Conditions and Processes Affecting Sand Resources at Archaeological Sites in the Colorado River Corridor

Amy E. East, Pacific Coastal and Marine Science Center

Brian D. Collins, Geology, Minerals, Energy, & Geophysics Science Center

Joel B. Sankey, Grand Canyon Monitoring and Research Center

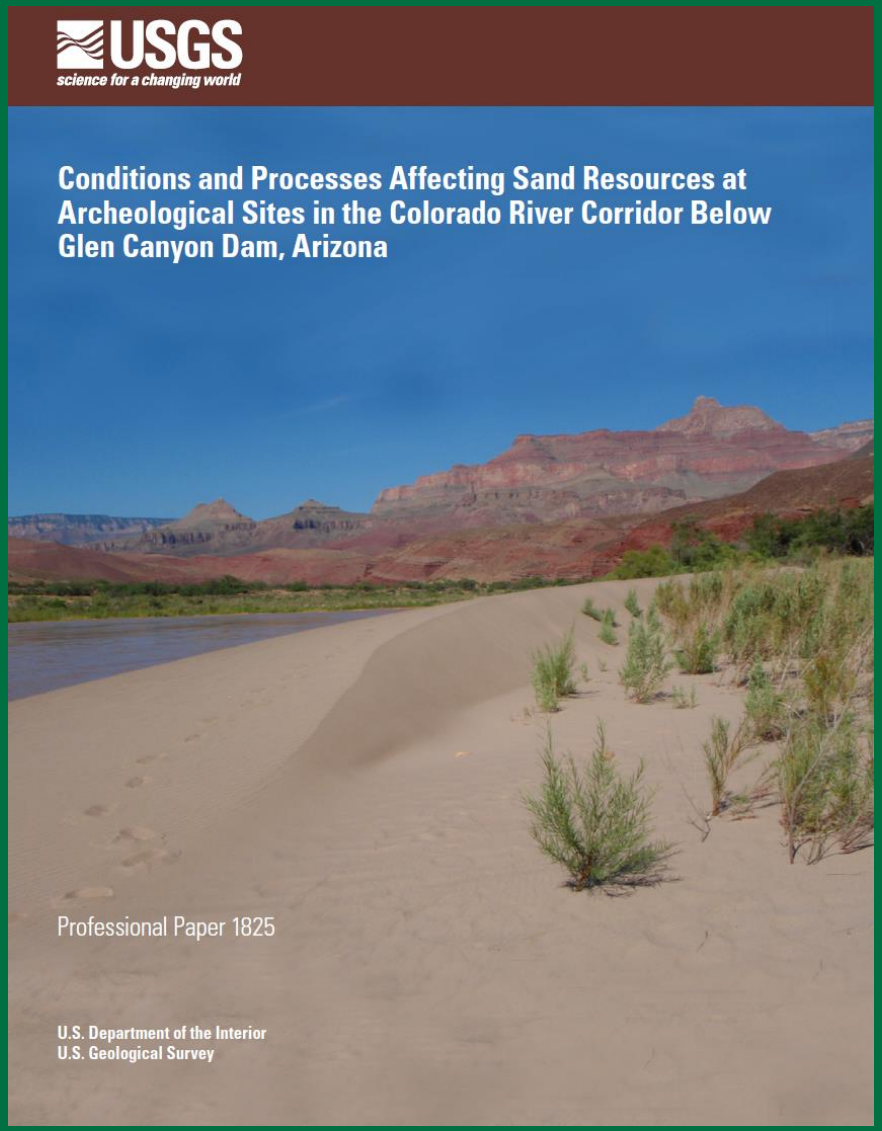
Skye C. Corbett, Geology, Minerals, Energy, & Geophysics Science Center

Helen C. Fairley, Grand Canyon Monitoring and Research Center

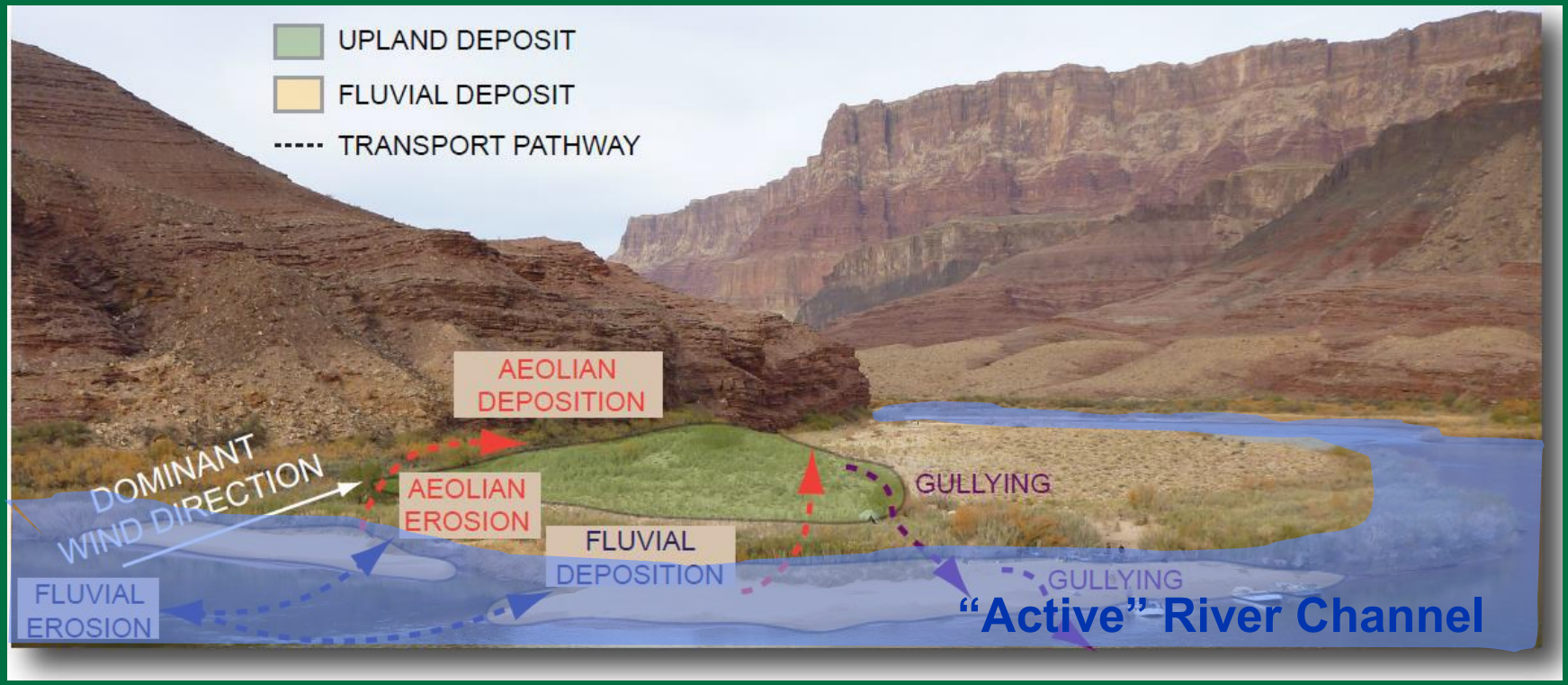
Joshua Caster, Grand Canyon Monitoring and Research Center

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

East, A.E., Collins, B.D., Sankey, J.B., Corbett, S.C., Fairley, H.C., and Caster, J., 2016, Conditions and processes affecting sand resources at archeological sites in the Colorado River corridor below Glen Canyon Dam, Arizona: U.S. Geological Survey Professional Paper 1825, 104 p., http://dx.doi.org/10.3133/pp1825.



