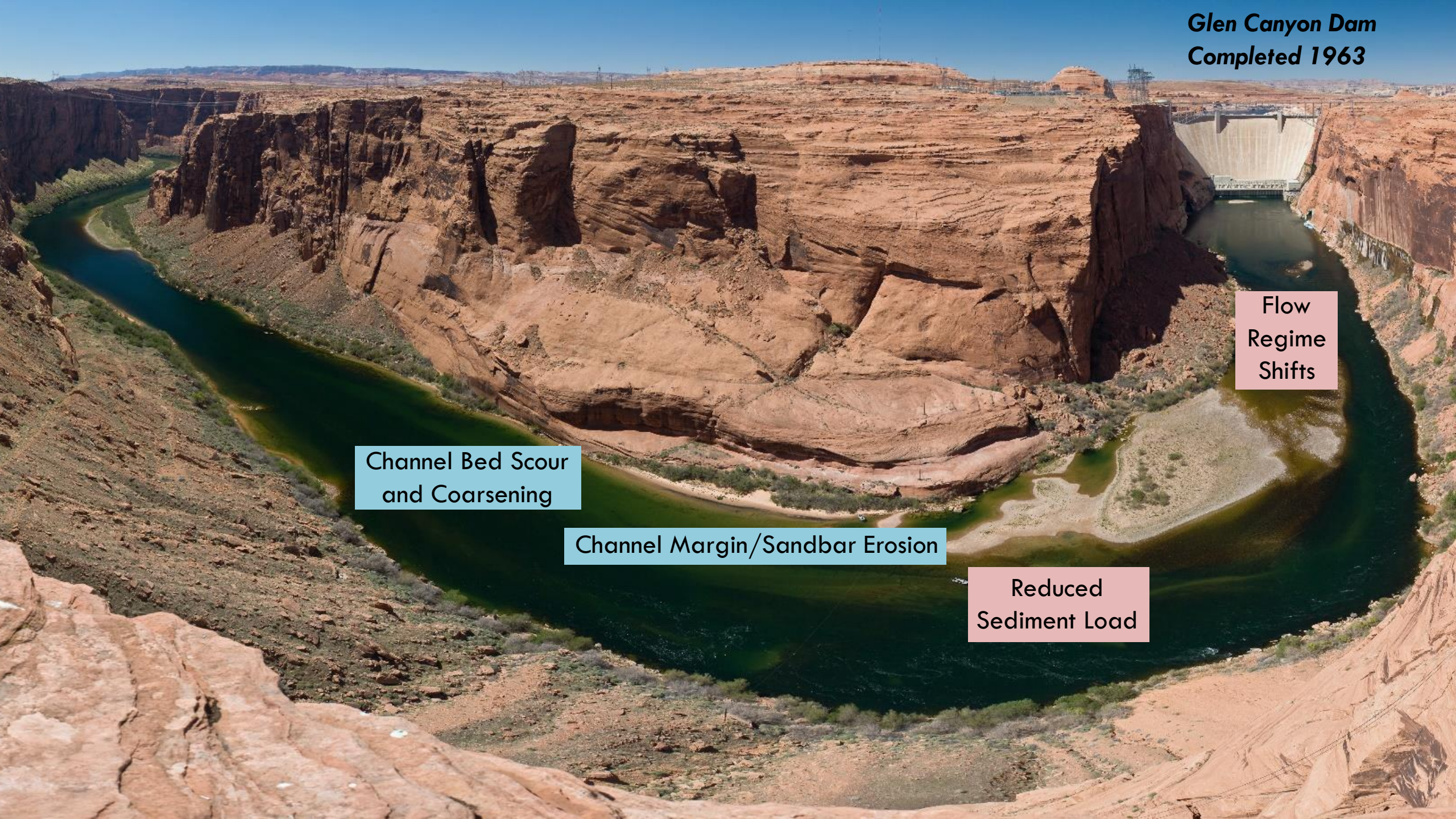
Flow Alteration, River Valley Morphology, and the Influence of Glen Canyon Dam on Sediment Availability along the Colorado River in Grand Canyon

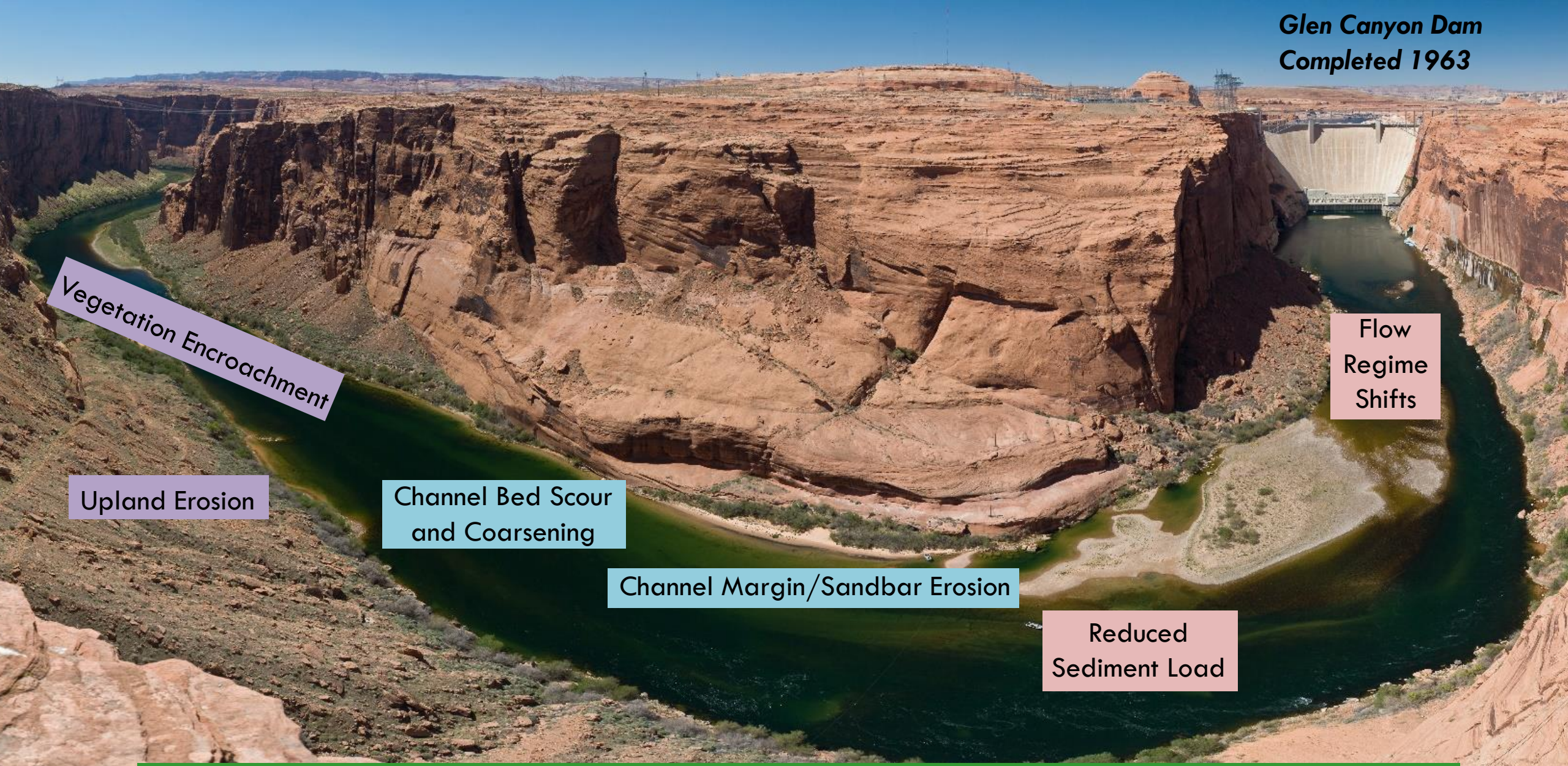
Alan Kasprak
U.S. Geological Survey
12 December 2018

with Joel Sankey, Joshua Caster, Amy East, Paul Grams [USGS]
Dan Buscombe, Brad Butterfield, Laura Durning [Northern Arizona University]

USGS Grand Canyon Monitoring and Research Center
Flagstaff, Arizona
**Now at USGS, Iowa City, Iowa*

Glen Canyon Dam
Completed 1963
Flow Regime Shifts
Reduced Sediment Load


Glen Canyon Dam
Completed 1963
Flow Regime Shifts
Channel Bed Scour and Coarsening
Channel Margin/Sandbar Erosion
Reduced Sediment Load



These aren't unique to Glen Canyon Dam, Grand Canyon, or the Colorado River

[Bellmore et al., 2017; Collier et al., 2000; East et al., 2015 & 2018; Graf, 1999 & 2006; Grant et al., 2003; Kondolf, 1997; Magilligan and Nislow, 2005; Schmidt and Wilcock, 2008, and many others…]

Today:

Two alterations to Colorado River driven by Glen Canyon Dam

- *Flow Regime Shift (Direct Effect)*
- *Vegetation Encroachment (Indirect Effect)*

…and how these have fundamentally altered **exposed sand area** at **big spatial scales**

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Progress in Physical Geography
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Quantifying and forecasting changes in the areal extent of river valley sediment in response to altered hydrology and land cover

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We examined these questions in a 2018 article in *Progress in Physical Geography* for a <u>28 km reach</u>

We've recently upscaled this work to <u>168 km</u> of the Colorado River in Grand Canyon

Exposed Sand is an important part of Grand Canyon

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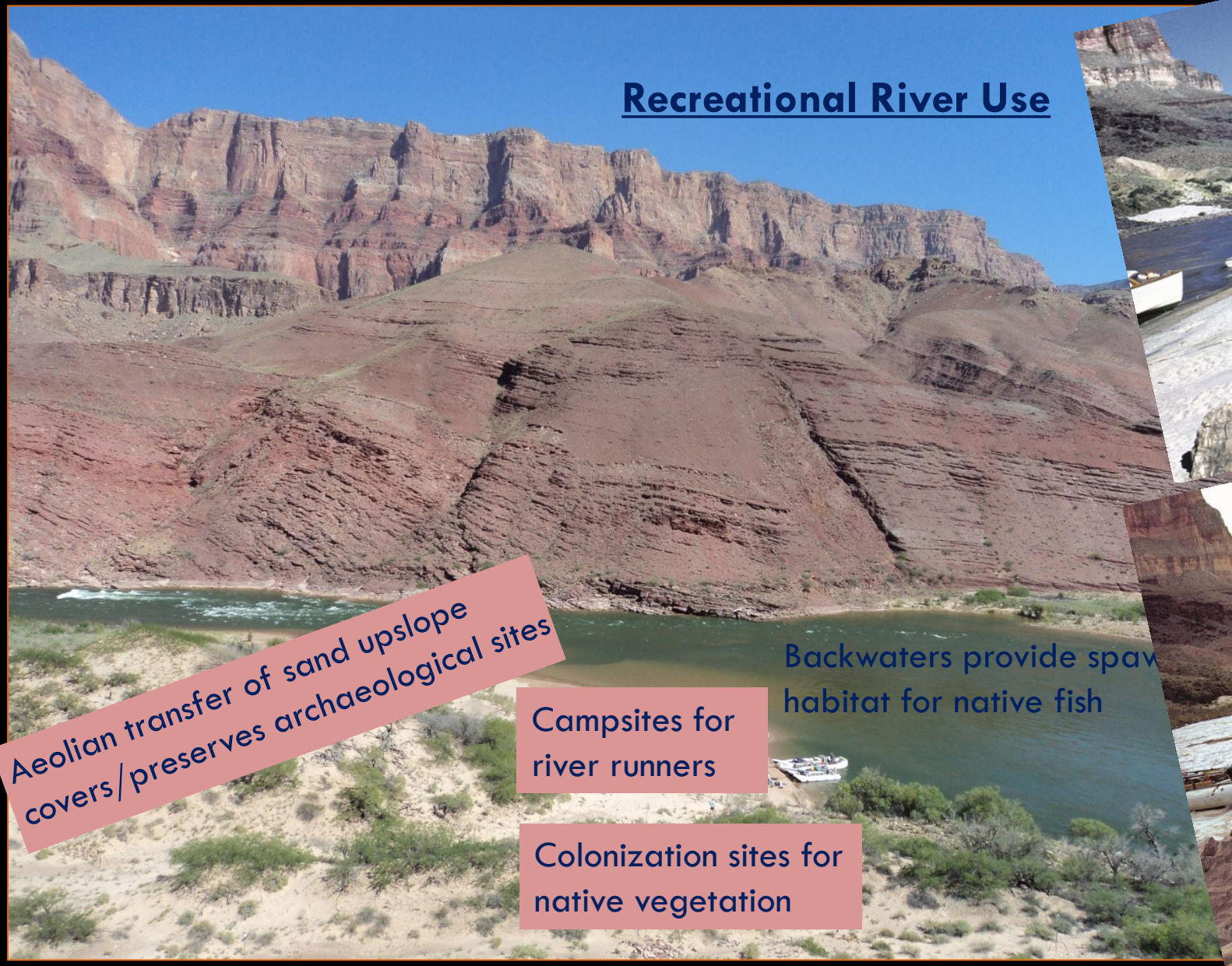

