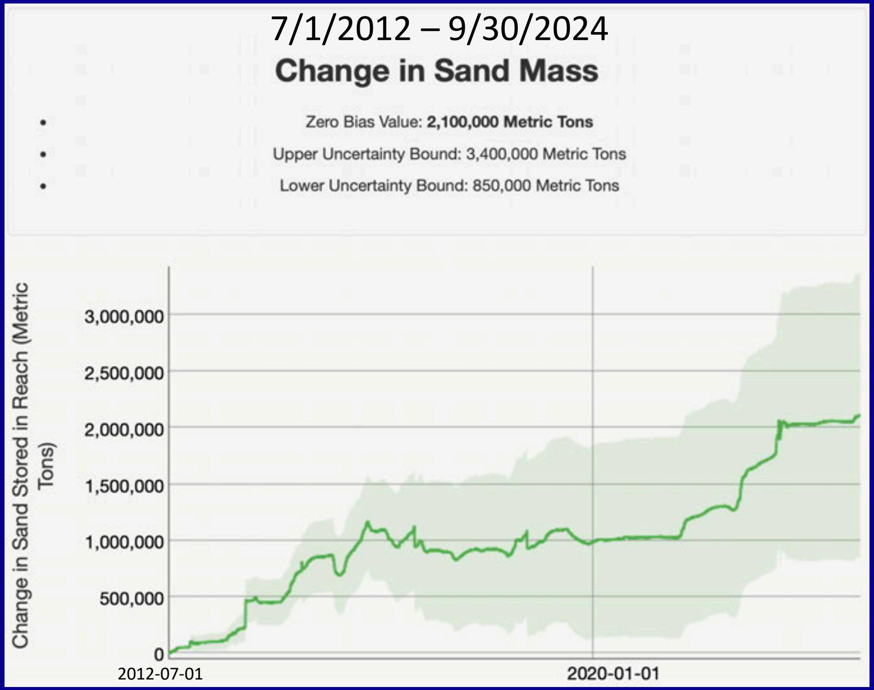
MOSTLY POSITIVE AFTER HFE YEARS

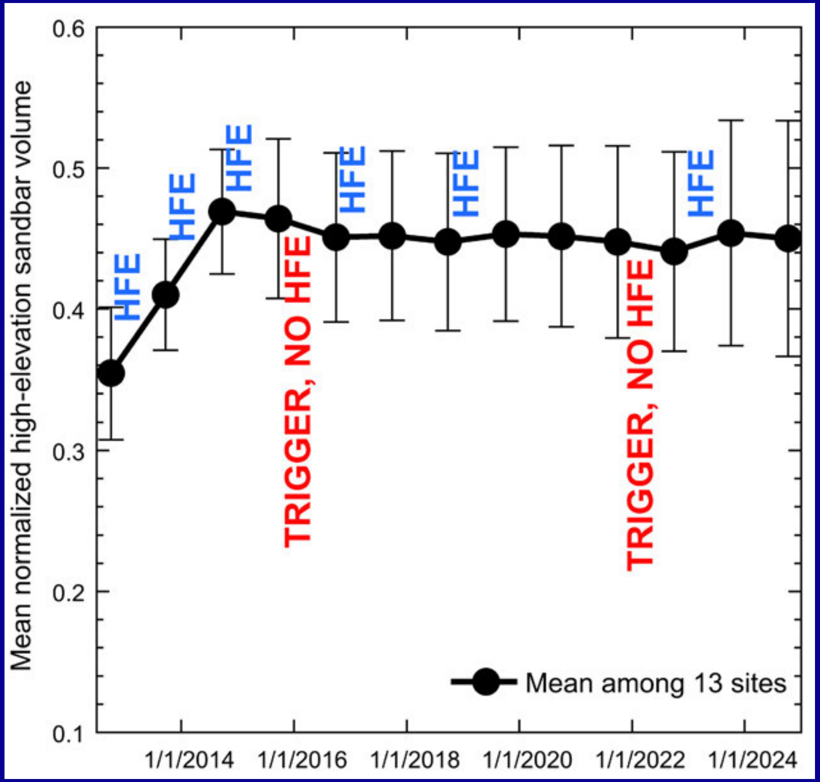
Possibly sustainable

Data from USGS (2025a, b)