USGS



The problem: Landscapes downstream from Glen Canyon Dam contain archaeological resources that are affected by fluvial (river), aeolian (wind), and hillslope (gravity and rainfall-runoff) geomorphic processes.

The question: Can Colorado River sediment enhance the preservation of river-corridor archeological resources in these landscapes through aeolian sand deposition and mitigation of gully erosion?

The results: Relatively few archeological sites are now ideally situated to receive aeolian sand supply from sandbars deposited by recent controlled floods from Glen Canyon Dam.

The possible solutions to increase preservation potential for sand-dependent resources:

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Sediment-rich high flows above 45,000 CFS, and/or
Seasonal low flows below 8,000 CFS, and/or
Riparian vegetation removal

East et al., 2016 Professional Paper 1825

Outline

1) Introduction and Background (8 slides)

2) Project Objectives (1 slide)

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7) Conclusions and A Path Forward (6 slides)

USGS

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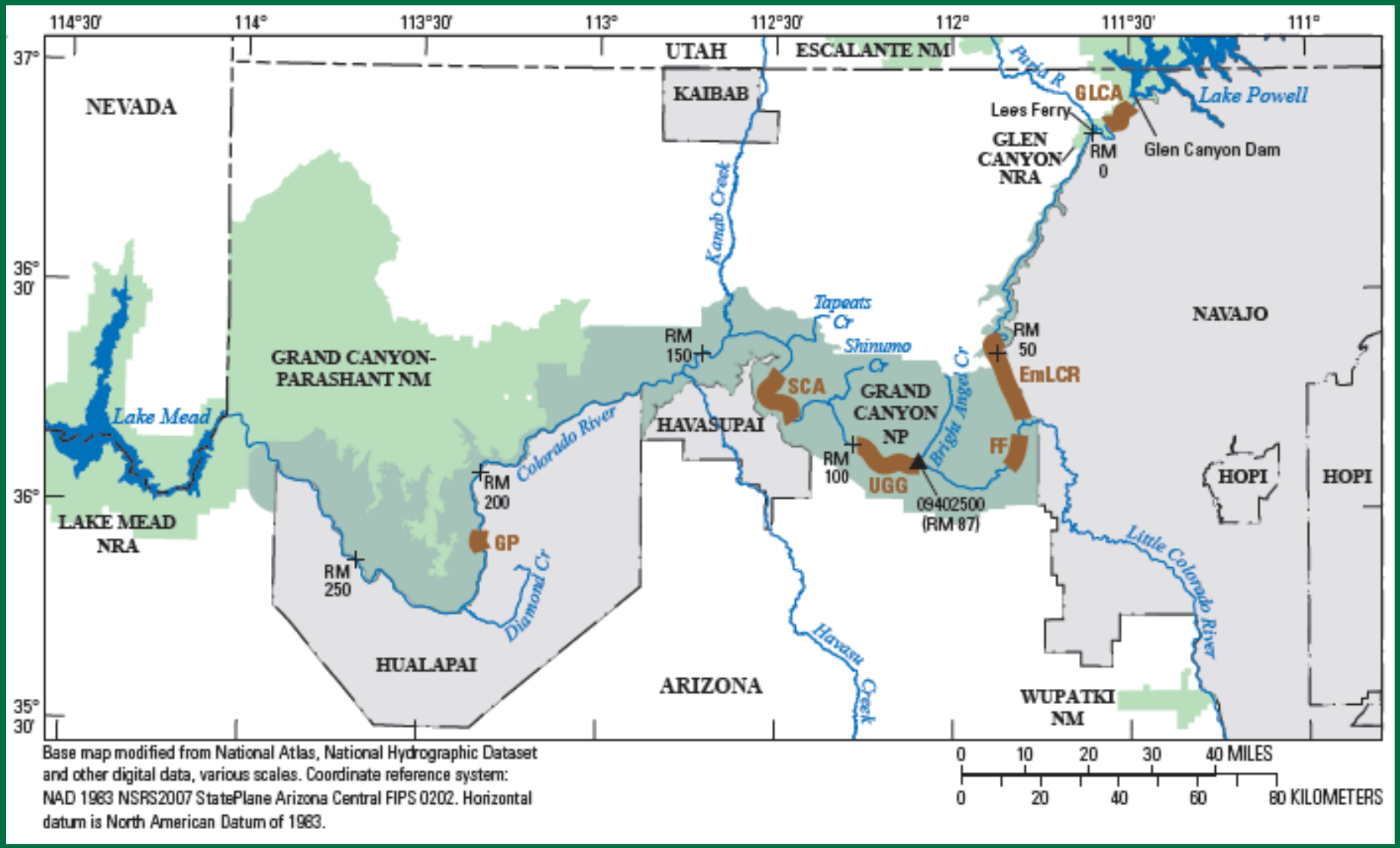


Base map modified from National Atlas, National Hydrographic Dataset and other digital data, various scales. Coordinate reference system: NAD 1983 NSRS2007 StatePlane Arizona Central FIPS 0202. Horizontal datum is North American Datum of 1983.

USGS

Landscapes downstream from Glen Canyon Dam contain archaeological resources that are affected by geomorphic processes

USGS

Sand can potentially help preserve archaeological features by direct burial and/or by mitigating gullying

USGS

Aeolian sand exists within a variety of landscape characteristics along the river corridor…

USGS

Aeolian sand exists within a variety of landscape characteristics along the river corridor (cont'd)

"Active" w/ respect to aeolian transport

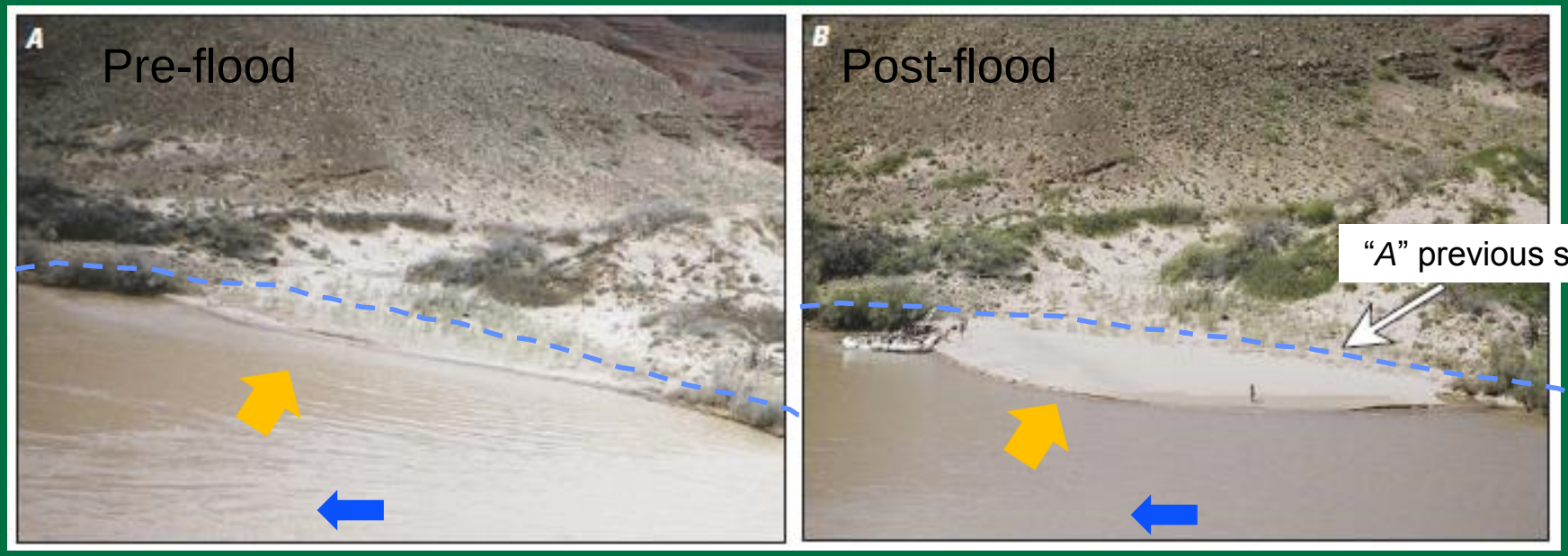
"Inactive" w/ respect to aeolian transport