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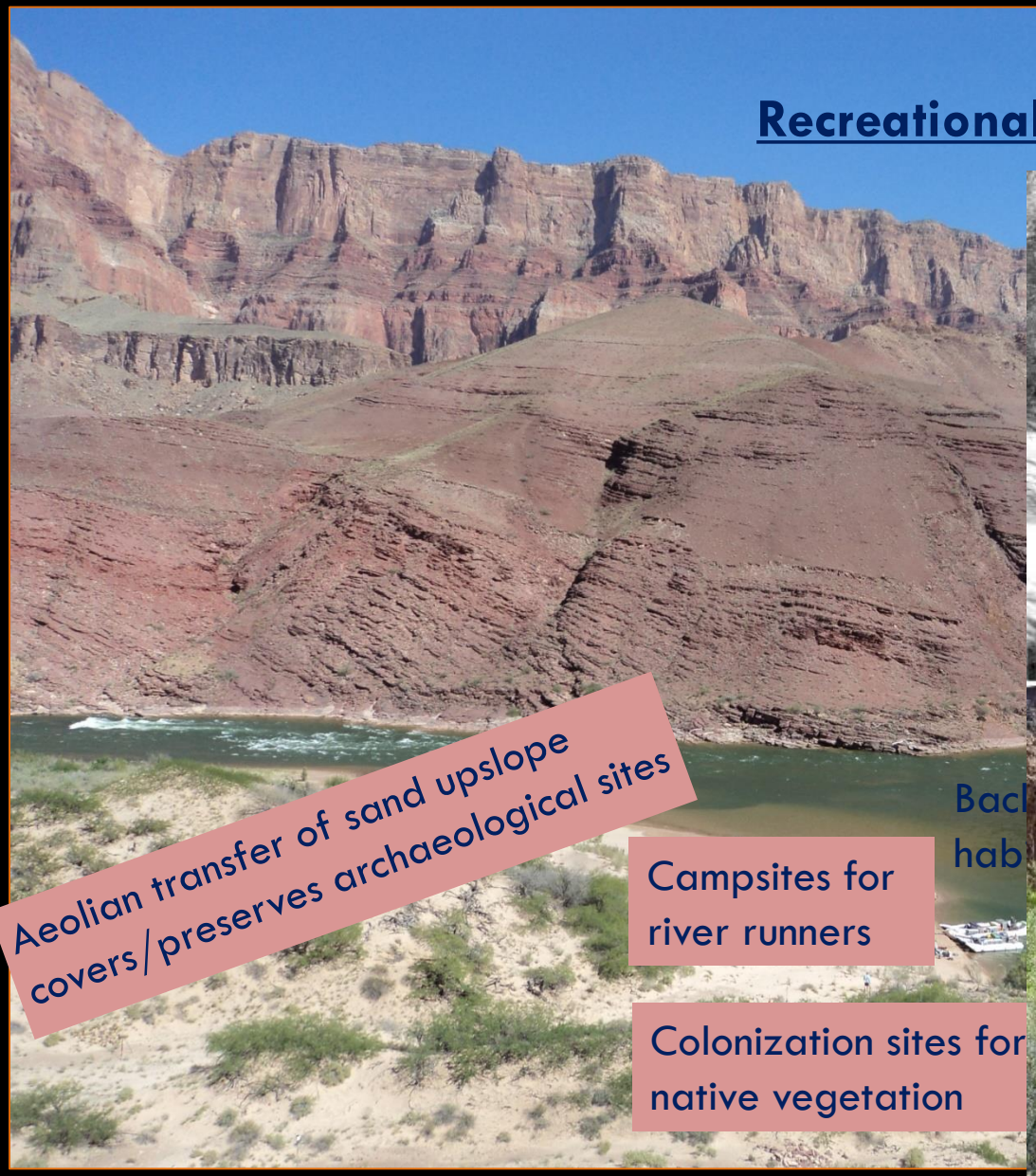


Recreational River Use

Aeolian transfer of sand upslope covers/preserves archaeological sites

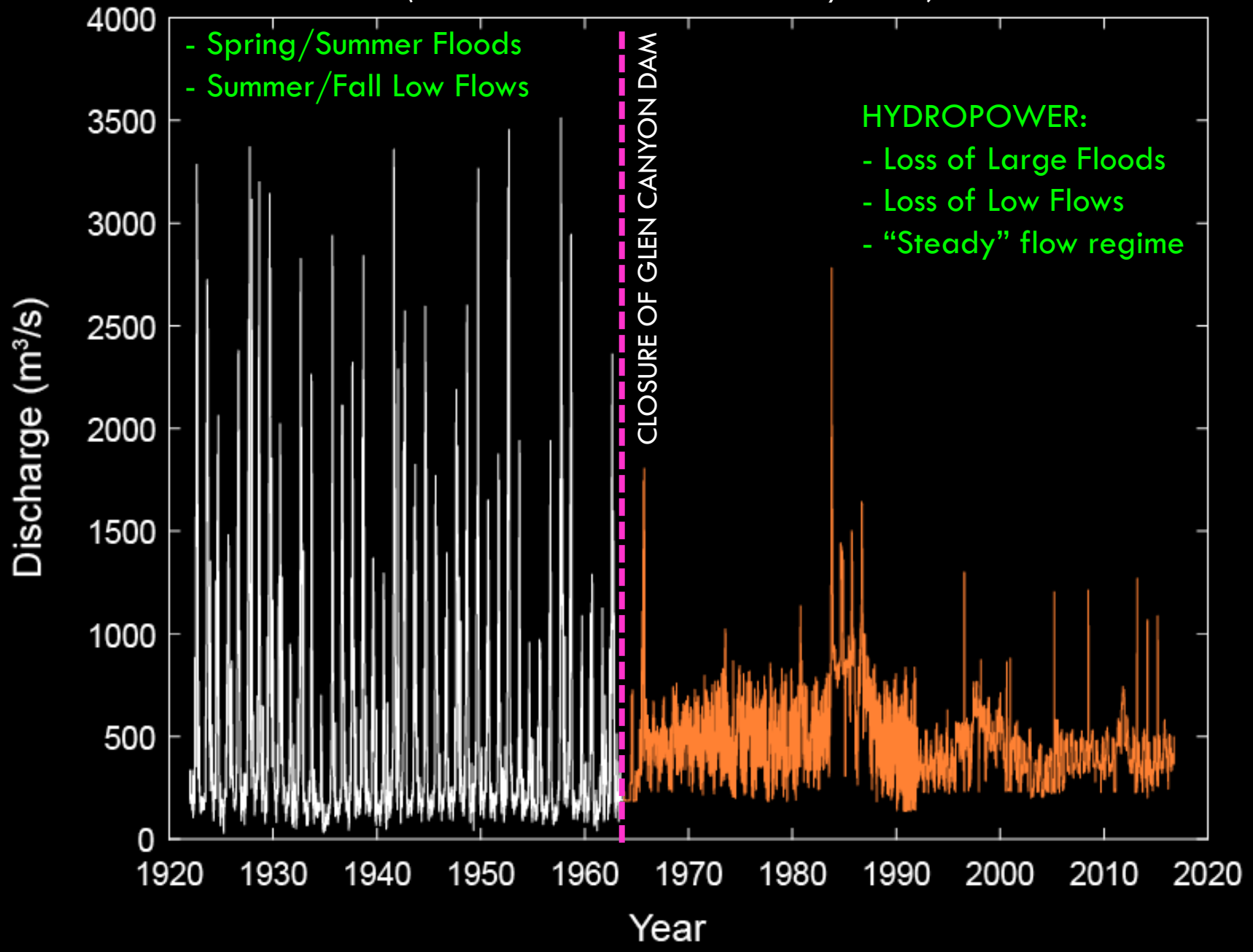
Campsites for river runners

Colonization sites for native vegetation

Bac
hab

Colorado River at Lees Ferry

(~ 25 km downstream from Glen Canyon Dam)



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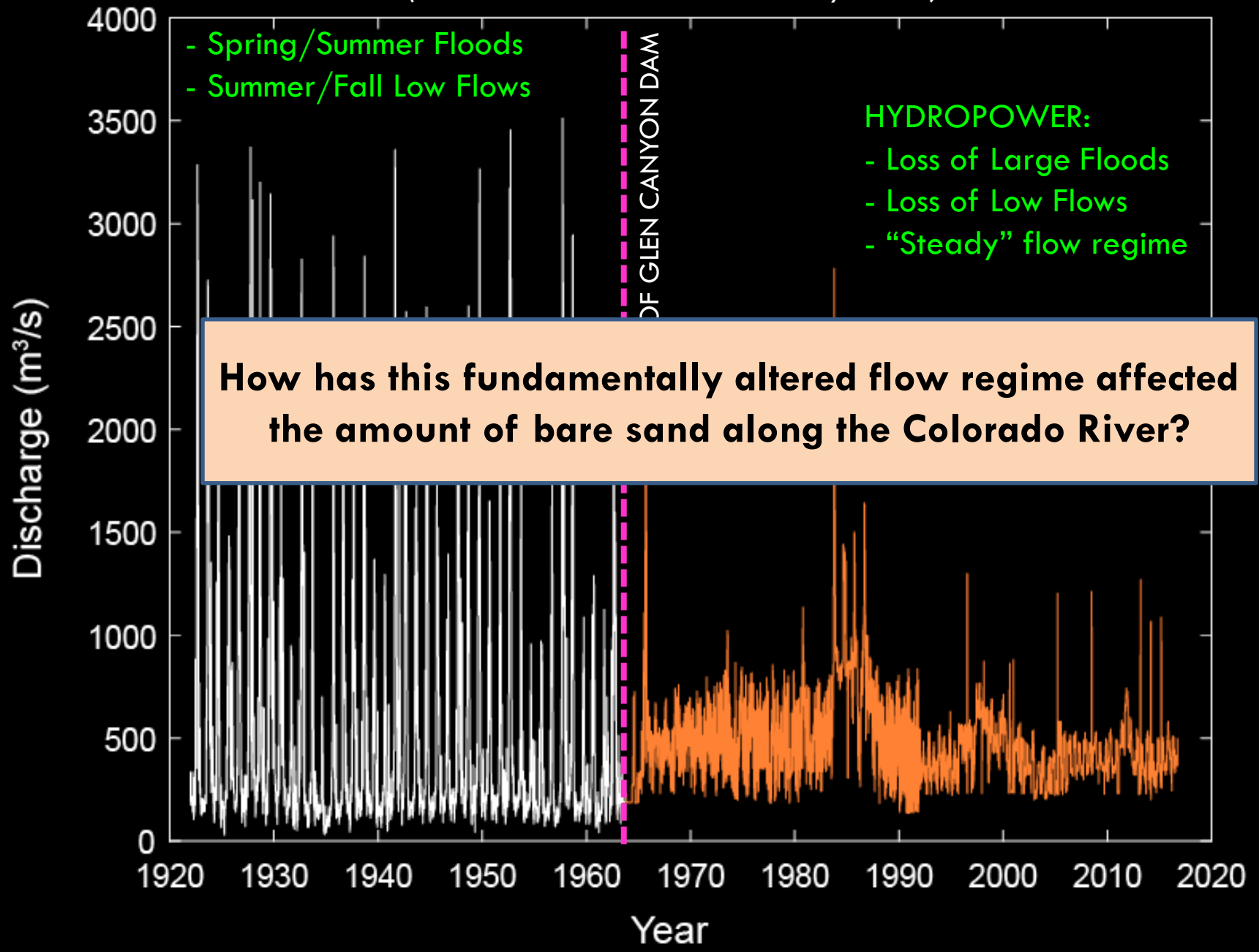
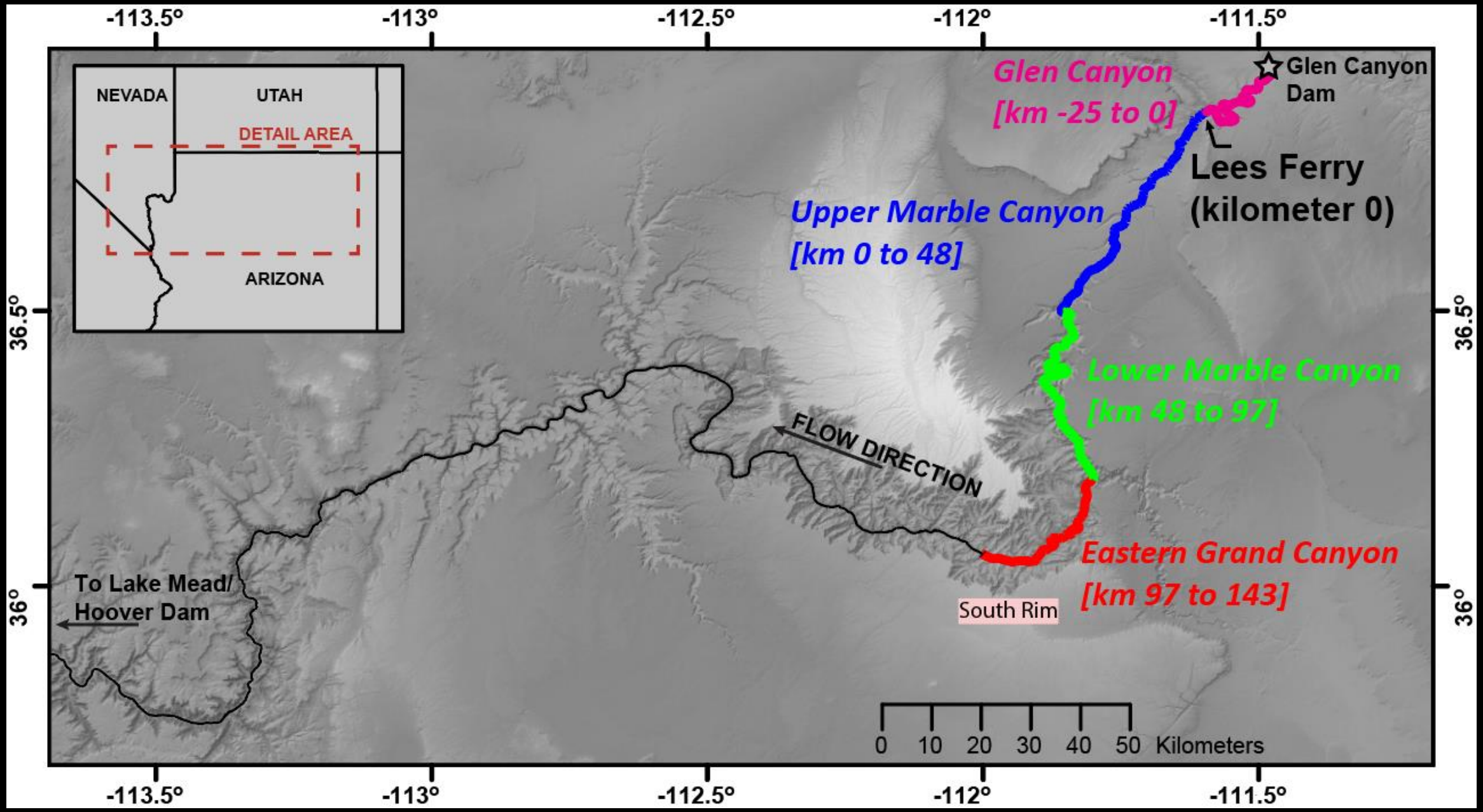
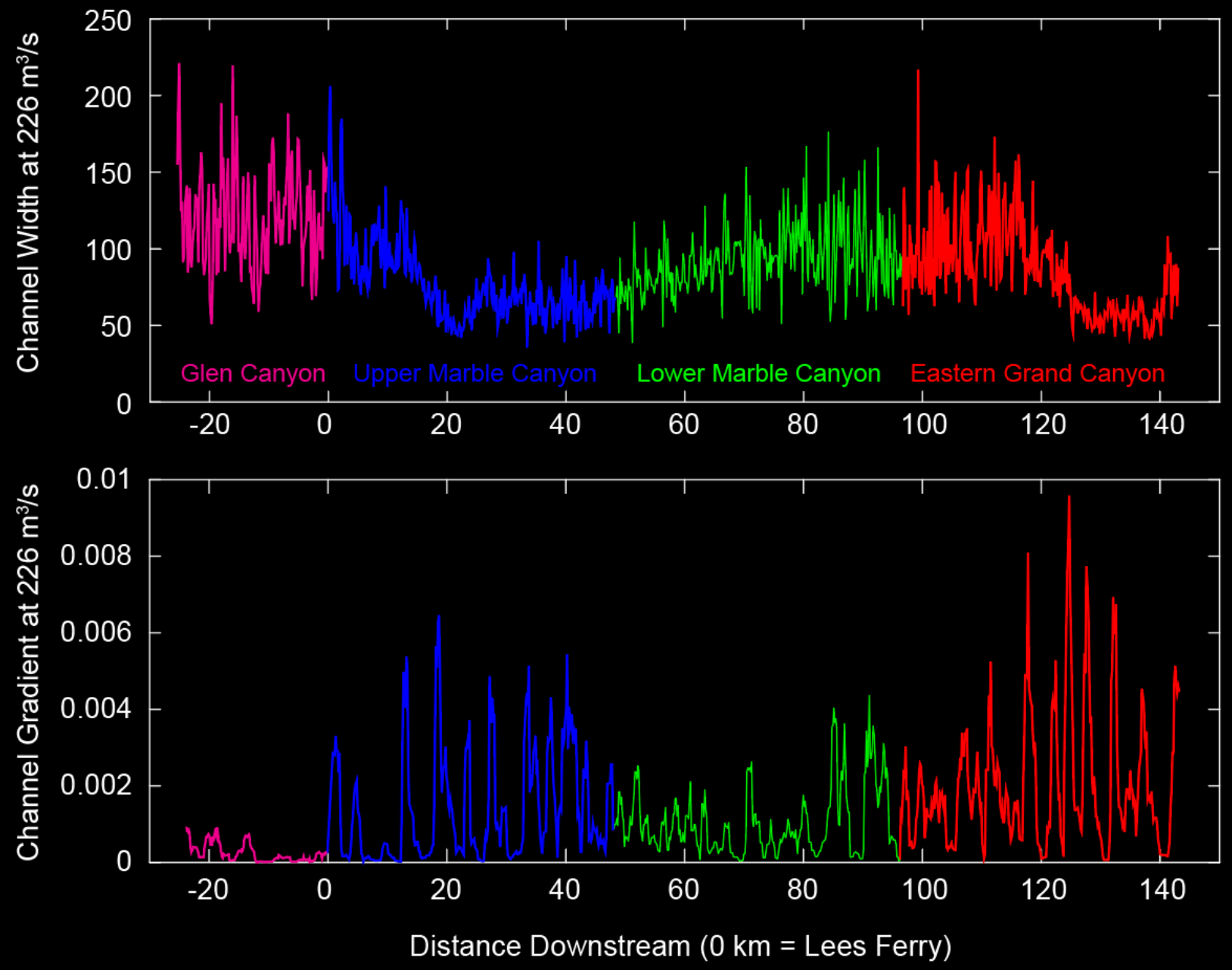