HFE-Protocol/LTEMP Period Lower Marble Canyon



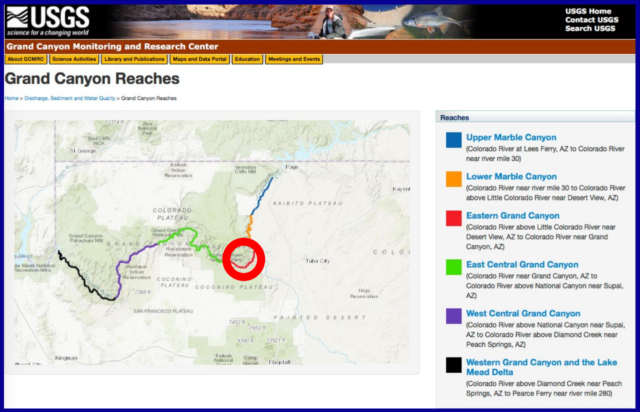


POSITIVE

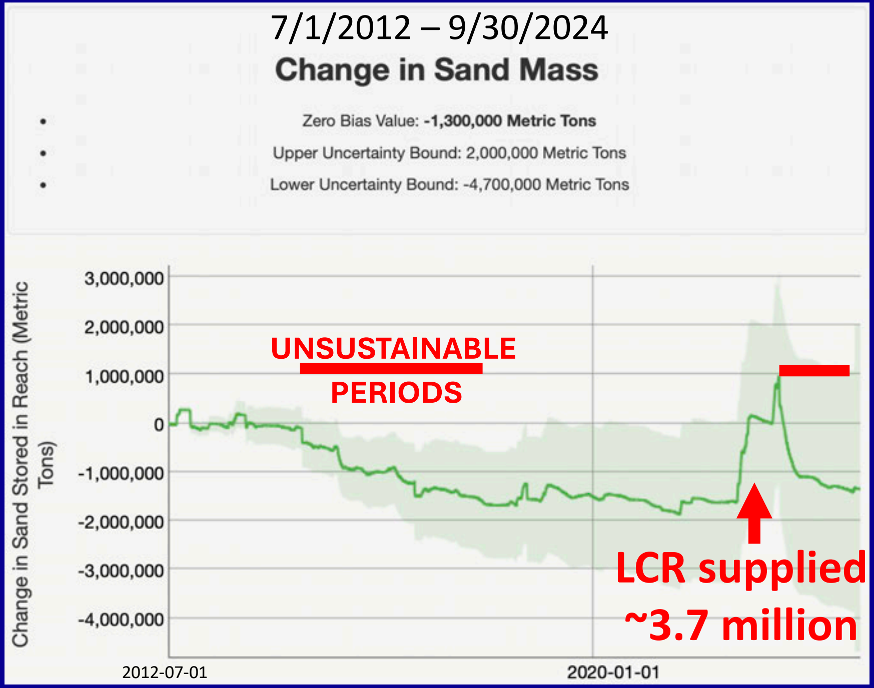
POSITIVE AFTER ONLY FIRST 2 HFE YEARS

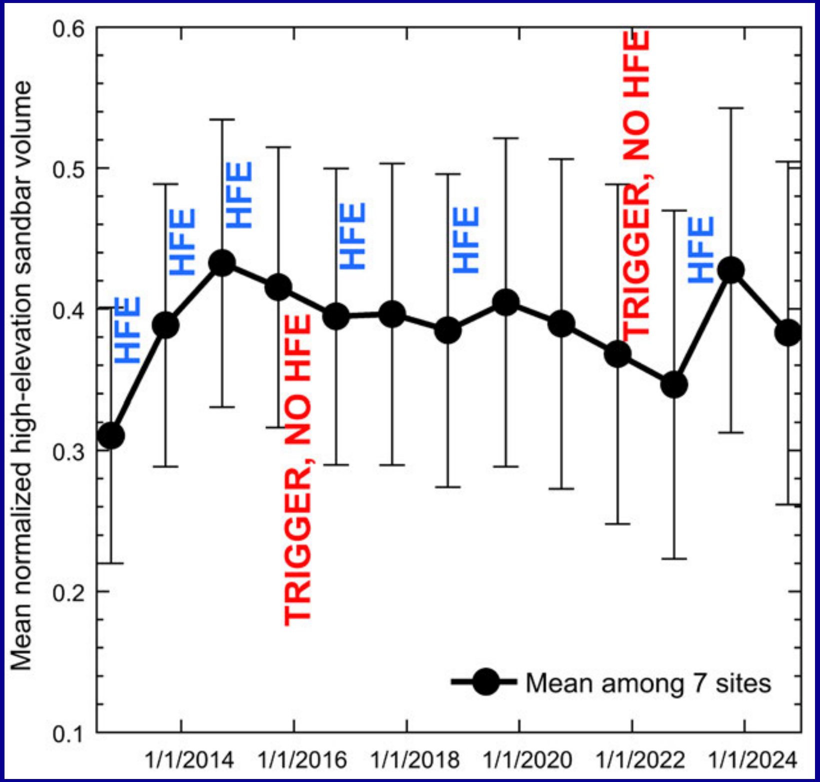
Insufficient HFE magnitude/duration or intervening flows too high?

Data from USGS (2025a, b)