USGS

Aeolian sand is currently predominantly sourced from river sandbars and therefore from controlled floods (High Flow Experiments)…

USGS

Aeolian sand is currently predominantly sourced from river sandbars and therefore from controlled floods (High Flow Experiments) (cont'd)



Approximate elevation of controlled floods

Direction of wind

Direction of Colorado River Flow

USGS

Aeolian dune
6.5 years after 2008 HFE

Aeolian dune
7 months after 2008 HFE

Sandbar
1 month after 2008 HFE

Feb. 10, 2008
April 5, 2008
October 18, 2008
October 18, 2009
October 09, 2012
Sept. 28, 2013
May 8, 2014
Oct. 1, 2014

41, 000 CFS

Elevation (m)

785

780

0 20 40 60 80

Distance From Arbitrary Datum (m)

Higher elevation valley margin ← River

Joe Hazel, Northern Arizona University, unpublished data, do not cite

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7) Conclusions and A Path Forward (6 slides)

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Objectives

- Are archeological sites in the Colorado River corridor eroding or changing faster or in a significantly different manner than they would if Glen Canyon Dam were operated differently than it has been?
  - What number, and what proportion, of cultural sites in the Colorado River corridor potentially receive aeolian sand supply from controlled flood flows?
  - How effective is aeolian sand activity as a gully-annealing process?
  - Does aeolian sand supply from controlled-flood sandbars to archeological sites cause enough deposition to offset erosion, and thereby protect the archeological resources?
  - In areas with modern aeolian sand supply, and with land surfaces undergoing both gully erosion and active aeolian sand transport, is there net sediment loss and topographic lowering such that cultural resources are affected?

USGS

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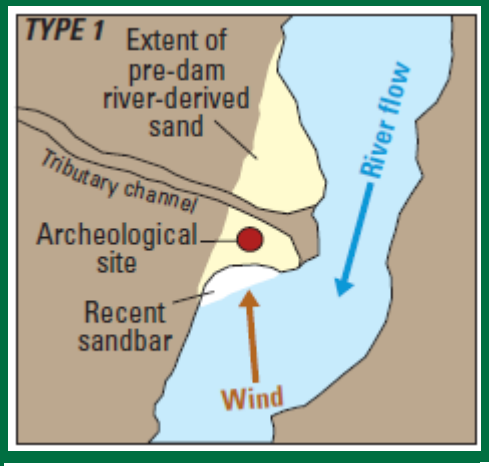
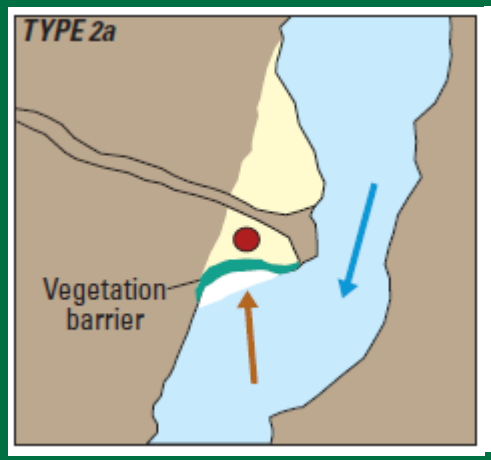
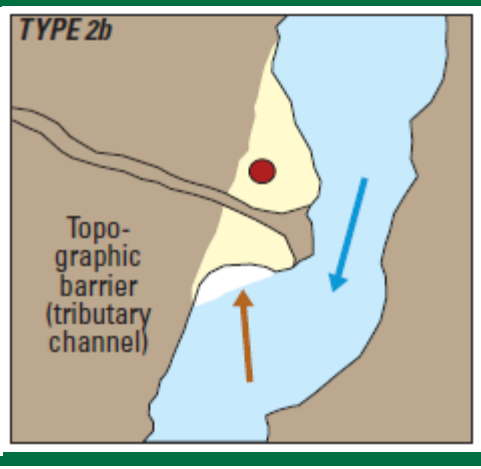
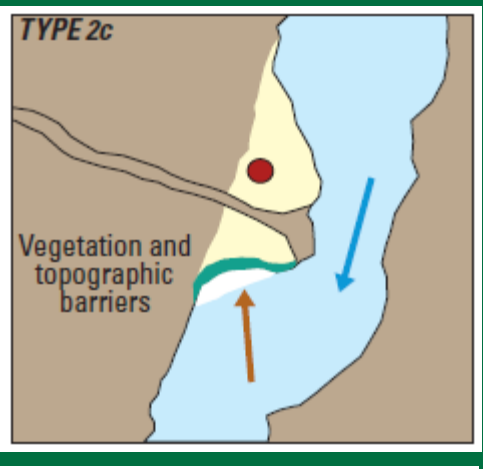
Potential Aeolian Sand Supply to River-Corridor Archeological Sites in Grand Canyon National Park

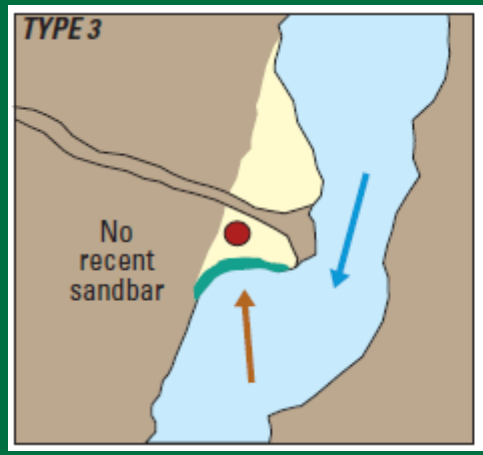
What number, and proportion, of cultural sites in the Colorado River corridor potentially receive aeolian sand supply from controlled flood flows?