How has this fundamentally altered flow regime affected the amount of bare sand along the Colorado River?



168 km reach of Colorado River in Grand Canyon National Park

These Four Sub-Reaches are Geomorphically Distinct…



Glen Canyon

- *wide channel*
- *low gradient*
- *legacy of scour from Glen Canyon Dam [Grams et al., 2007, GSA-B]*

Upper Marble Canyon

- *transitional wide to narrow channel*
- *series of pools and drops*

Lower Marble Canyon

- *moderate width channel*
- *low gradient punctuated by rapids*

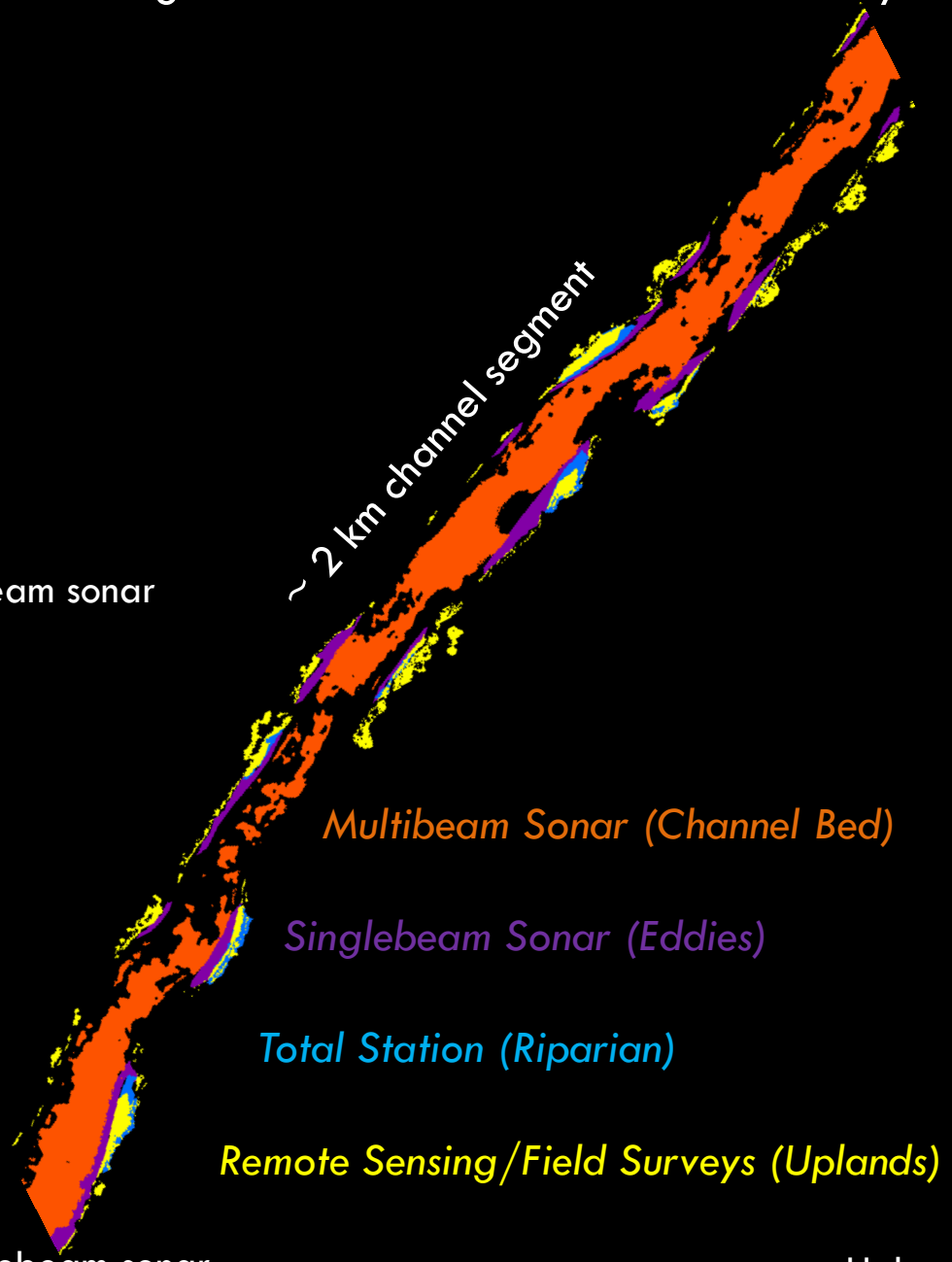
Eastern Grand Canyon

- *transitional wide to narrow channel*
- *steady gradient followed by pools-rapids*

How does the form of the channel in these reaches influence bare sand response to flow regime?

Mapping Sand Along the Colorado River in Grand Canyon – 2009 - 2015

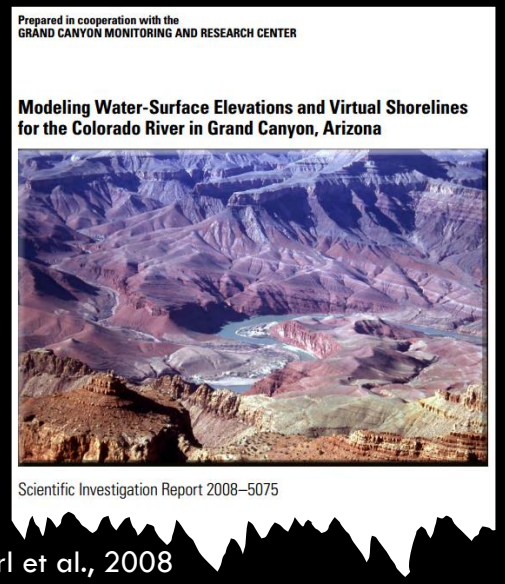
Main channel sand mapped with multibeam sonar



Riparian sand mapped with total station

Channel margin sand mapped with singlebeam sonar

Upland sand mapped with remote sensing/field surveys



Magirl et al., 2008

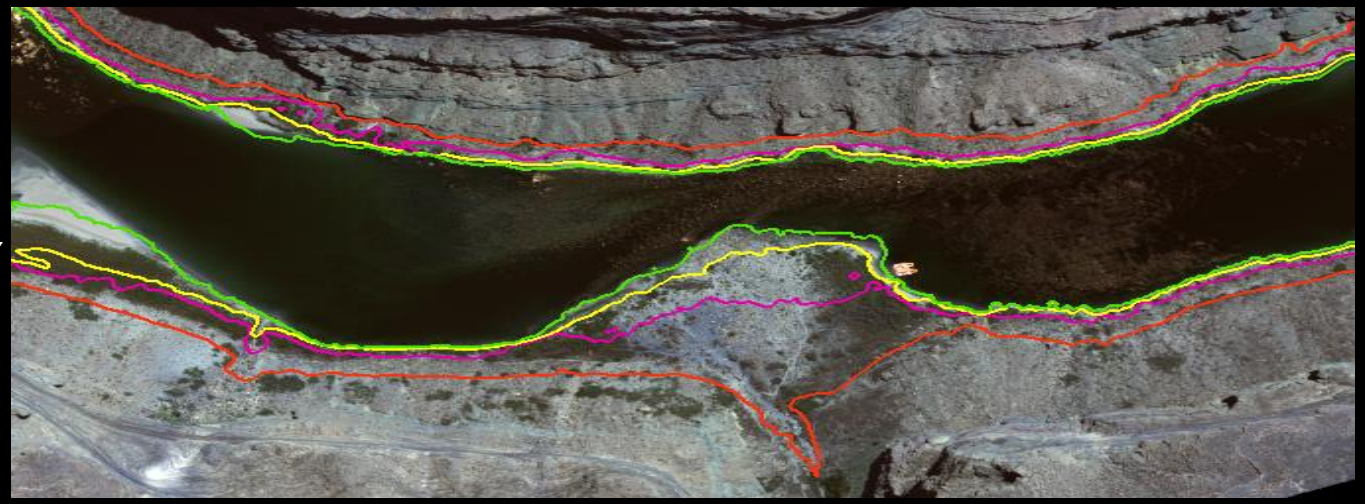
226 m^3/s

566 m^3/s

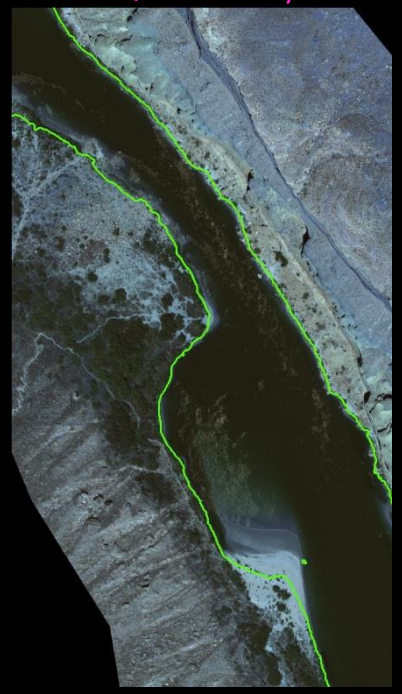
1,275 m^3/s

5,947 m^3/s

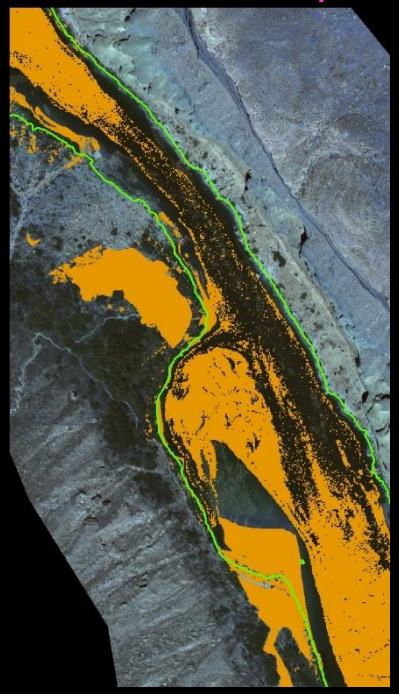
…and ten intermediate flows not shown here