HFE-Protocol/LTEMP Period
Eastern Grand Canyon



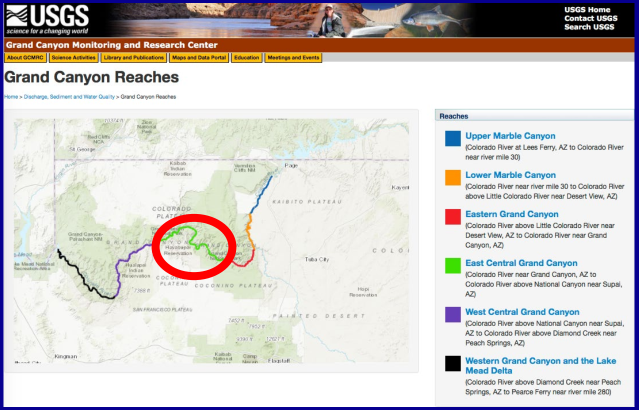


INDETERMINATE

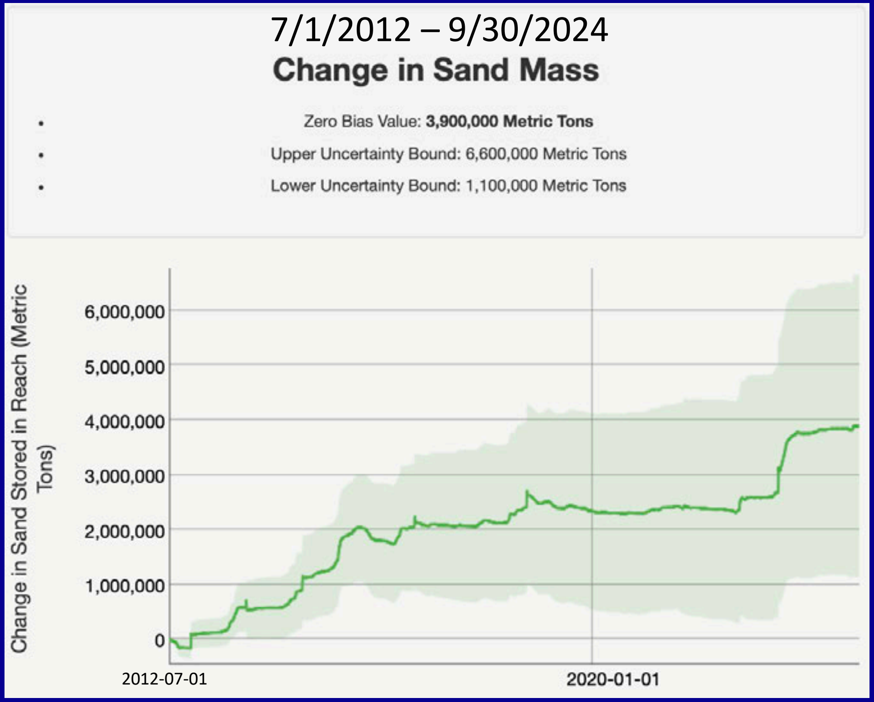
POSITIVE AFTER HALF OF HFE YEARS

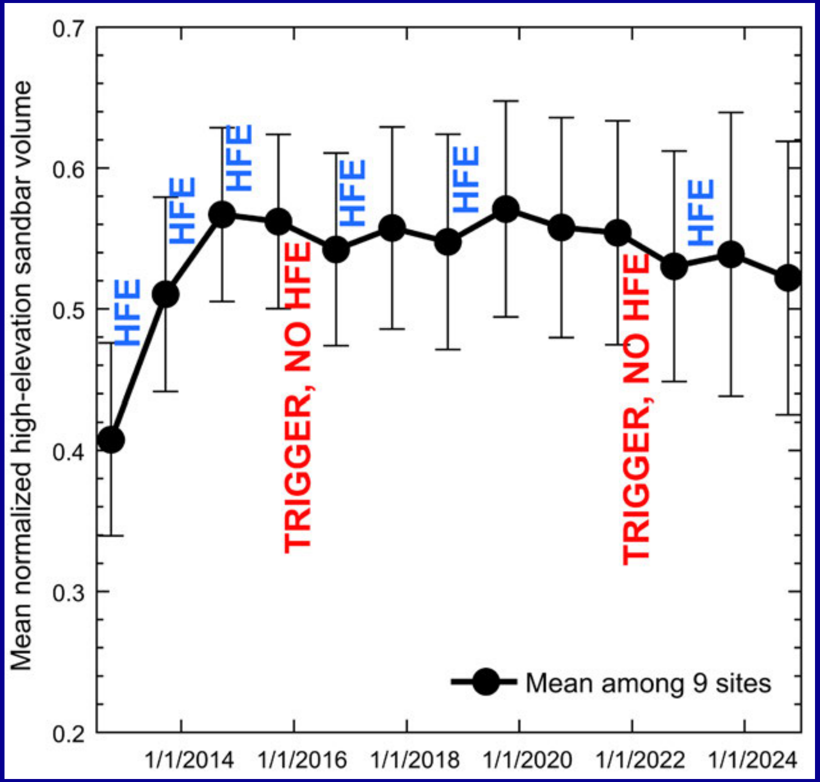
Intervening flows likely too high; saved by the LCR in Jul 2022–Mar 2023

Data from USGS (2025a, b)



HFE-Protocol/LTEMP Period East-Central Grand Canyon





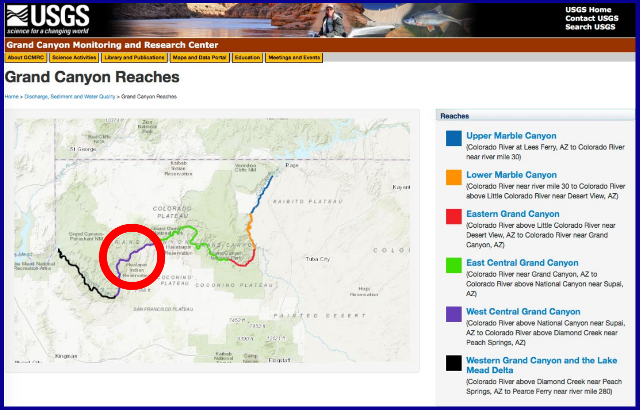
POSITIVE

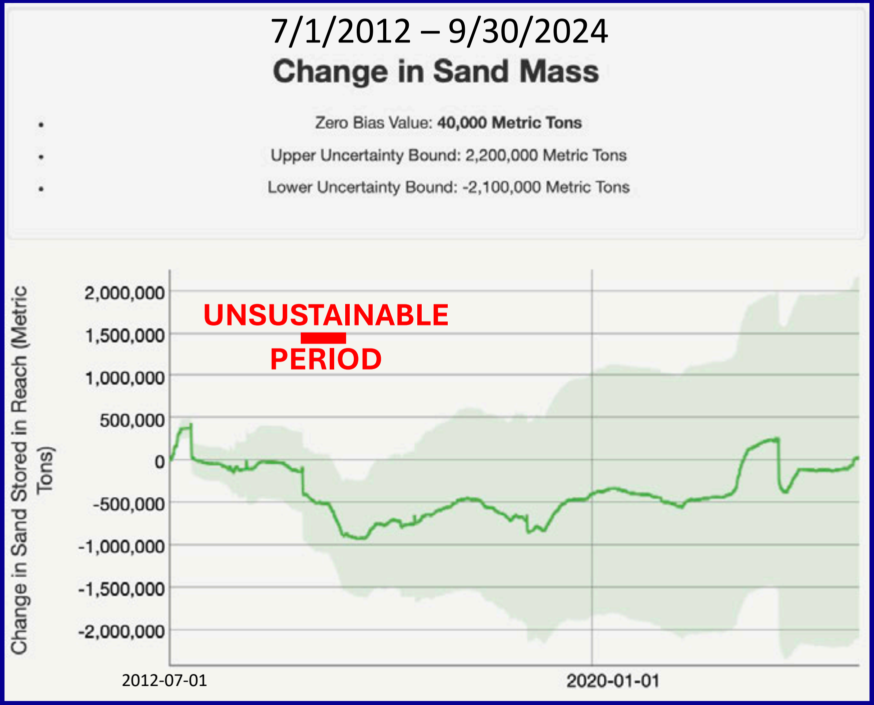
POSITIVE AFTER HALF OF HFE YEARS(?)