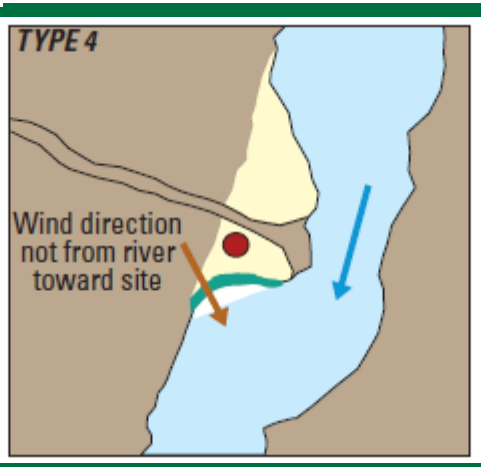


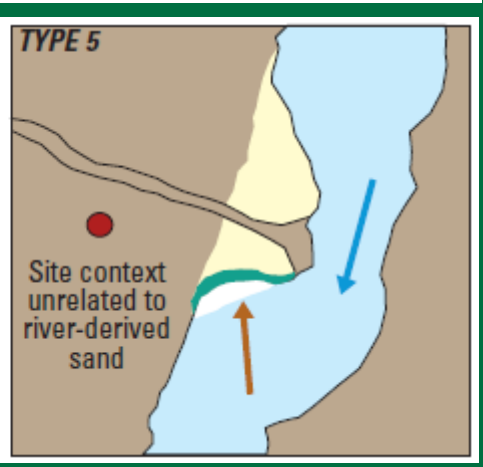








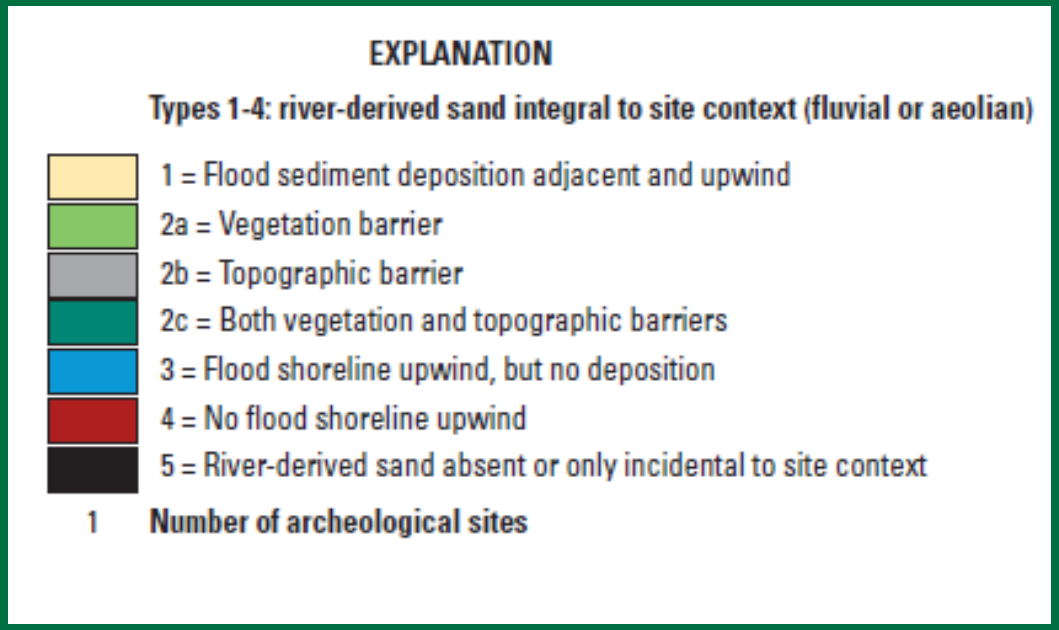


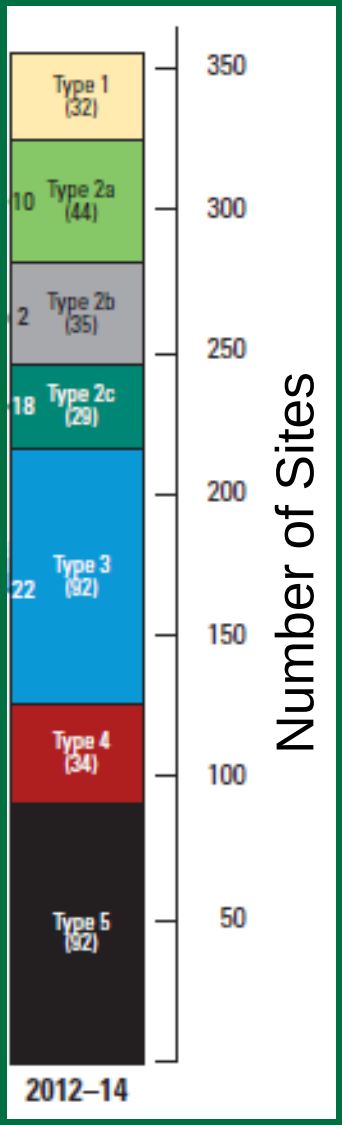


East et al., 2016 Professional Paper 1825

Potential Aeolian Sand Supply to River-Corridor Archeological Sites in Grand Canyon National Park

What number, and proportion, of cultural sites in the Colorado River corridor potentially receive aeolian sand supply from controlled flood flows?





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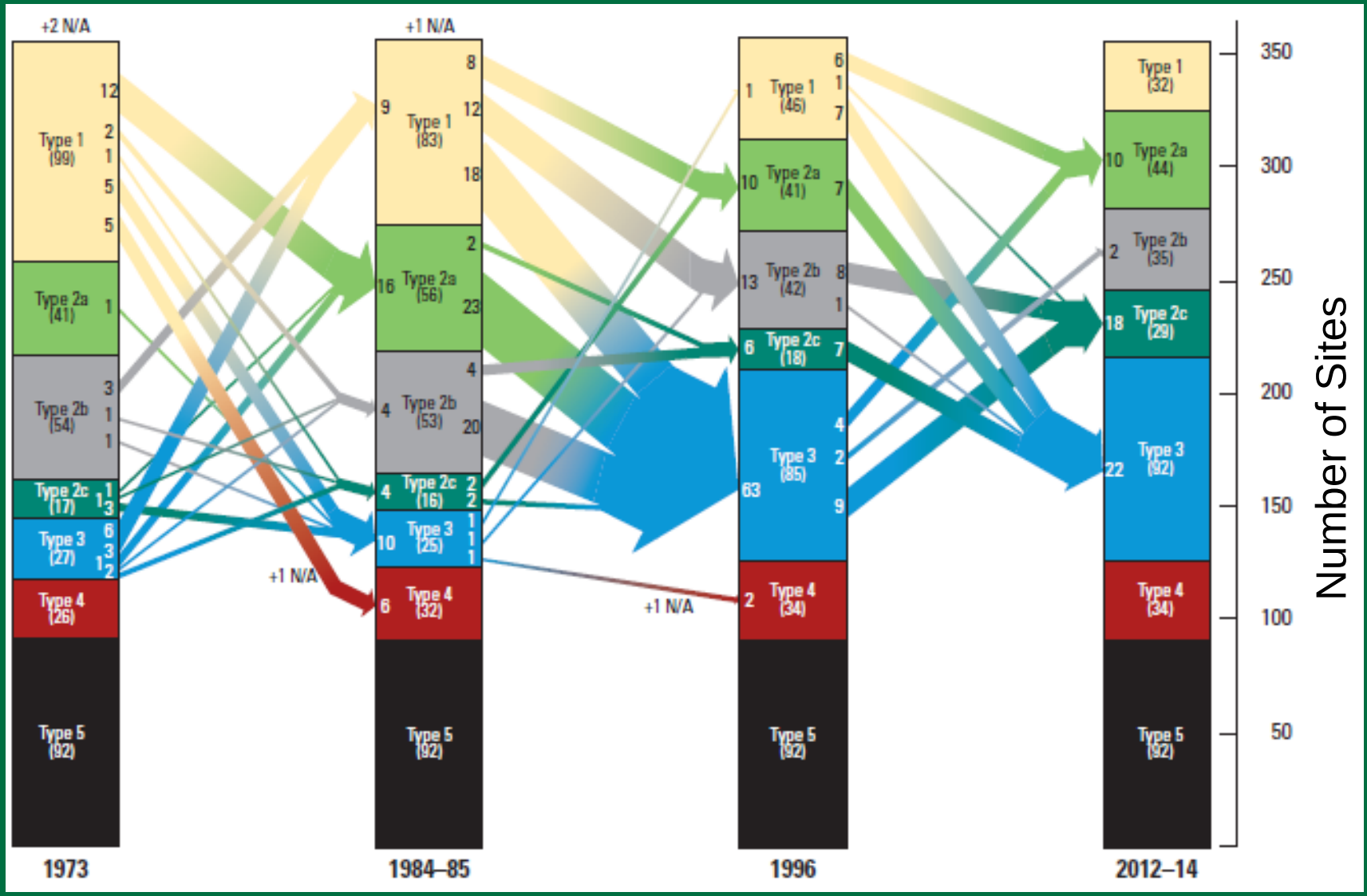