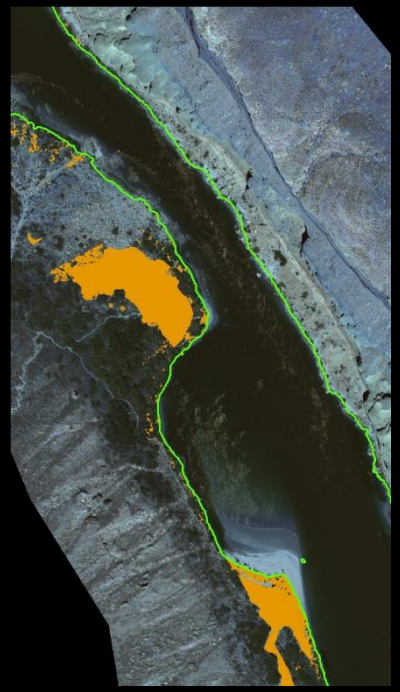
Inundation Extent at 1,274 m^3/s



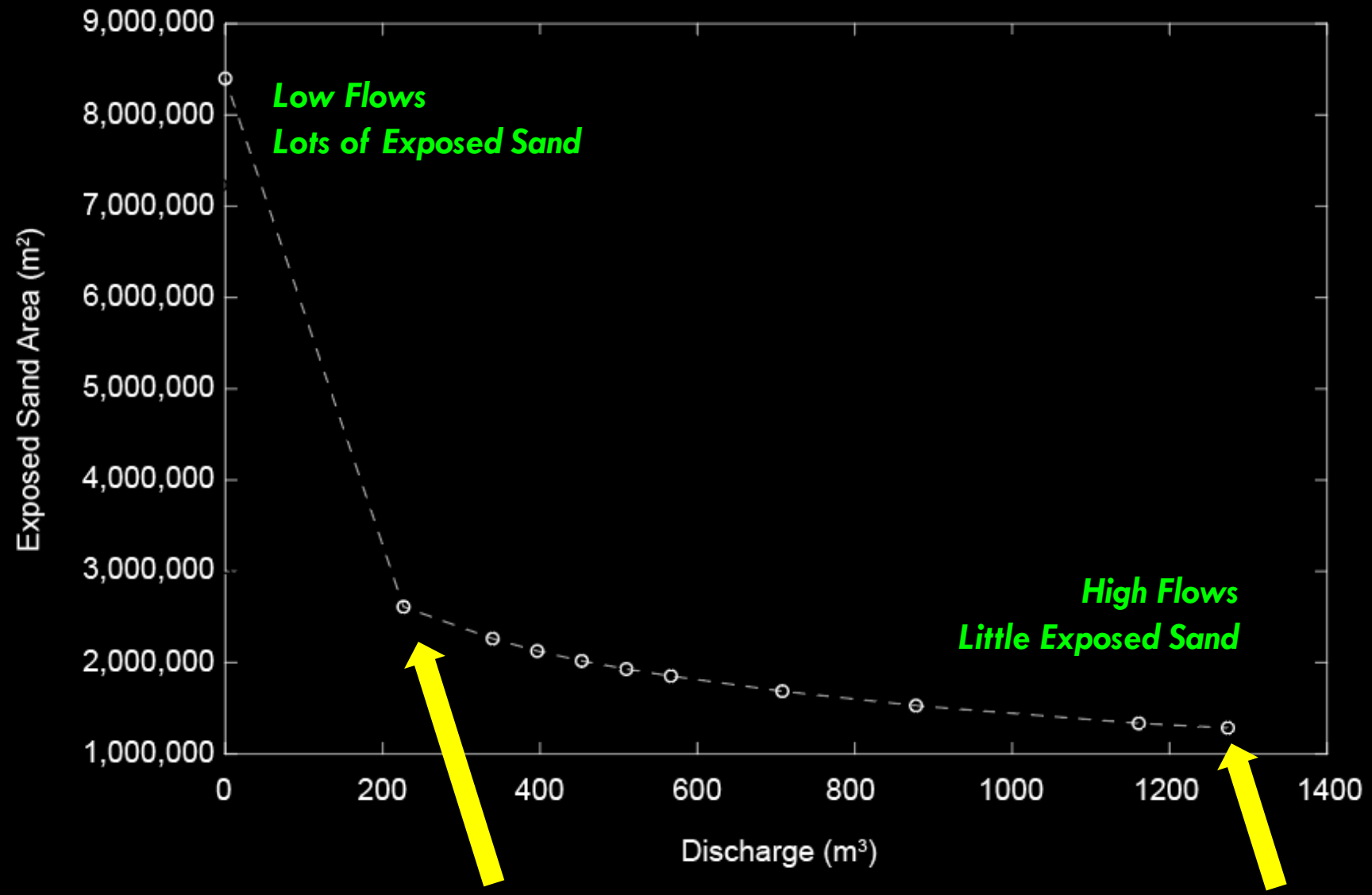
Total Sand Map



Exposed Sand at 1,274 m^3/s



Exposed Sand as a Function of Discharge



226 m^3/s: lowest regularly-occurring flows in Grand Canyon today

1,274 m^3/s: highest regularly-occurring flows in Grand Canyon today

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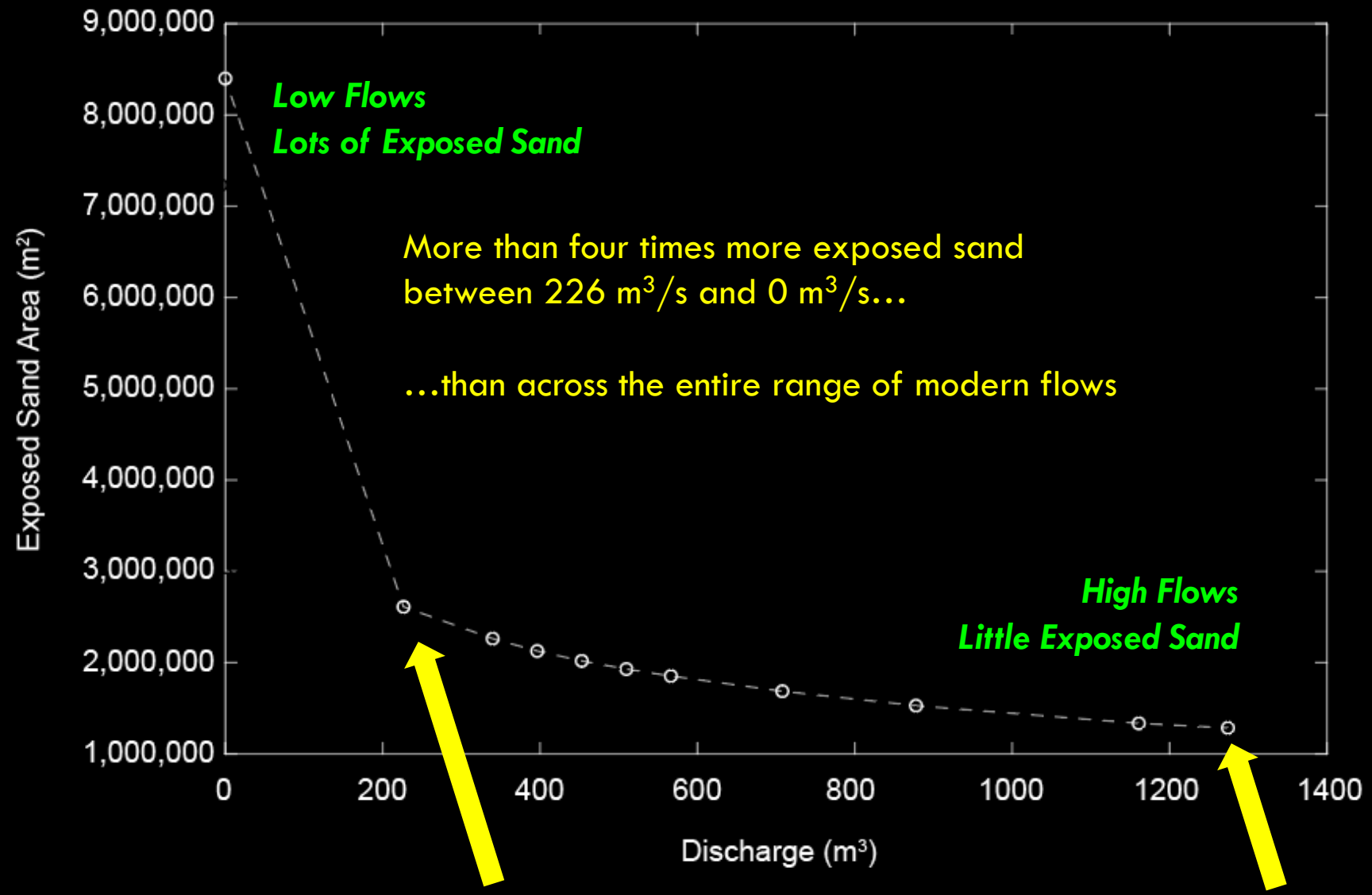

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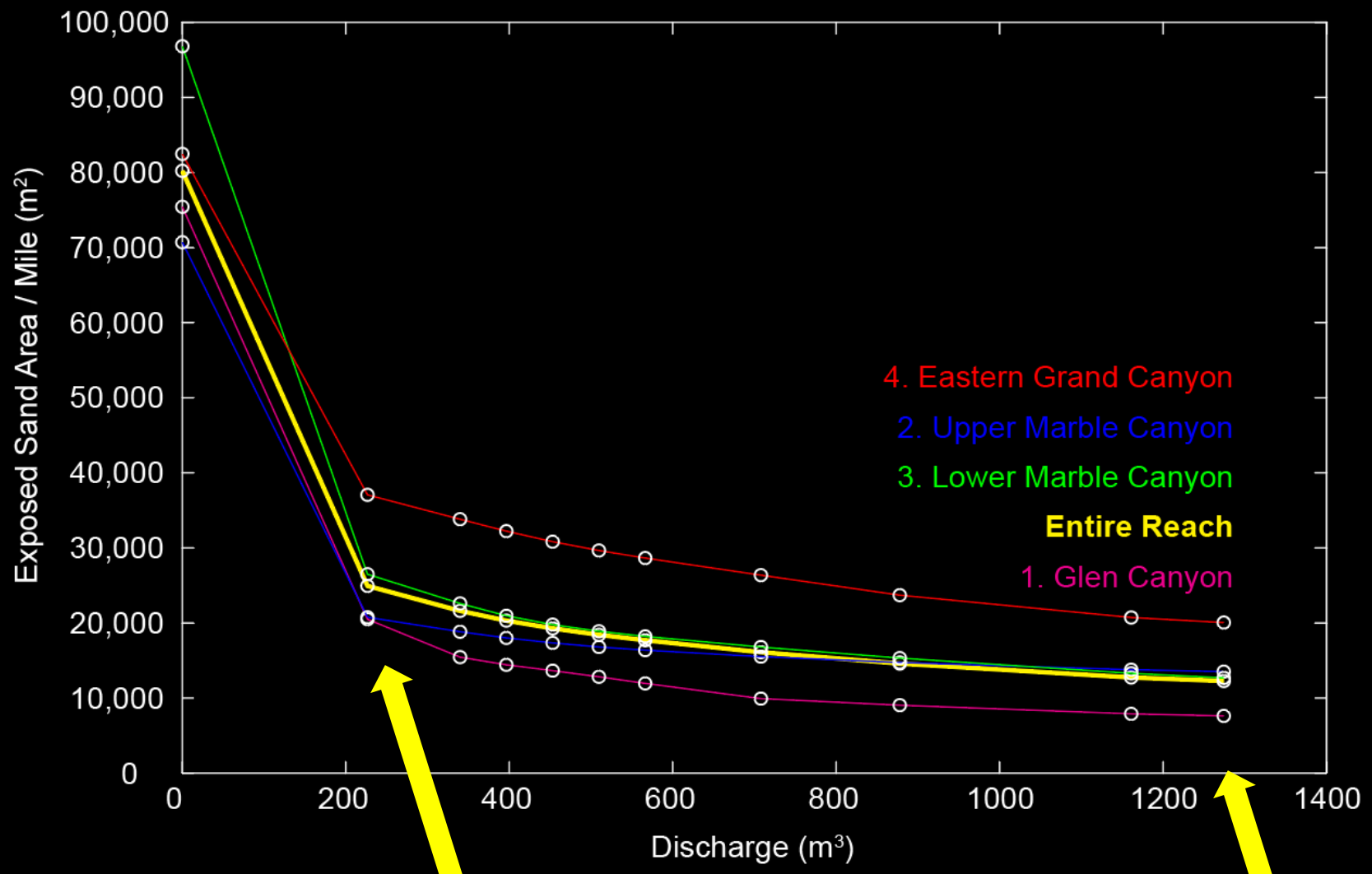