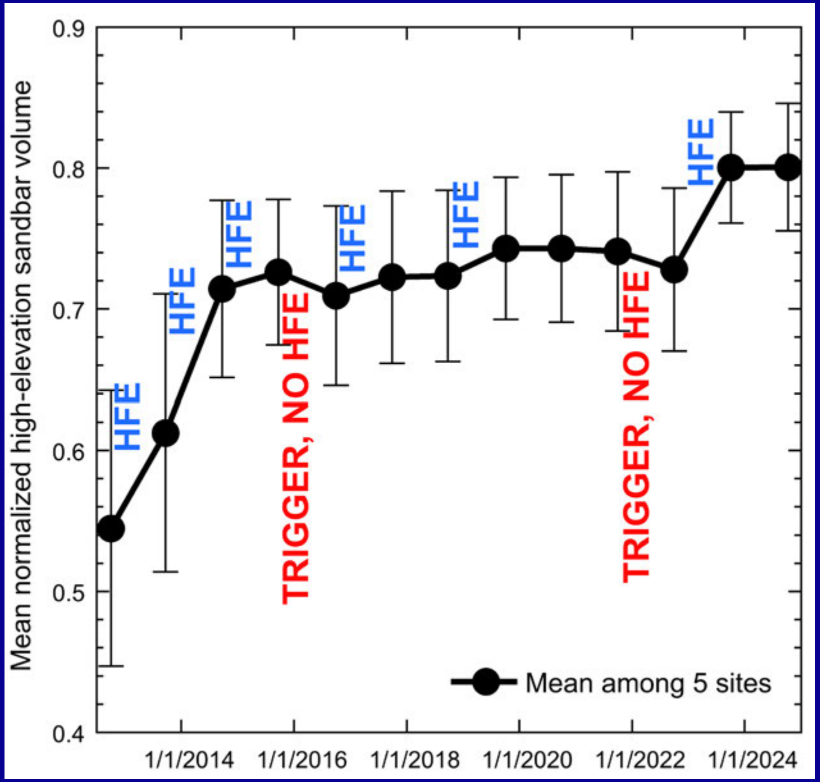
Insufficient HFE magnitude/duration or intervening flows too high?

Data from USGS (2025a, b)

HFE-Protocol/LTEMP Period West-Central Grand Canyon





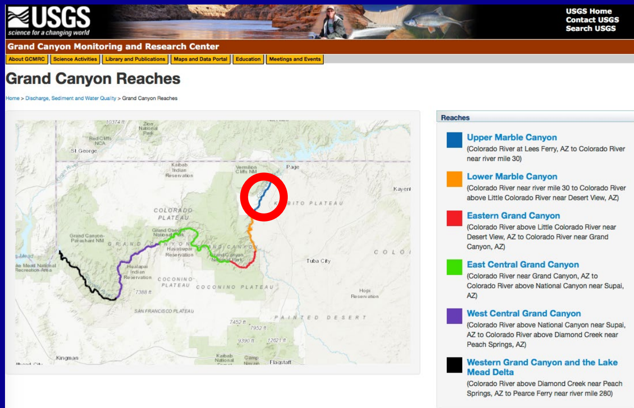


INDETERMINATE

MOSTLY POSITIVE AFTER HFE YEARS

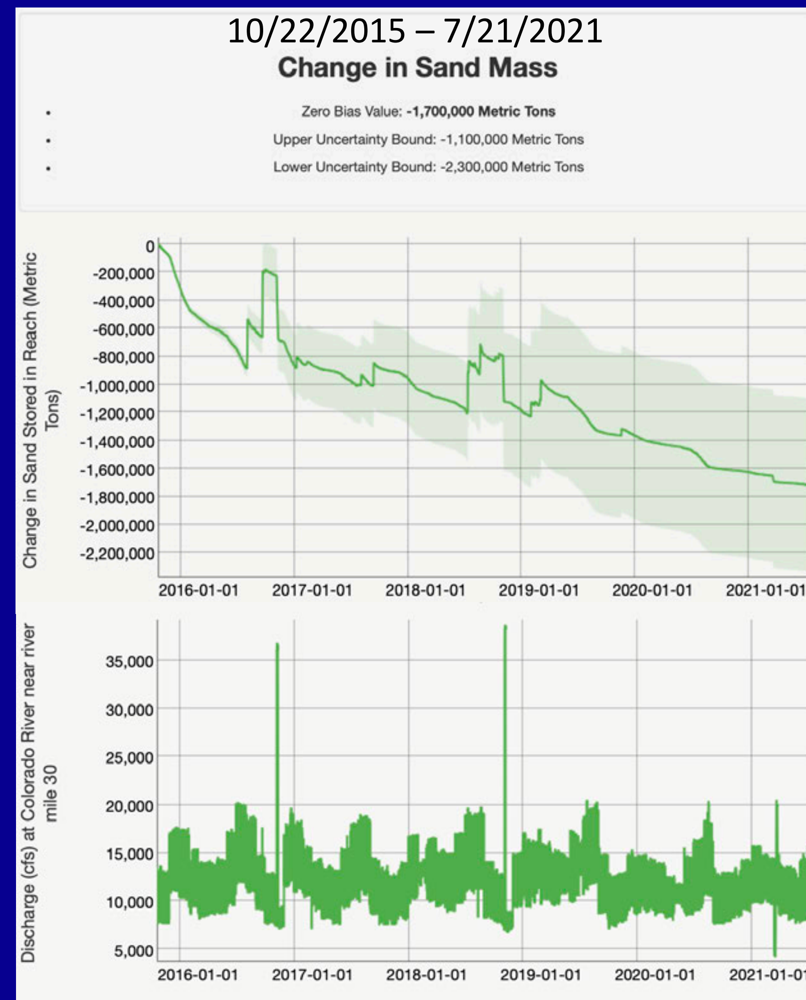
Possibly sustainable

Data from USGS (2025a, b)