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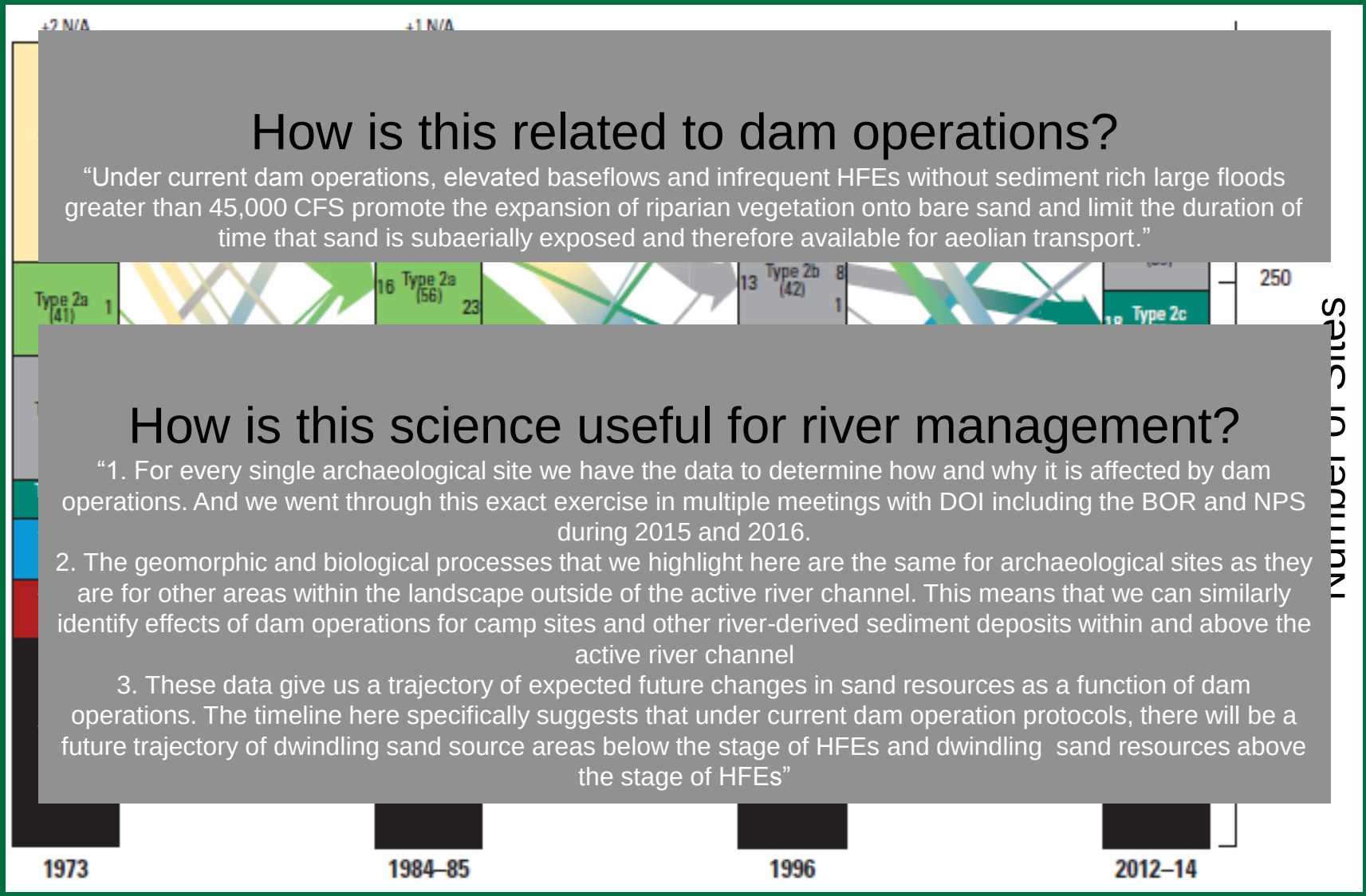

How is this related to dam operations?

"Under current dam operations, elevated baseflows and infrequent HFEs without sediment rich large floods greater than 45,000 CFS promote the expansion of riparian vegetation onto bare sand and limit the duration of time that sand is subaerially exposed and therefore available for aeolian transport."

How is this science useful for river management?

"1. For every single archaeological site we have the data to determine how and why it is affected by dam operations. And we went through this exact exercise in multiple meetings with DOI including the BOR and NPS during 2015 and 2016.

2. The geomorphic and biological processes that we highlight here are the same for archaeological sites as they are for other areas within the landscape outside of the active river channel. This means that we can similarly identify effects of dam operations for camp sites and other river-derived sediment deposits within and above the active river channel

3. These data give us a trajectory of expected future changes in sand resources as a function of dam operations. The timeline here specifically suggests that under current dam operation protocols, there will be a future trajectory of dwindling sand source areas below the stage of HFEs and dwindling sand resources above the stage of HFEs"

Small white text in quotes was not on original slide, but paraphrases what Joel said orally in presentation

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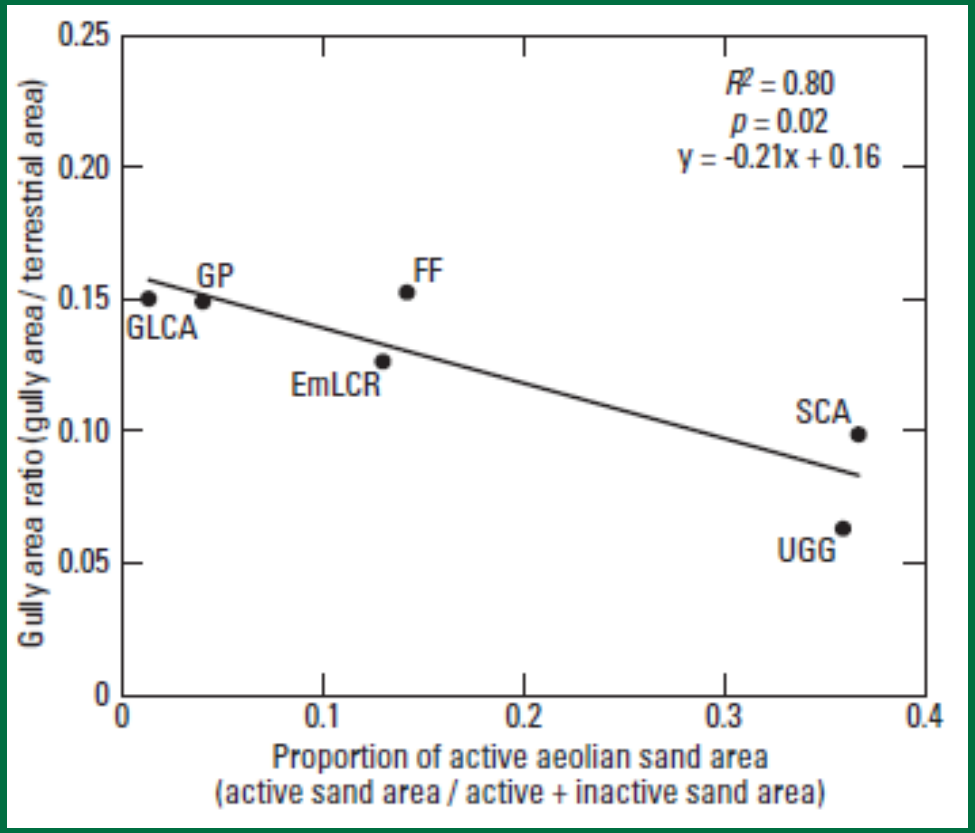
USGS

Gullies and Aeolian Sand Activity in the Geomorphic Context of the Colorado River Corridor

How effective is aeolian sand activity as a gully-annealing process?