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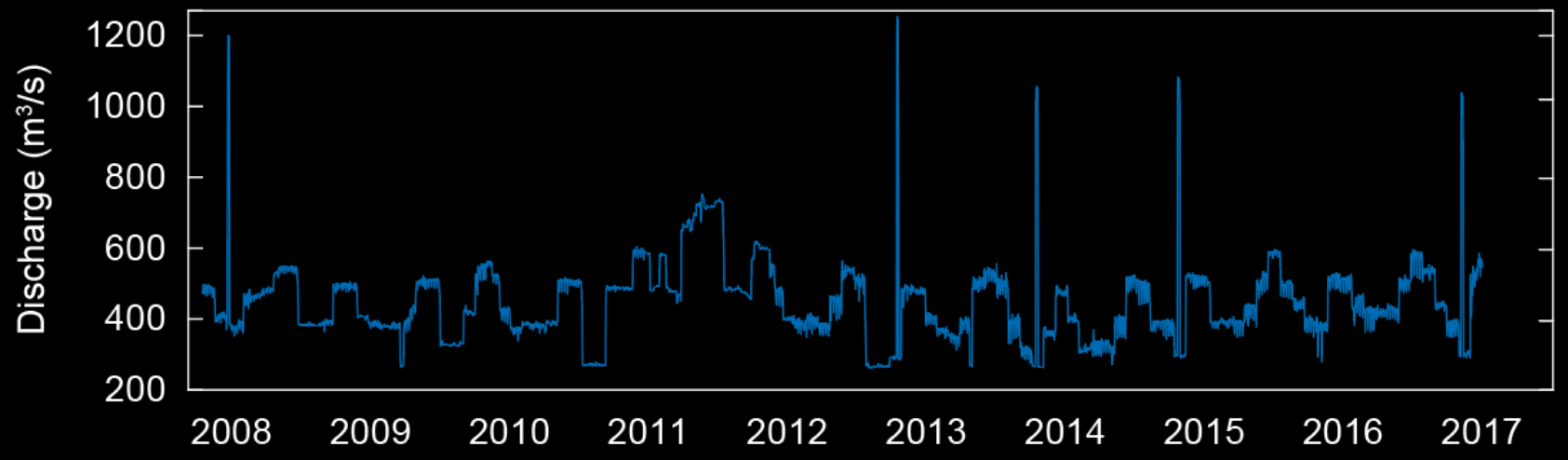
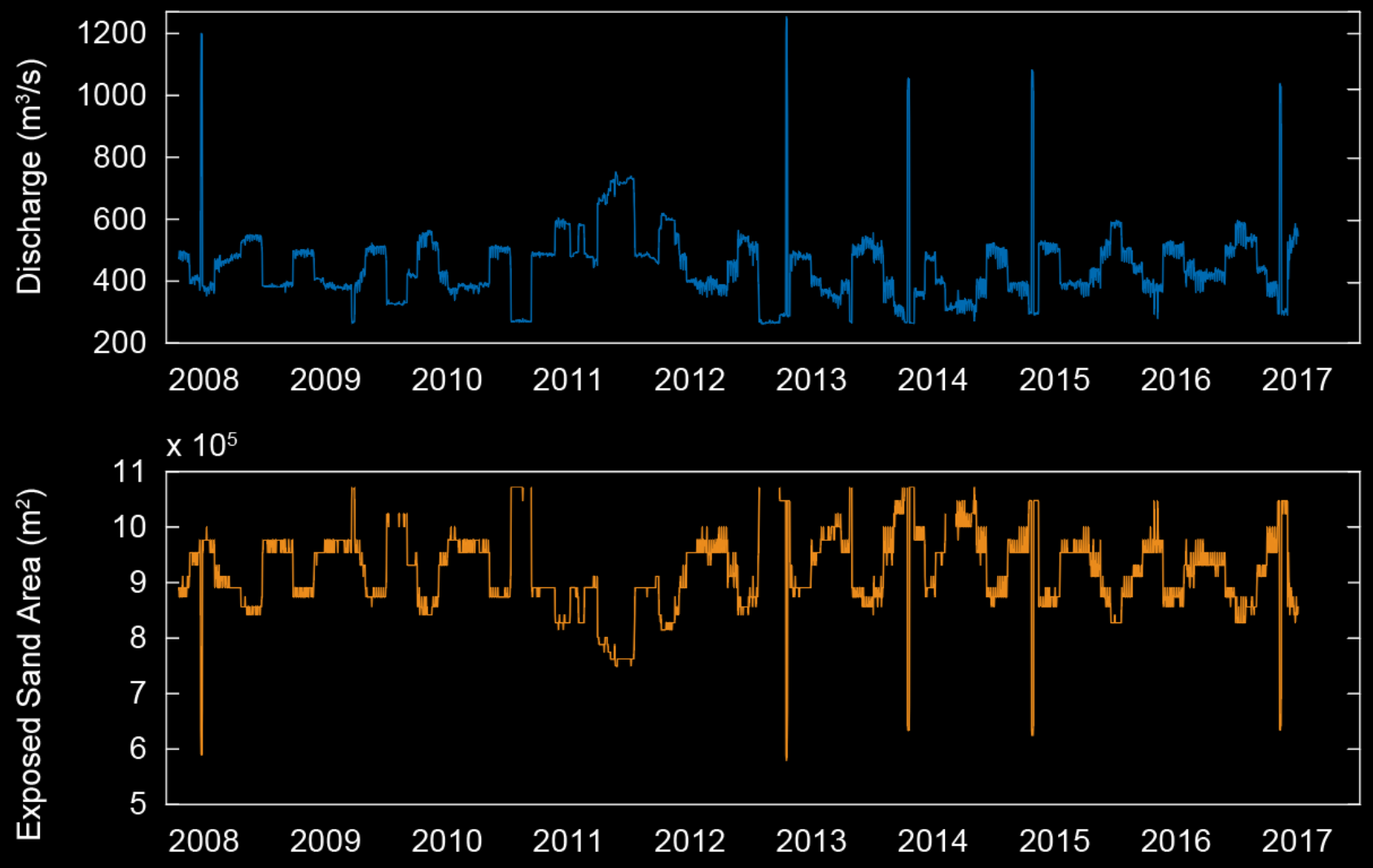
Exposed Sand as a Function of Discharge, 2007 - 2017



3,286 individual records of daily discharge…

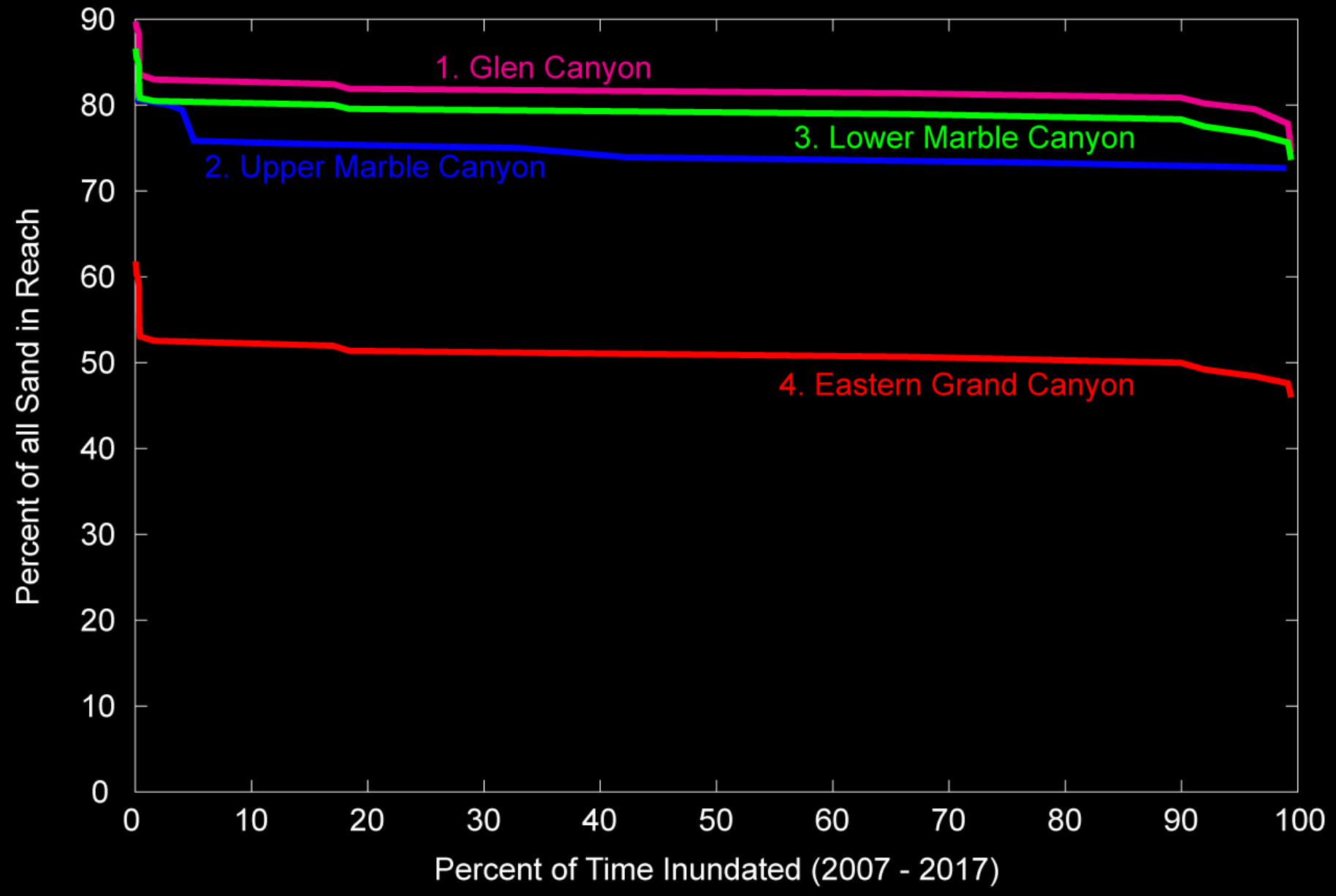
Exposed Sand as a Function of Discharge, 2007 - 2017



3,286 individual records of daily discharge…

…used to compute <u>daily exposed sand areas</u>

Exposed Sand Inundation Duration



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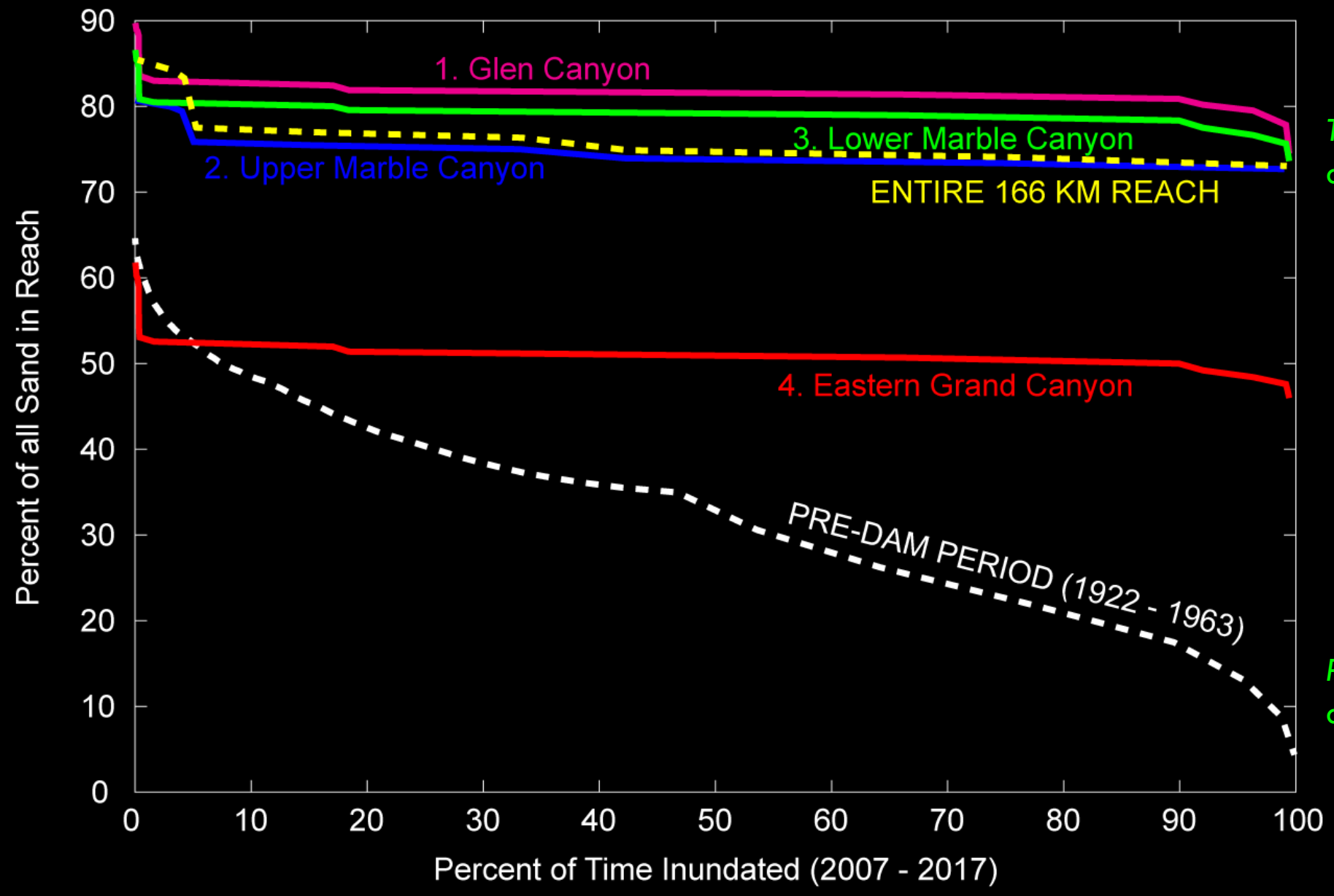