Unsustainable period example
Upper Marble Canyon

EXPANDED VIEW OF UNSUSTAINABLE PERIOD

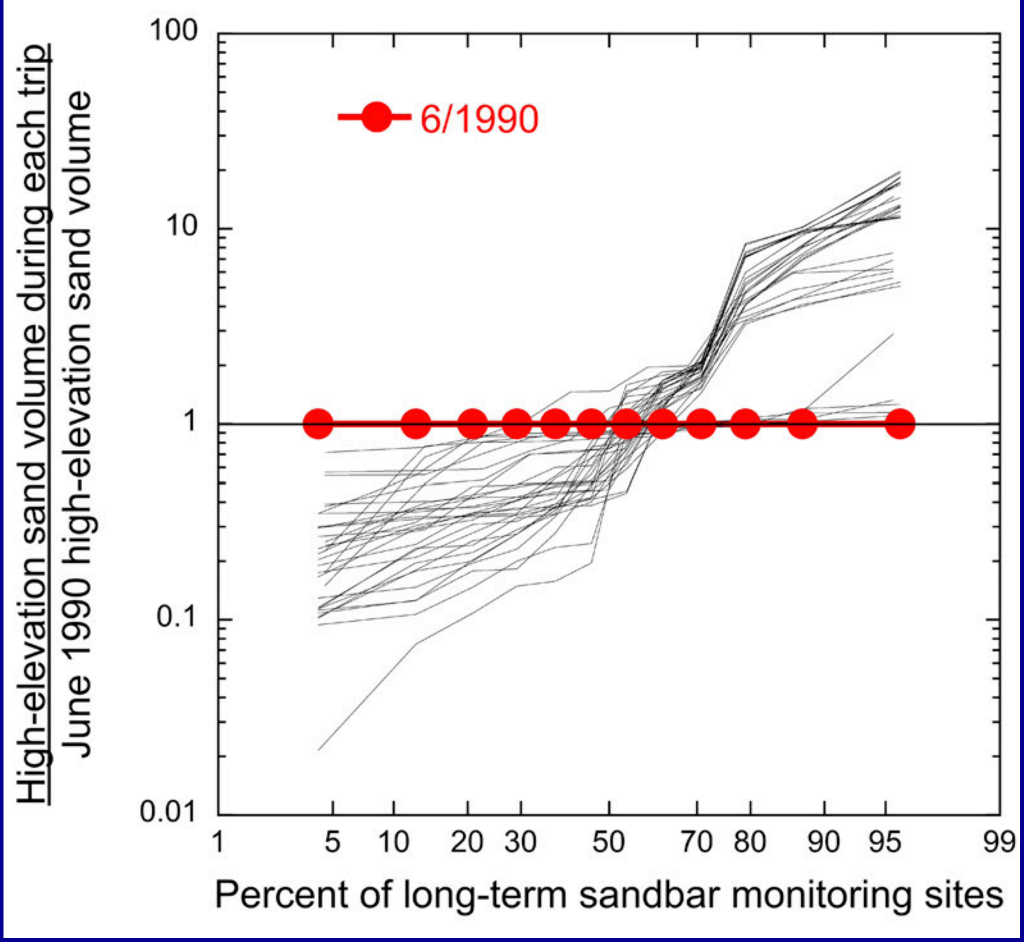


Data from USGS (2025a)

Averages do not tell the entire story

Although only a slight decrease in mean high-elevation normalized sand volume occurred between 1990 and 2024 among the 12 long-term sandbar monitoring sites in Marble Canyon…

- High-elevation sand at half of of these sites defines a downward spiral
- High-elevation sand at almost half of these sites defines an upward spiral

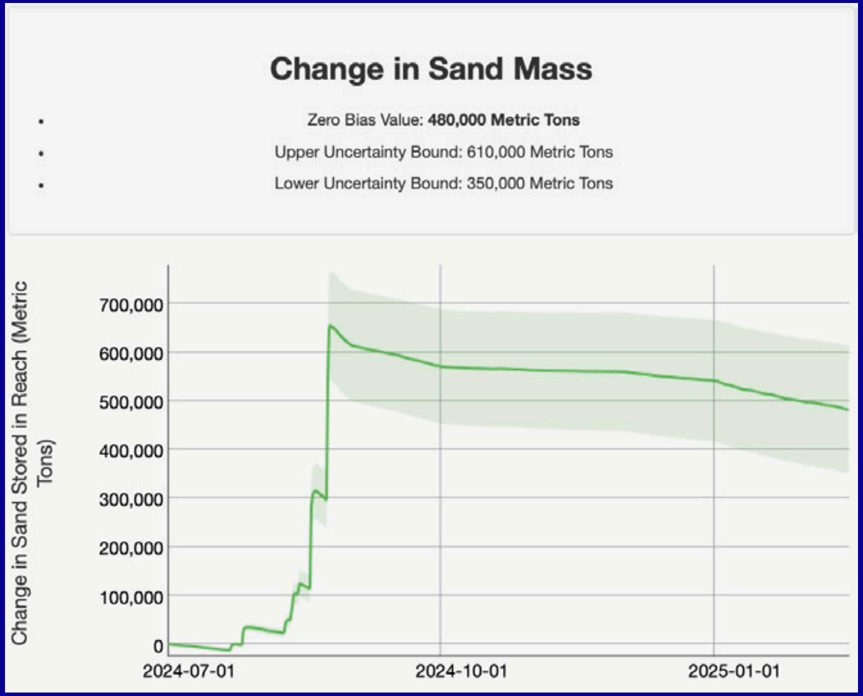


Data from USGS (2025b)

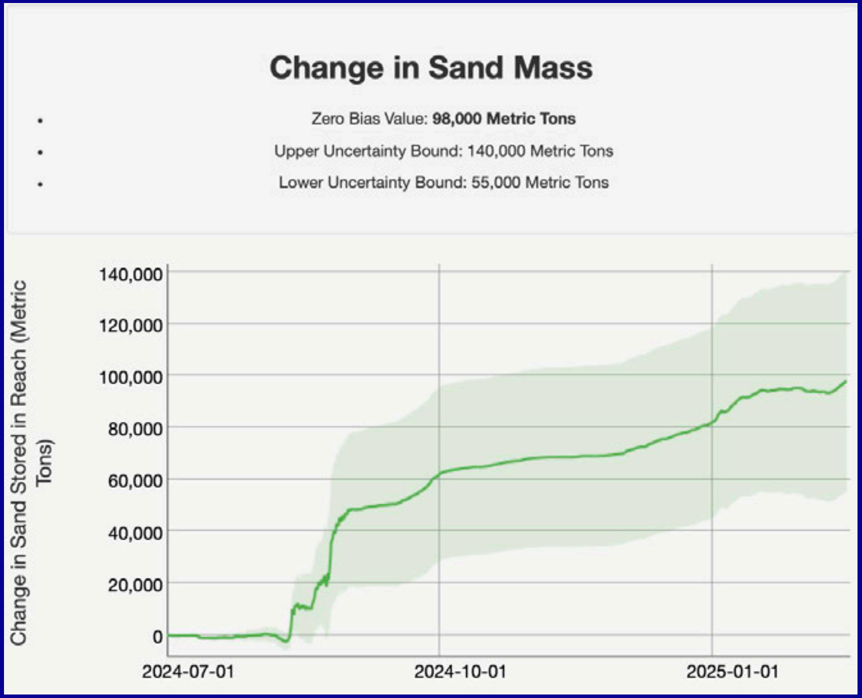
We currently have an HFE trigger

- Since July 1, 2024, the Paria River has supplied between 650,000 and 800,000 metric tons of sand
- As of February 15, 2025, at least 410,000 metric tons of the newly supplied sand remains in Marble Canyon
- Reclamation modeling on March 6, 2025, using USGS-GCMRC models and data suggested enough sand for a 60-hour 41,900 ft^3/s HFE in late May 2025