Gullies are less prevalent in river reaches w/ more sand that is active w/ respect to aeolian transport

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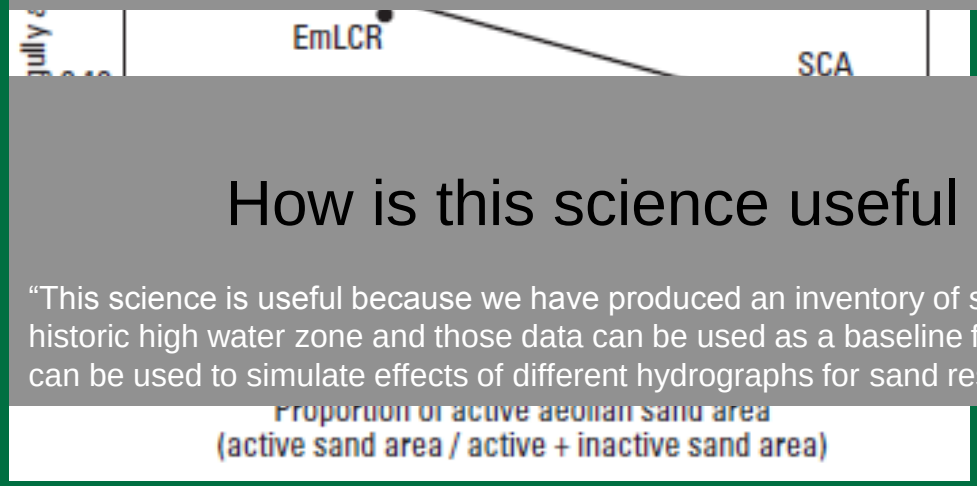
East et al., 2016 Professional Paper 1825

Gullies and Aeolian Sand Activity in the Geomorphic Context of the Colorado River Corridor

How effective is aeolian sand activity as a gully-annealing process?

How is this related to dam operations?

"Under current dam operations, elevated baseflows and infrequent HFEs without sediment rich large floods greater than 45,000 CFS promote the expansion of riparian vegetation onto bare sand and limit the duration of time that sand is subaerially exposed and therefore available for aeolian transport. This in turn results in landscapes above the stage of HFEs that contain less active aeolian sand and are therefore more erodible by rainfall runoff than they could be if the dam were operated differently."



How is this science useful to river management?

"This science is useful because we have produced an inventory of sand resources than spans the active river channel to the historic high water zone and those data can be used as a baseline for tracking changes into the future. Specifically the data can be used to simulate effects of different hydrographs for sand resources at and above the HFE stage."

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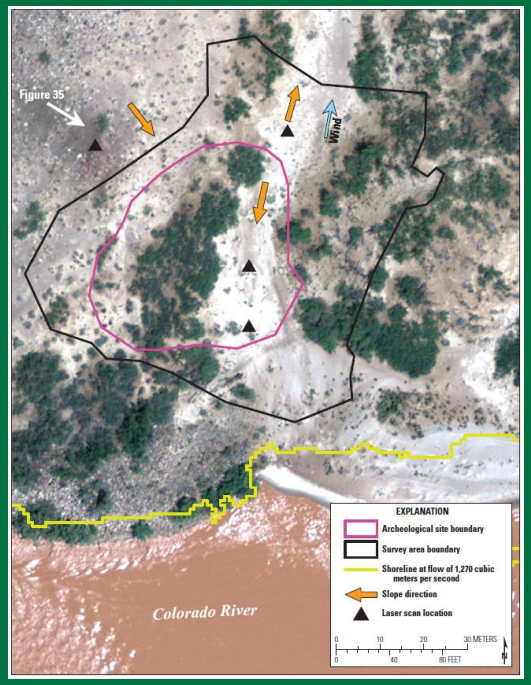
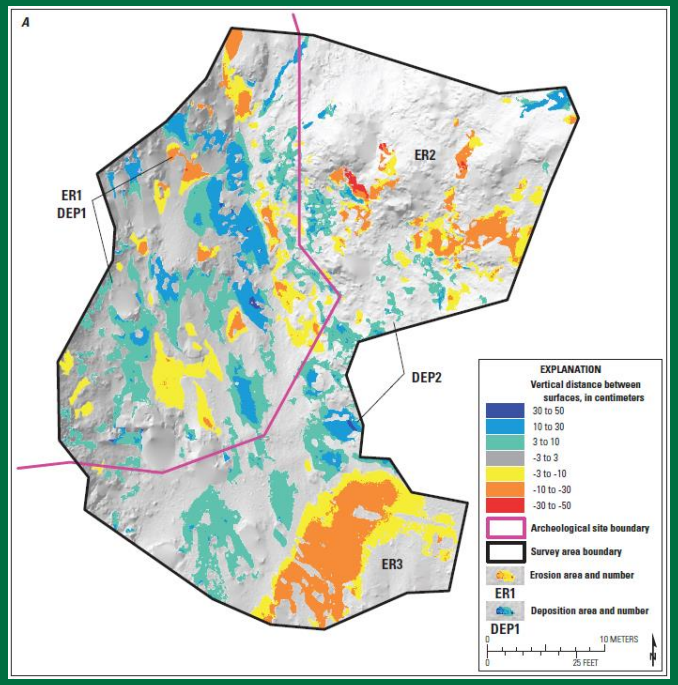
Landscape Change at Archeological Sites Receiving Sand Supply After Controlled Floods, Grand Canyon National Park

Does aeolian sand supply from controlled-flood sandbars to archeological sites cause enough deposition to offset erosion, and thereby protect the archeological resources?

In areas with modern aeolian sand supply, and with land surfaces undergoing both gully erosion and active aeolian sand transport, is there net sediment loss and topographic lowering such that cultural resources are affected?