Today: > 75% of sand continuously inundated

Predam: < 10% of sand continuously inundated

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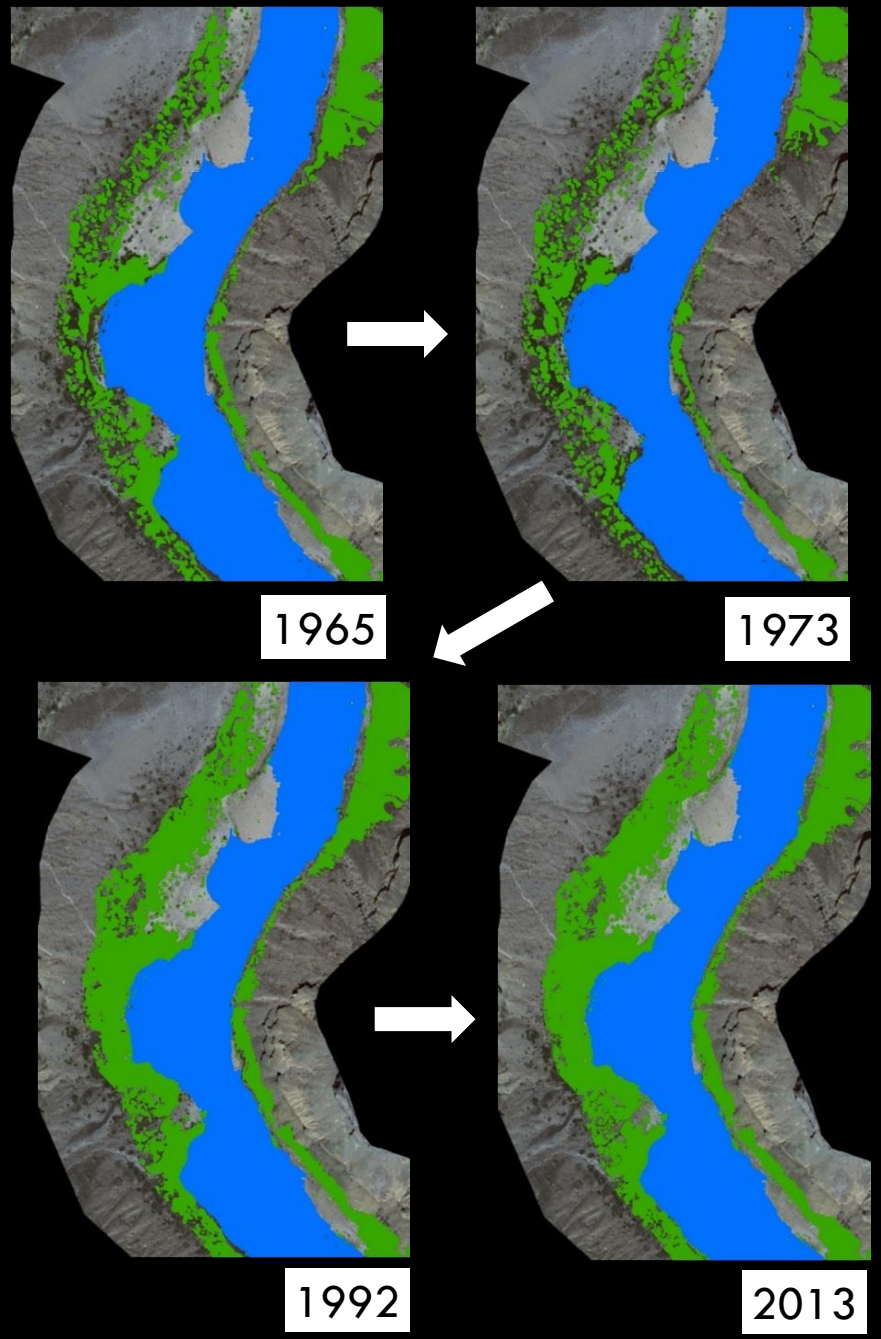
…and how these have fundamentally altered exposed sand area at big spatial scales

Observations of vegetation encroachment following dam construction

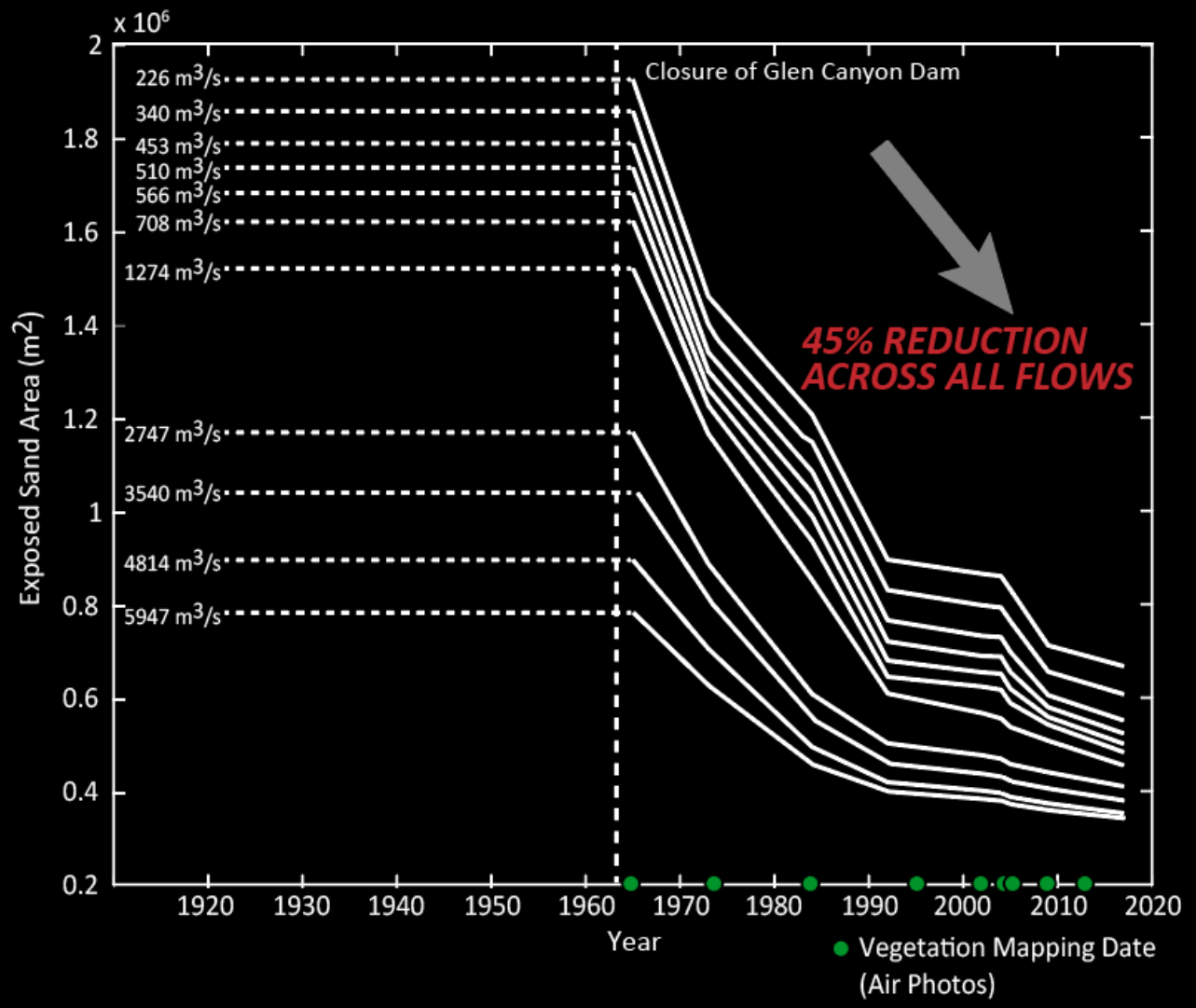


A trend toward:

- Increased vegetation area, particularly along the river
- Correspondingly reduced area of bare sand

In a 28 km segment in Lower Marble Canyon, we found:

- Large-scale reduction in bare sand area following dam construction
- Most sand loss occurred in first ~30 years after Glen Canyon Dam
- Most rapid growth at low stages



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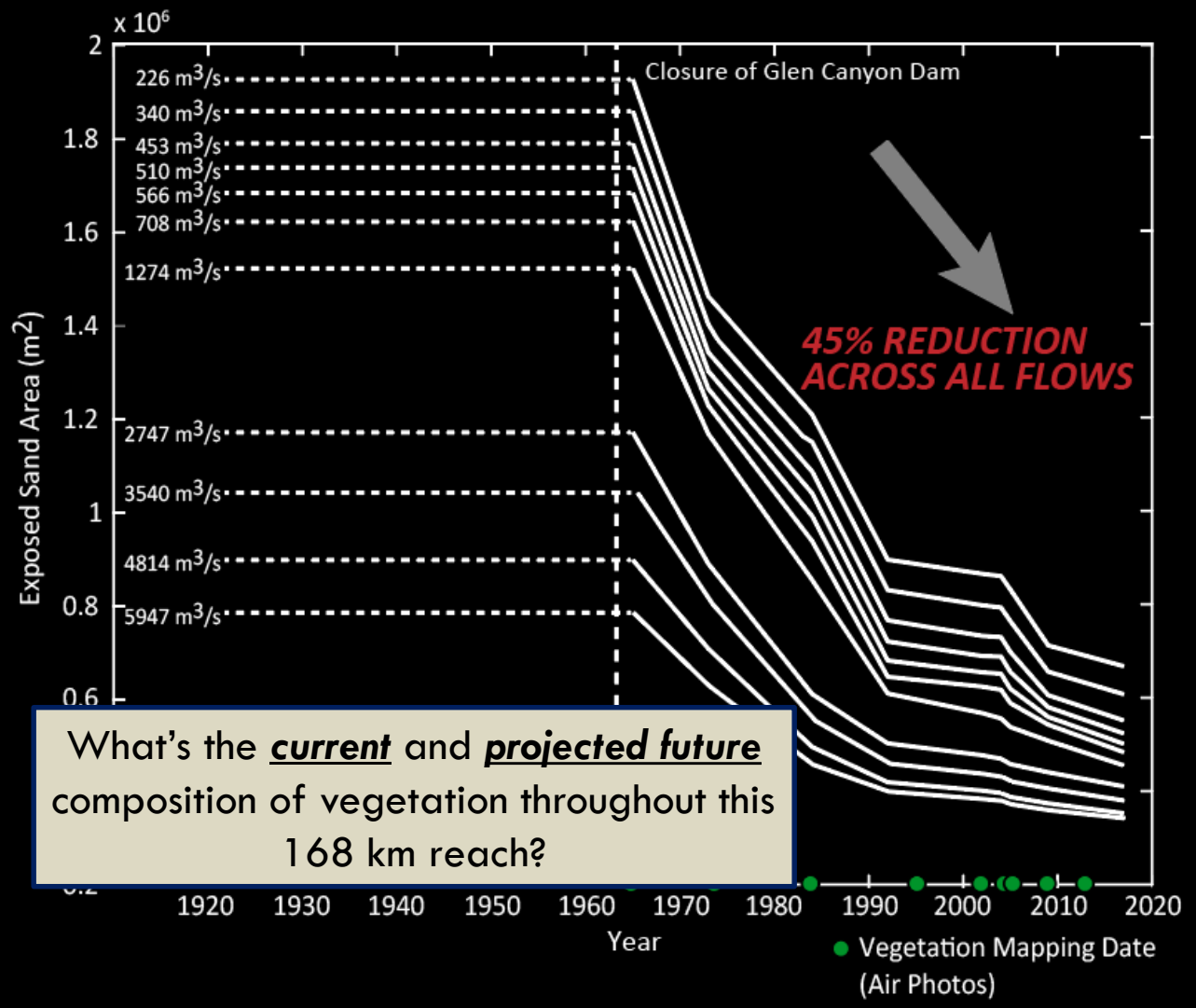

What's the ***current*** and ***projected future*** composition of vegetation throughout this 168 km reach?

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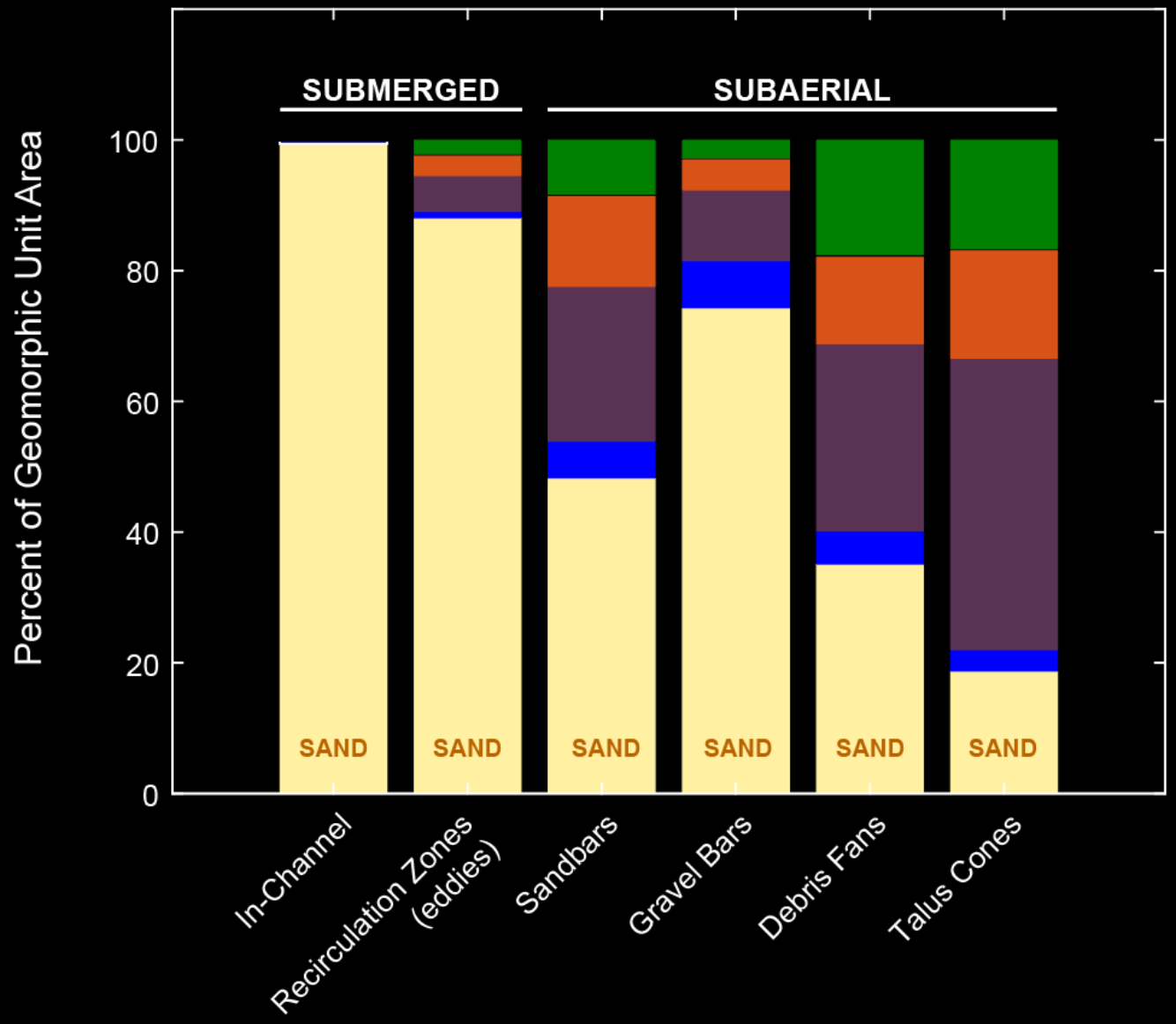
Current Vegetation:

[classified by Durning et al. (2018) via 4-band, 0.2 m aerial imagery]



RIPARIAN HERBS

(e.g., phragmites, Bermuda grass)

NATIVE RIPARIAN SHRUBS

(e.g., baccharis, willow, mesquite)

NON-NATIVE RIPARIAN SHRUBS

(e.g., tamarisk)

XERIC SHRUBS/GRASSES

(e.g., brittlebush, creosote, annual/perennial grasses)

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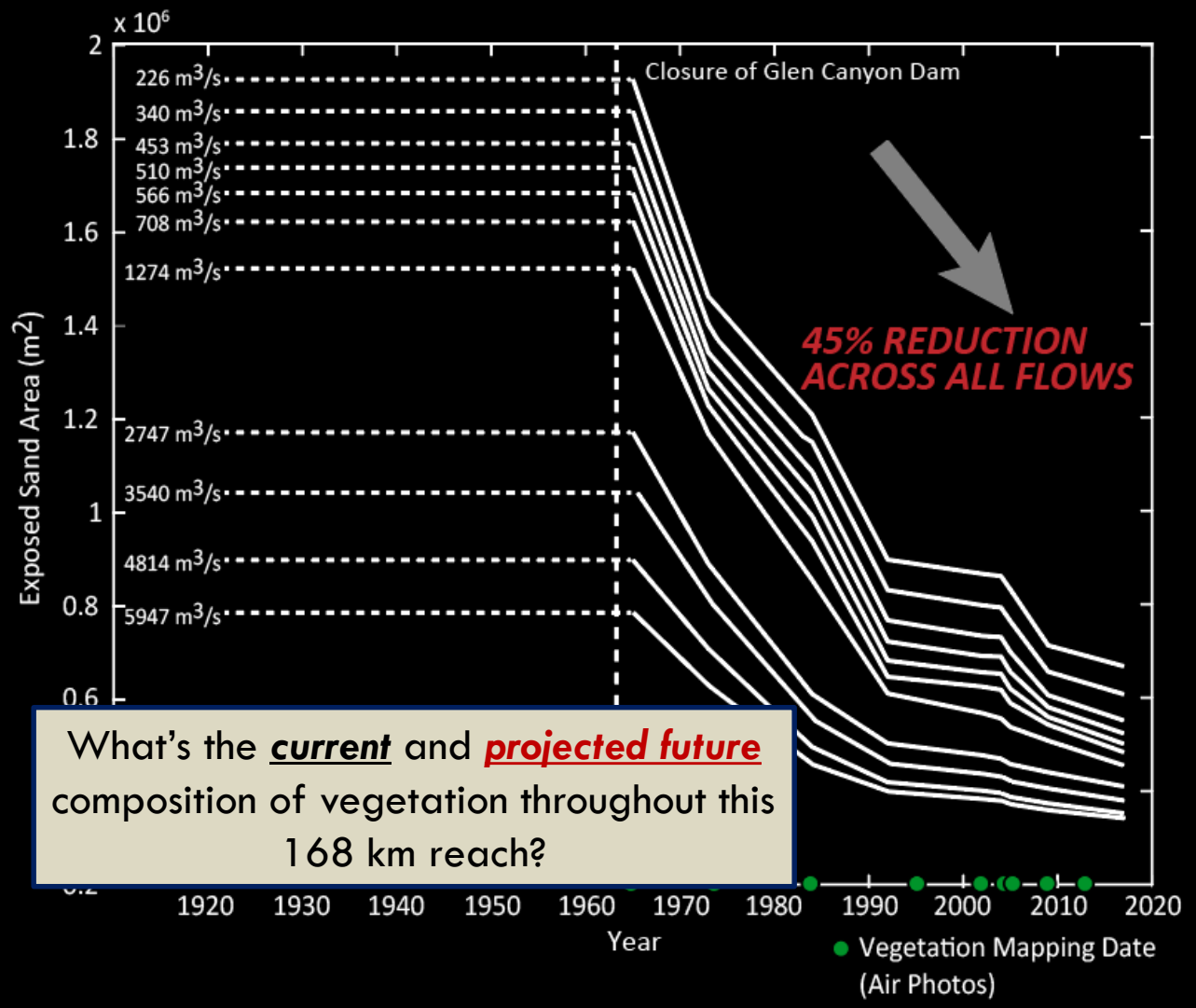

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RESEARCH ARTICLE

Applied Vegetation Science IAVS

Hydrological regime and climate interactively shape riparian vegetation composition along the Colorado River, Grand Canyon

Bradley J. Butterfield[1] | Emily Palmquist[1,2] | Barbara Ralston[3]

Vegetation Suitability Modeling (future conditions)

Predicted binary (i.e., suitable/unsuitable) habitat for 75 plant species, which we aggregated into four groups

Suitability =

f (elevation above daily peak flow)

f (maximum inundation duration)

…over period October 2017 – October 2018

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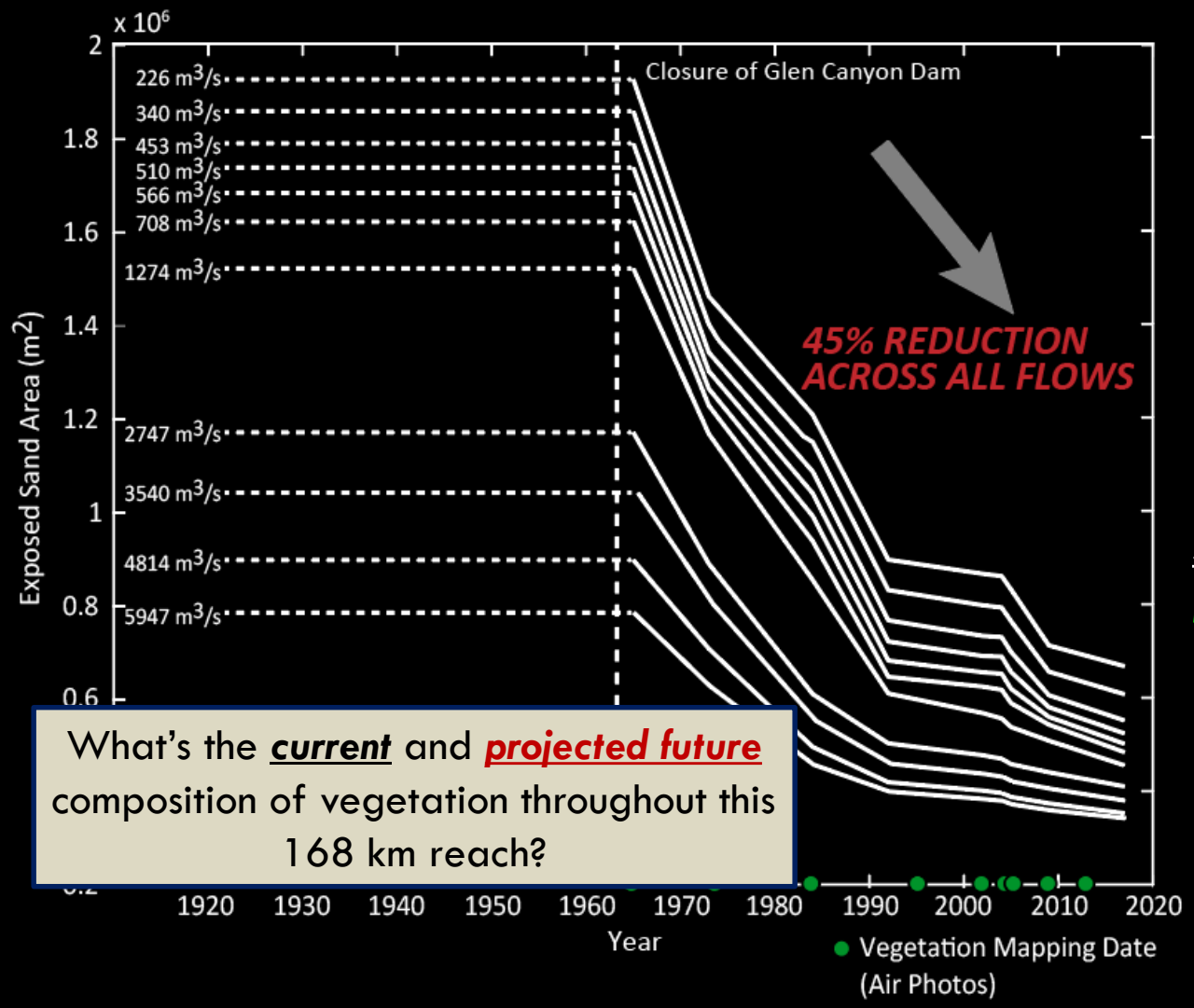

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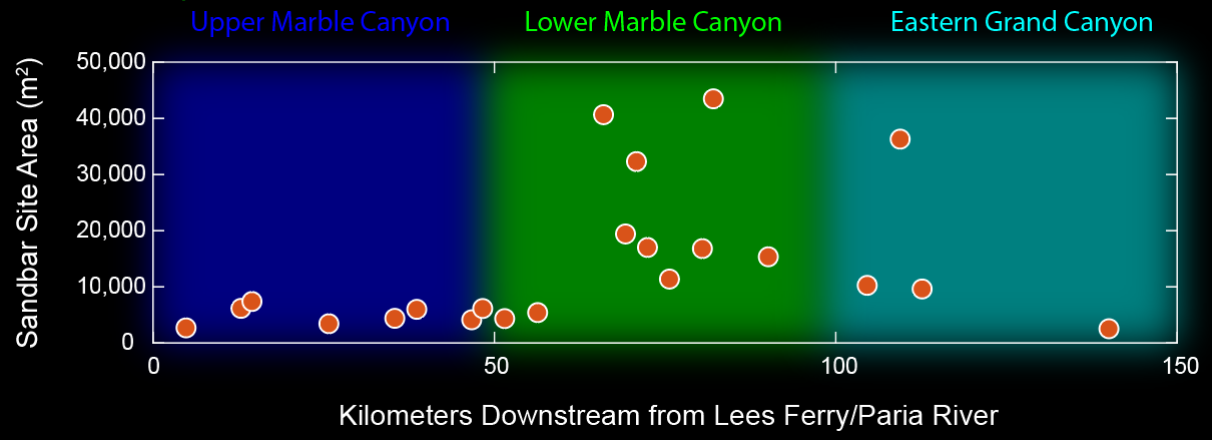
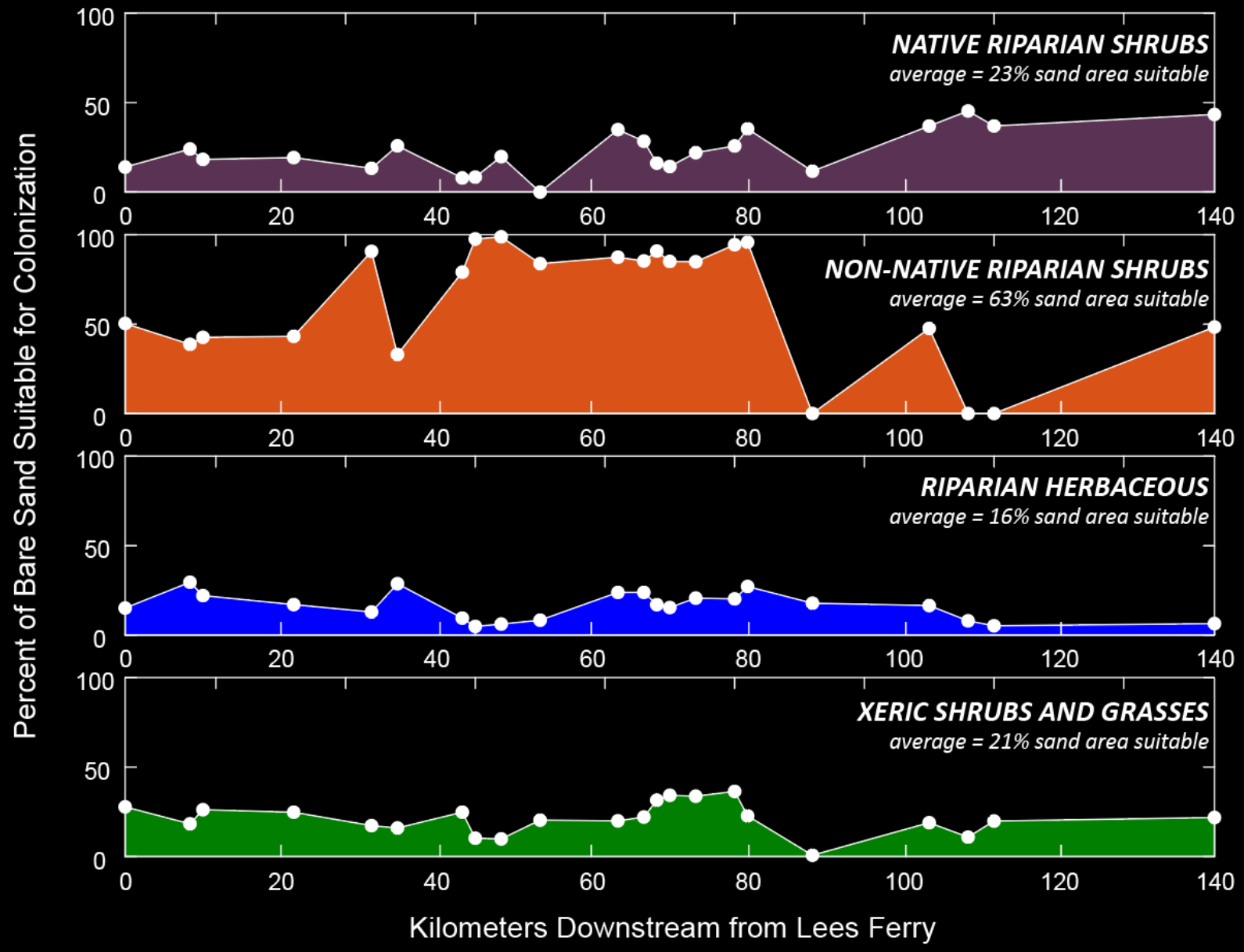
Suitability modeling completed at 25 sandbars