Upper Marble Canyon



Lower Marble Canyon



Data from USGS (2025a)

Powerplant-capacity releases generally erode high-elevation sand

	Nov. 1997 40-hour 31,000 ft^3/s powerplant release	May 2000 80-hour 30,000 ft^3/s powerplant release	Sep. 2000 80-hour 31,000 ft^3/s powerplant release	Mar. 2008 60-hour 42,000 ft^3/s sand-enriched HFE
Relative change in mean normalized sandbar volume above 25,000 ft^3/s in Marble Canyon (n = 12 sites)	**-21%**	**-6%**	**-1%**	**+26%**
Relative change in mean normalized sandbar volume above 25,000 ft^3/s in Grand Canyon (n = 21 sites)	**-8%**	**-2%**	Surveys not conducted throughout Grand Canyon	**+68%**

Analysis conducted using sites surveyed before and after all 4 experimental releases; data from USGS (2025b)

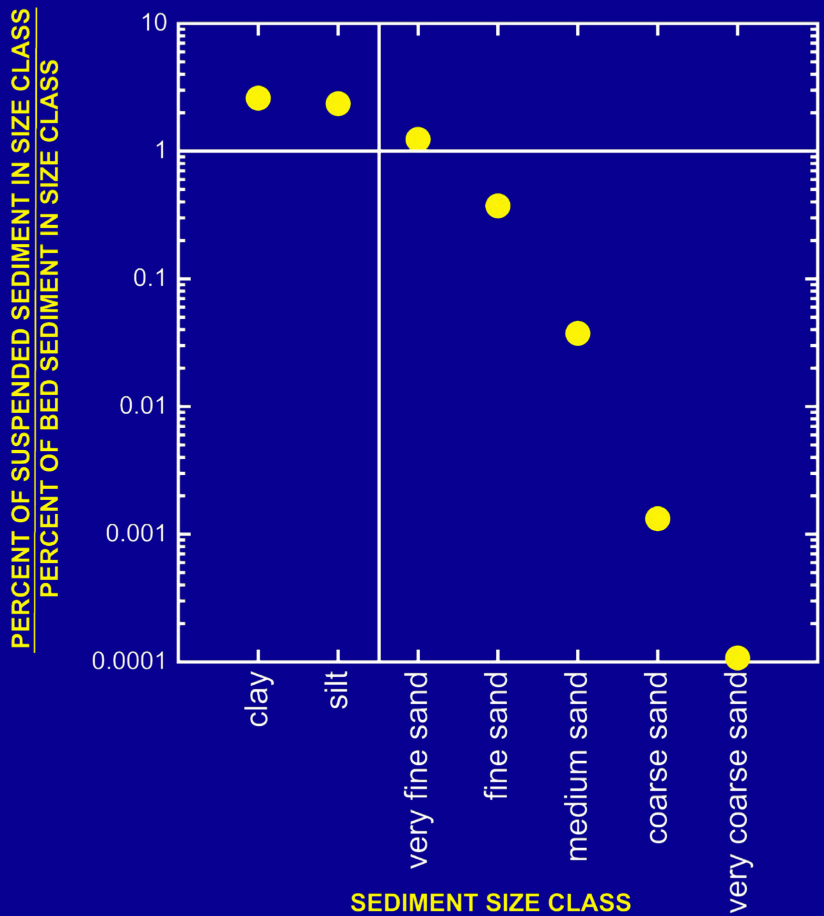
USGS science for a changing world

- Powerplant-capacity releases can result in slight deposition or erosion of sand above 8,000 ft^3/s
- Sand-enriched HFEs generally result in much larger amounts of sand deposition above 8,000 ft^3/s

	Nov. 1997 40-hour 31,000 ft^3/s powerplant release	May 2000 80-hour 30,000 ft^3/s powerplant release	Sep. 2000 80-hour 31,000 ft^3/s powerplant release	Mar. 2008 60-hour 42,000 ft^3/s sand-enriched HFE
Relative change in mean normalized sandbar volume above 8,000 ft^3/s in Marble Canyon (n = 12 sites)	**-10%**	**+1%**	**+16%**	**+33%**
Relative change in mean normalized sandbar volume above 8,000 ft^3/s in Grand Canyon (n = 21 sites)	**-7%**	**+4%**	Surveys not conducted throughout Grand Canyon	**+42%**

Analysis conducted using sites surveyed before and after all 4 experimental releases; data from USGS (2025b)