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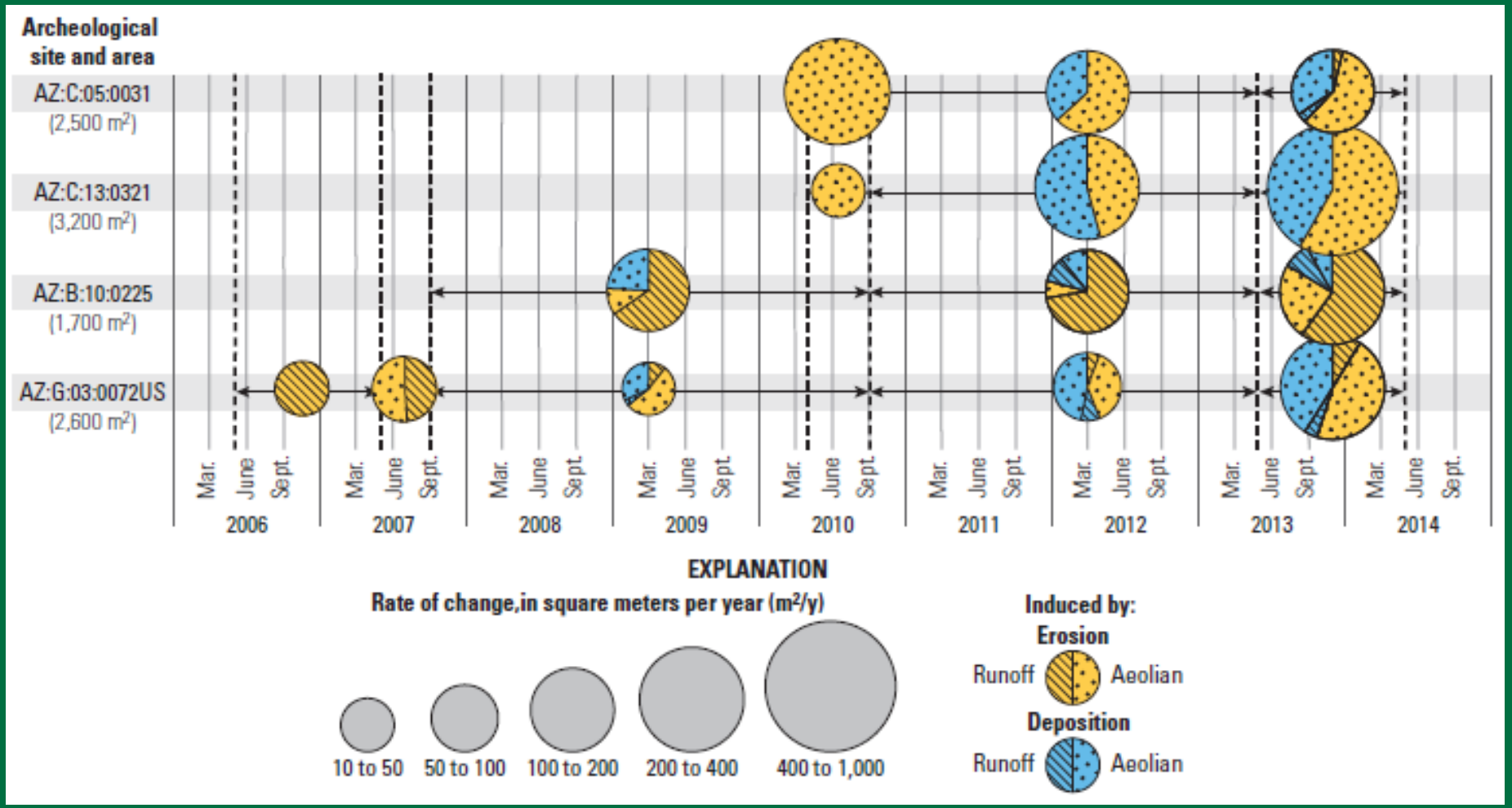
Landscape Change at Archeological Sites Receiving Sand Supply After Controlled Floods, Grand Canyon National Park



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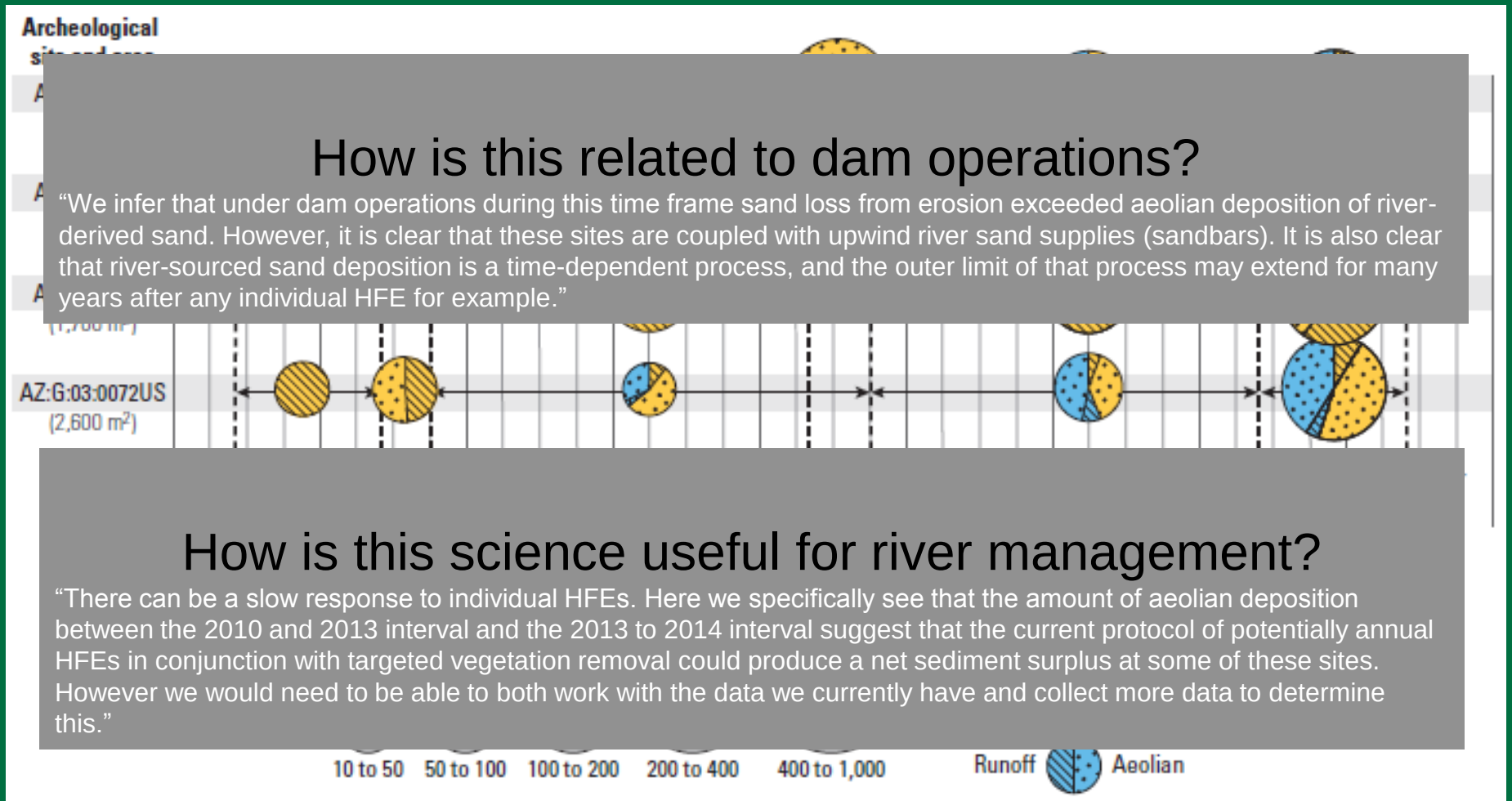

How is this related to dam operations?

"We infer that under dam operations during this time frame sand loss from erosion exceeded aeolian deposition of river-derived sand. However, it is clear that these sites are coupled with upwind river sand supplies (sandbars). It is also clear that river-sourced sand deposition is a time-dependent process, and the outer limit of that process may extend for many years after any individual HFE for example."

How is this science useful for river management?

"There can be a slow response to individual HFEs. Here we specifically see that the amount of aeolian deposition between the 2010 and 2013 interval and the 2013 to 2014 interval suggest that the current protocol of potentially annual HFEs in conjunction with targeted vegetation removal could produce a net sediment surplus at some of these sites. However we would need to be able to both work with the data we currently have and collect more data to determine this."