[gcmrc.gov/sandbar]





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(e.g., tamarisk)

RIPARIAN HERBS

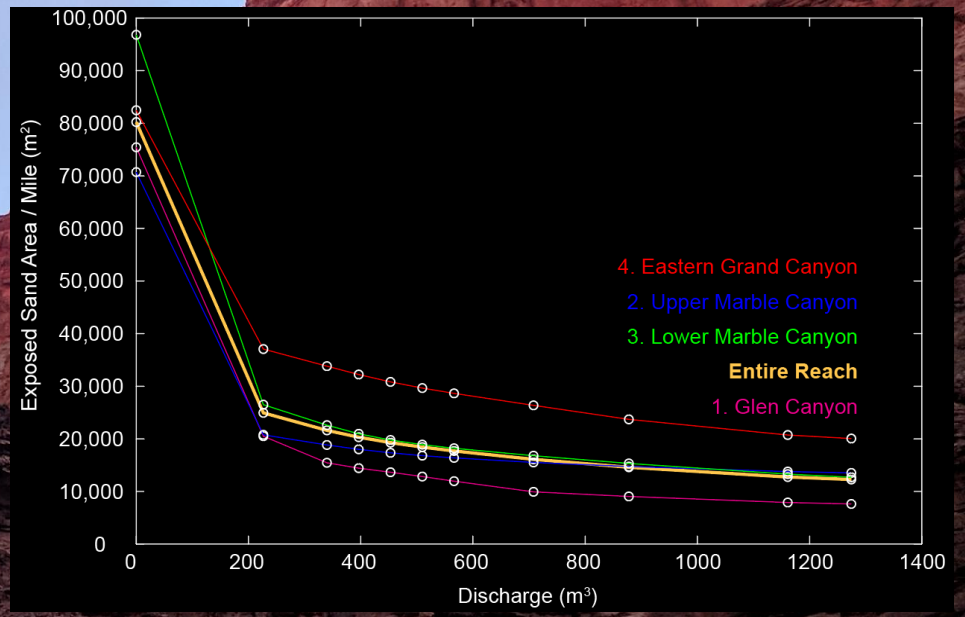
(e.g., phragmites, Bermuda grass)

XERIC SHRUBS/GRASSES

(e.g., brittlebush, creosote, annual/perennial grasses)

In many locations,
Vegetation is likely to colonize most of the remaining bare sand area

Take-Home 1: the majority of the bare sand throughout this 168 km reach is underwater; any reductions in current low flows have the potential to expose a great deal of sand.



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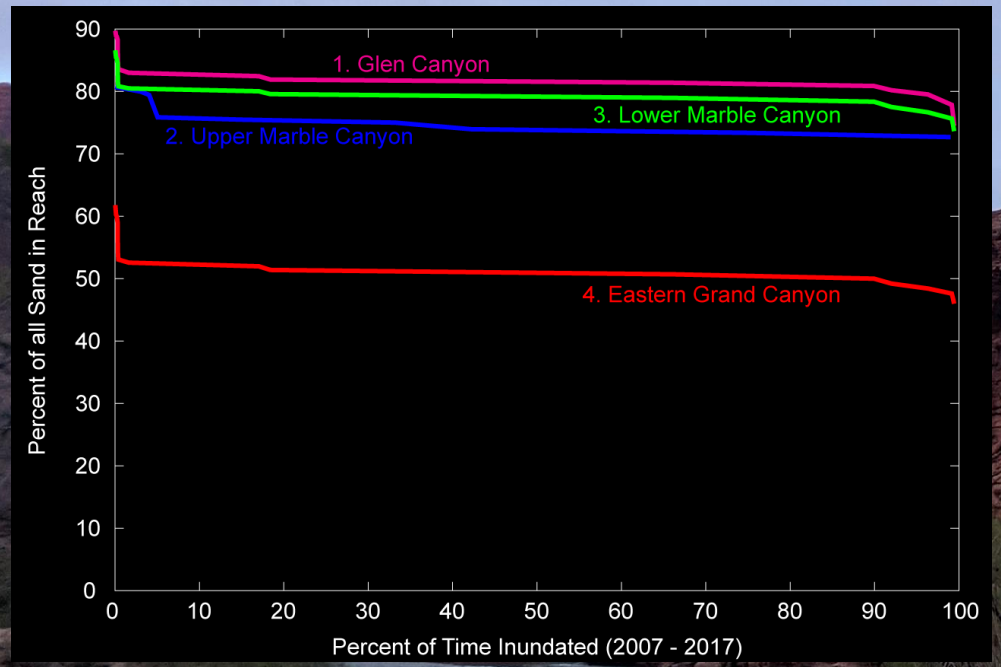

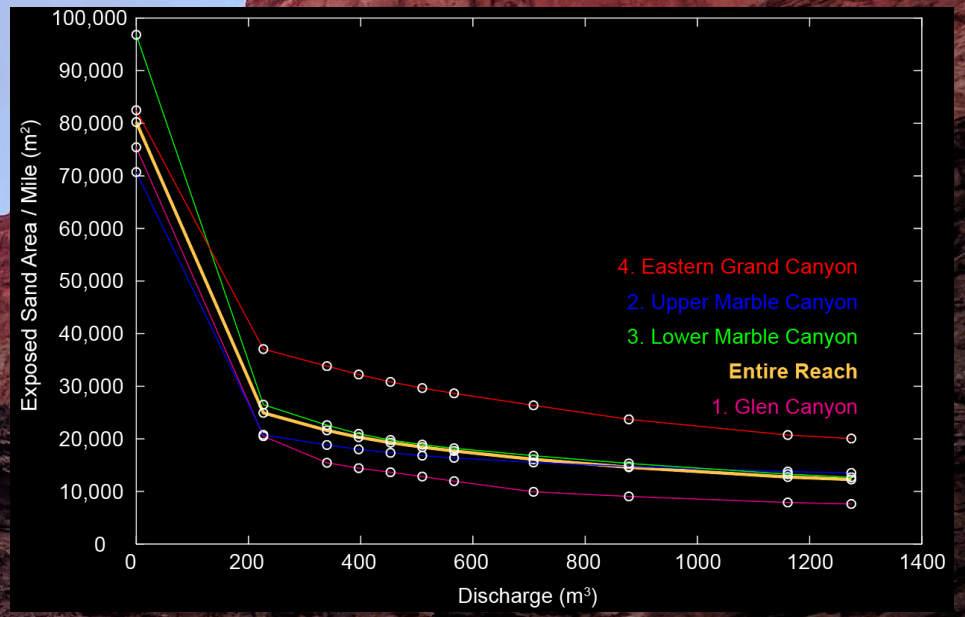

Take-Home 2: the area of bare/exposed sand along Colorado River, and the sensitivity of that area to flow alteration by Glen Canyon Dam, is a function of reach-scale geomorphology

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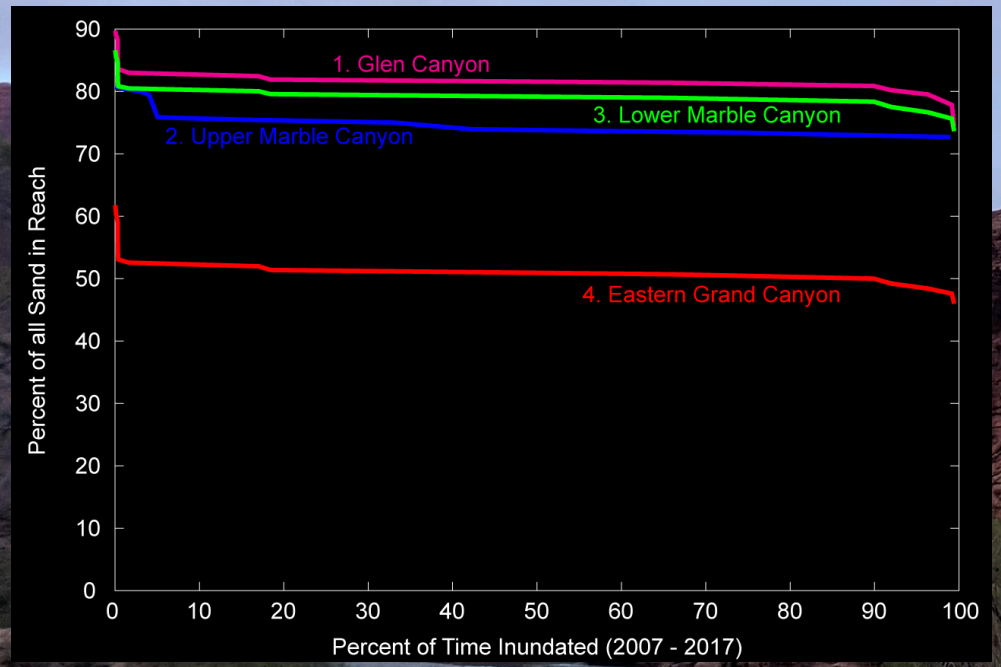

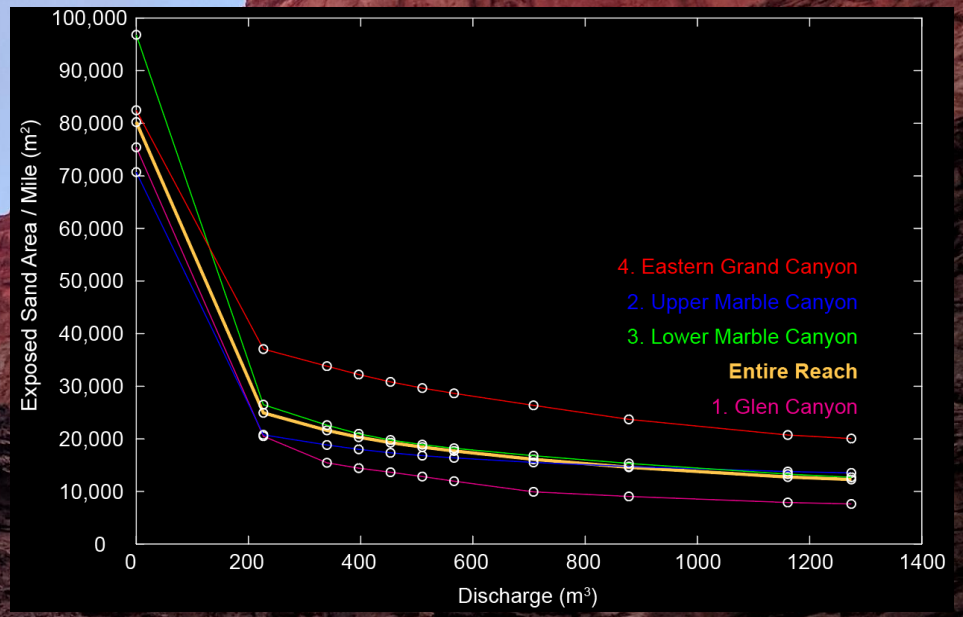

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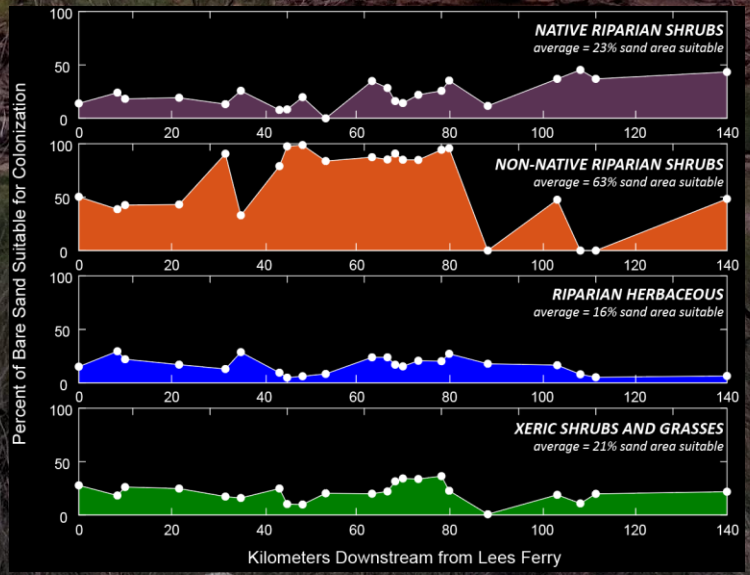

Take-Home 3: Potential for future vegetation encroachment is variable by site, but we can expect lots more plants in the future

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