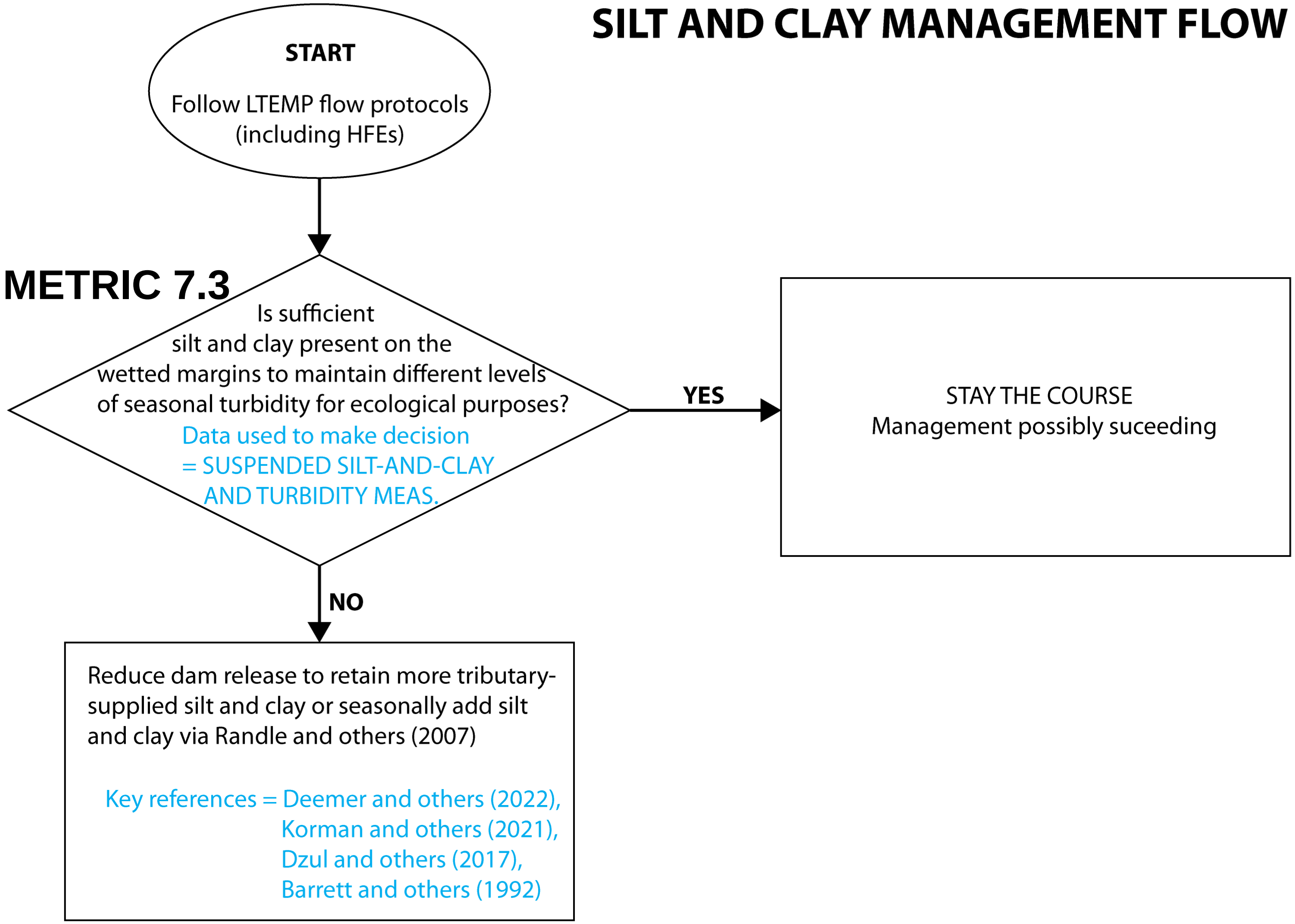
Progressively less finer sediment is required on the channel perimeter to support a given sediment concentration



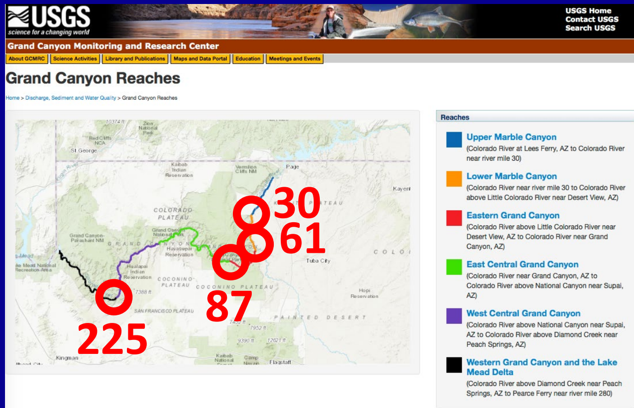
- Easier to detect large changes in the amount of silt and clay on the bed and banks via measurements made in the water column

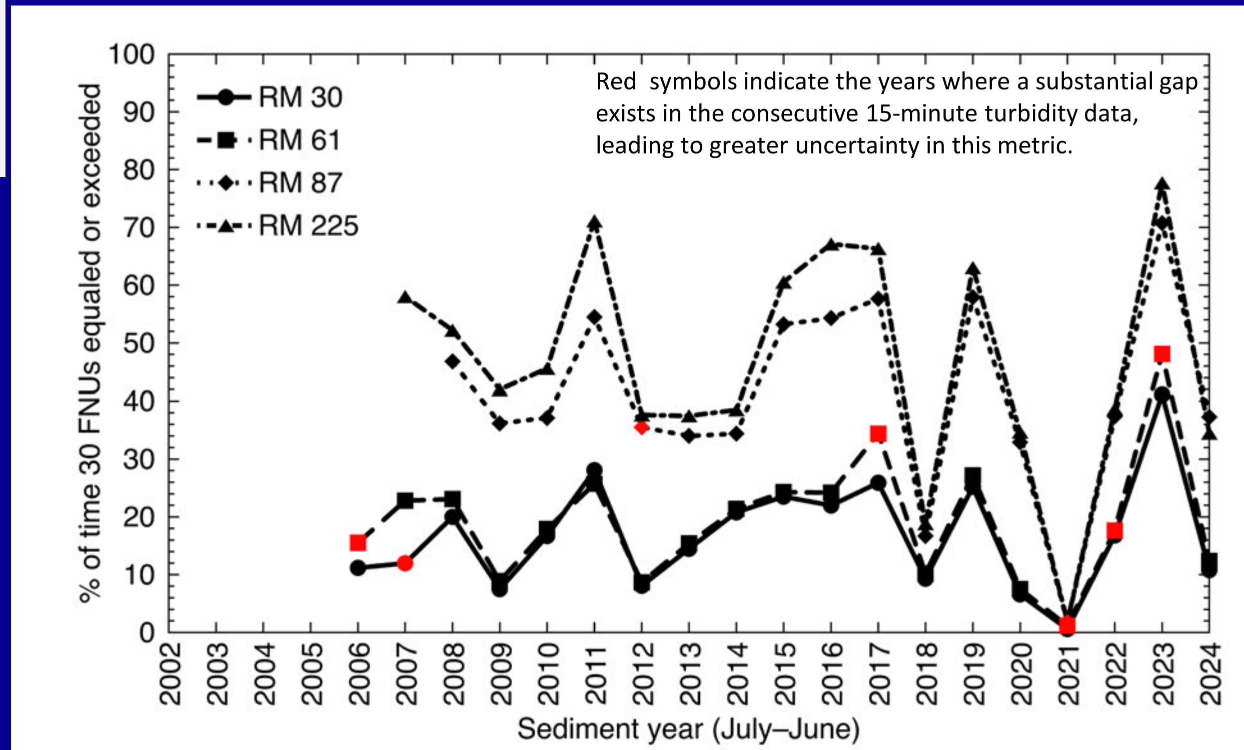
Data from Nordin (1963); modeled results after Topping (1997)

SILT AND CLAY MANAGEMENT FLOW CHART



Example of metric 7.3





- Sediment years 2018 and 2021 are noteworthy for being, by far, the two years of clearest water throughout Marble and Grand canyons.
- These years had far less silt and clay on the perimeter and banks of the Colorado River compared to any other year since monitoring began in the mid 2000s.
- Dam releases were too high relative to the meager tributary resupply of silt and clay in these two years to retain much silt and clay in Marble and Grand canyons.

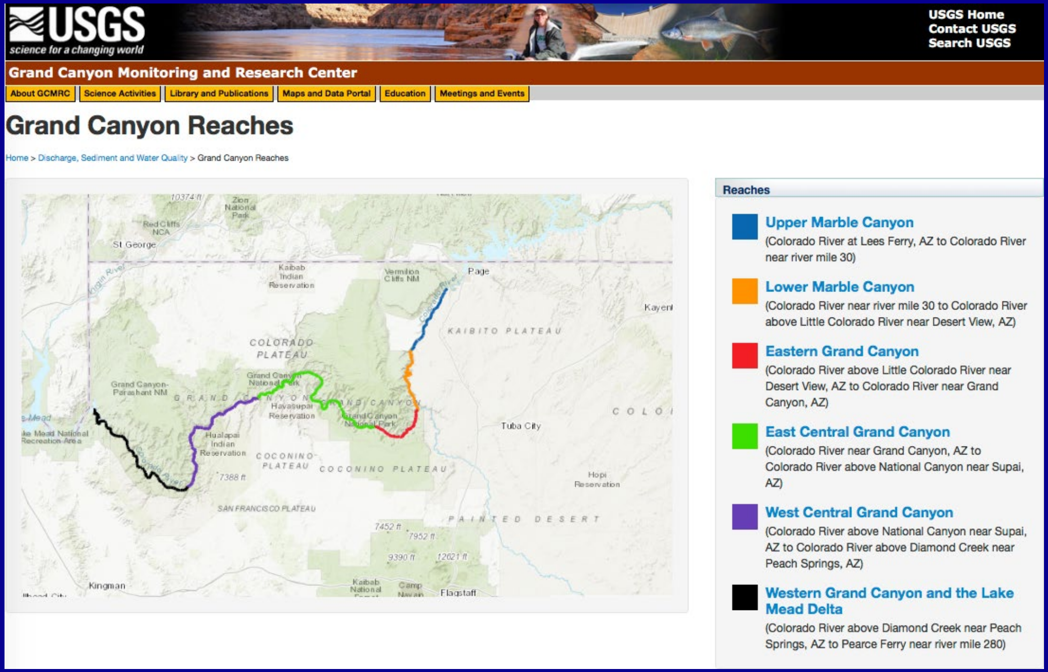
Data from USGS (2025a)

Conclusions

- Sediment years 2018 and 2021 had far less silt and clay on the bed and banks of the Colorado River in Marble and Grand canyons than any other year

- LTEMP sand management seems to be "working" in two segments (Upper Marble Canyon and West-Central Grand Canyon)

- LTEMP sand management may require adjustment in two segments (Lower Marble Canyon and East-Central Grand Canyon) by increasing HFE magnitude/duration or by reducing dam releases between HFEs (ANALYSES ARE ONGOING)

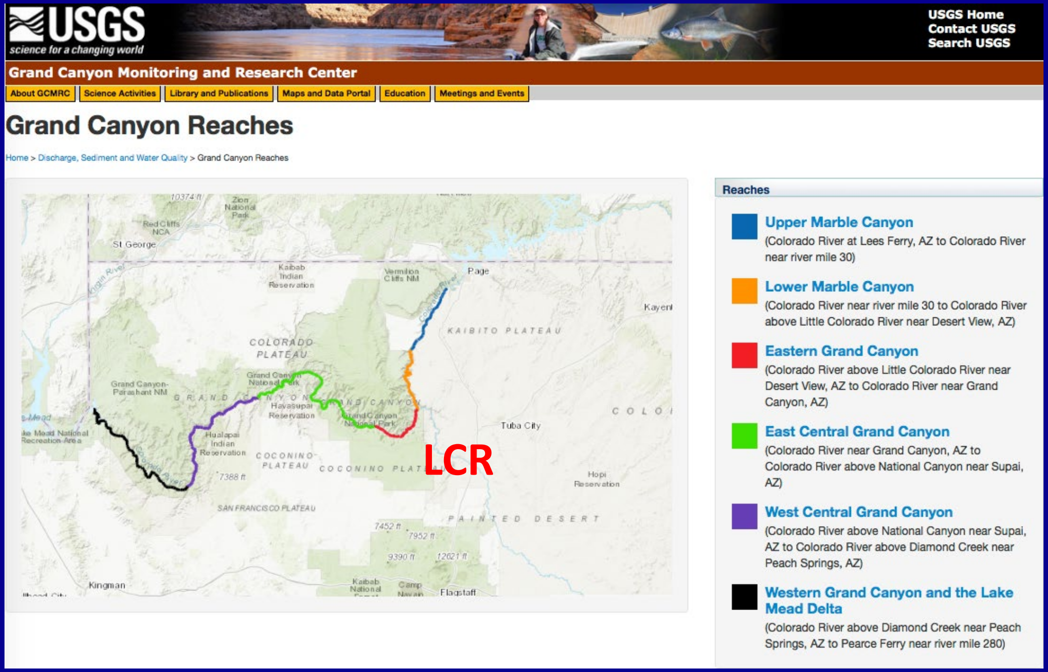


Conclusions continued

- As with the sand mass balance in Eastern Grand Canyon (Topping and others, *JGR*, 2021), sandbar response in this segment during HFEs seems to be driven largely by LCR activity

- Because the LCR cannot be easily controlled, LTEMP sand management in the Eastern Grand Canyon segment may also require a reduction in dam releases between HFEs

- Evaluation of only the time series of mean sandbar volume can be misleading because of the variation in response among sandbars (this is why we need to examine sandbar response in more than one way)



Thank you

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