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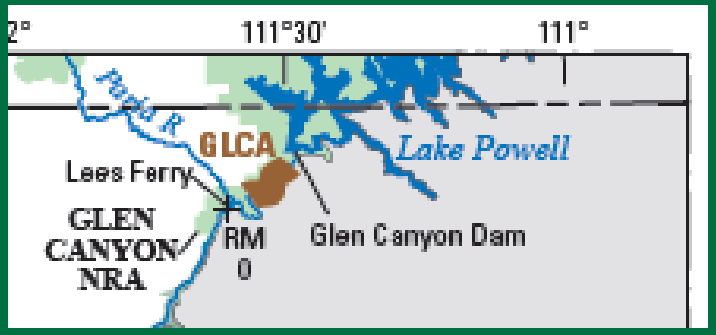
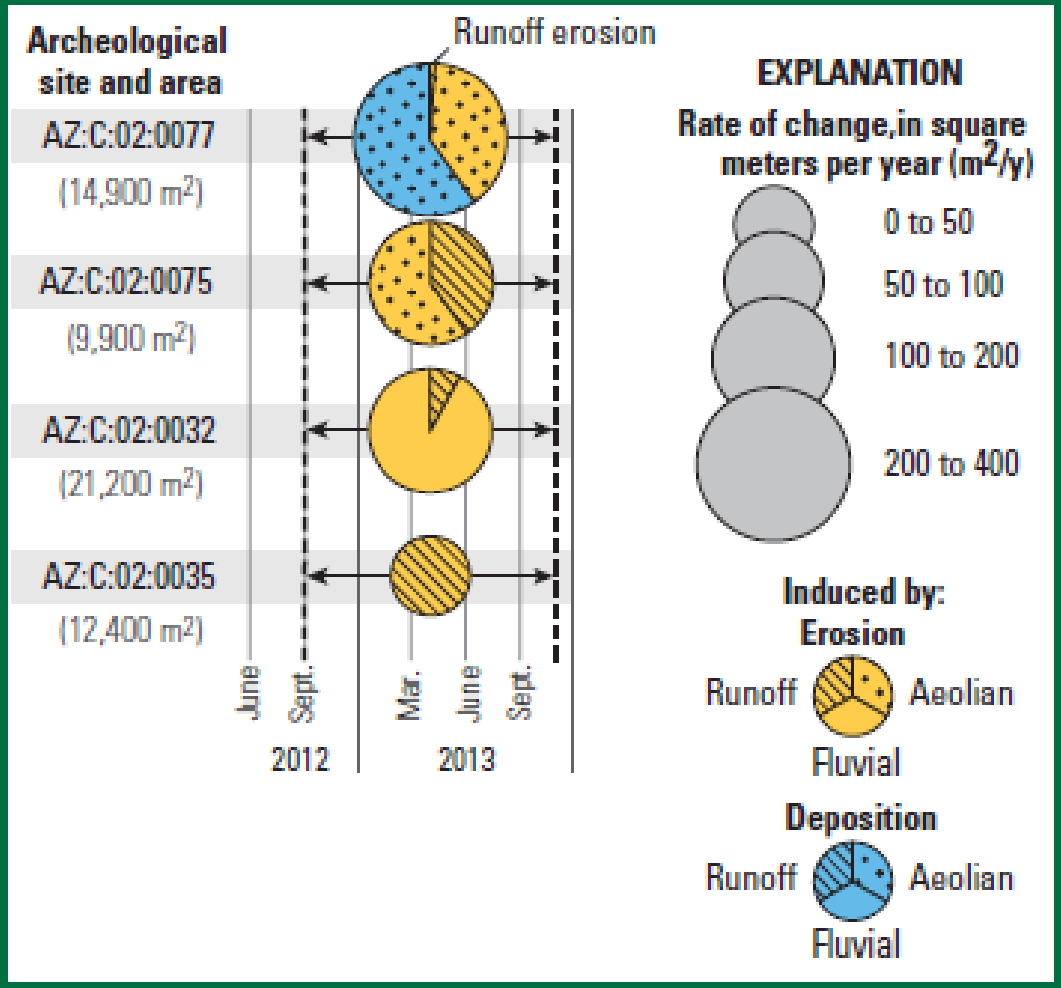
Landscape Change at Archeological Sites in a Sediment-Starved Reach: Glen Canyon National Recreation Area



Downstream of Glen Canyon Dam, but upstream of the Paria River at Lees Ferry (sand supply for controlled floods)



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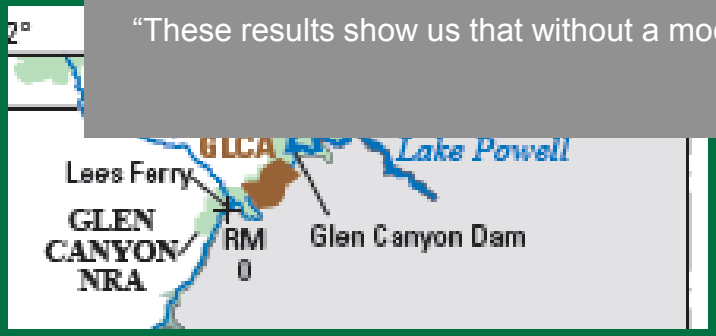
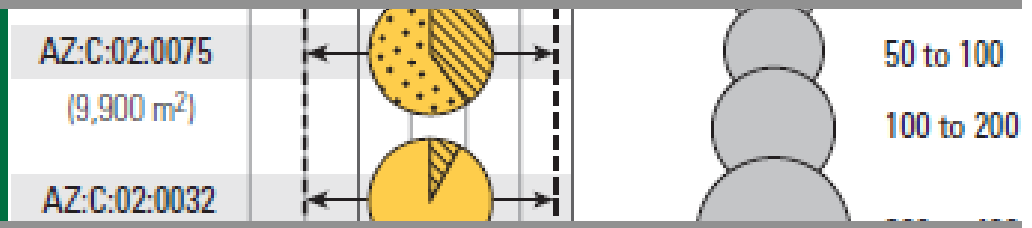
Landscape Change at Archeological Sites in a Sediment-Starved Reach: Glen Canyon National Recreation Area

How is this related to dam operations?

"These results show us that without a modern river sand supply, sites and landscapes above the stage of HFEs are dominated by erosion
"





How is this science useful for river management?

"The one site in Glen Canyon that experienced net aeolian deposition is not sourced so much by an upwind sand bar as by an older, higher elevation and unvegetated terrace. This emphasizes the utility of maintaining sand sources that aren't covered by vegetation above the HFE stage

This work also underscores the fact that Glen Canyon is subject to a different suite of processes compared to Grand Canyon because it is sediment starved. And because of this our emphasis is now really on trying to help Glen Canyon NPS staff monitor cumulative effects of dam operations to terraces and specifically terrace erosion."
"

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Fluvial

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USGS

Conclusions

- Most of the river-corridor archeological sites are not ideally situated to receive aeolian sand supply from sandbars deposited by recent controlled floods from Glen Canyon Dam, and therefore are at elevated risk of net erosion under present dam operations.
- For archeological sites that depend upon river-derived sand, we infer elevated erosion risk owing to a combination of reduced sand supply (both fluvial and aeolian) through (1) the lower-than-natural flood magnitude, frequency, and sediment supply of the controlled-flooding protocol; (2) reduction of open, dry sand area available for wind redistribution under current normal (nonflood) dam operations, which do not include flows as low as natural seasonal low flows and do include substantial daily flow fluctuations; and (3) impeded aeolian sand entrainment and transport owing to increased riparian vegetation growth due to high baseflows and in the absence of larger, more-frequent floods.

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East et al., 2016 Professional Paper 1825

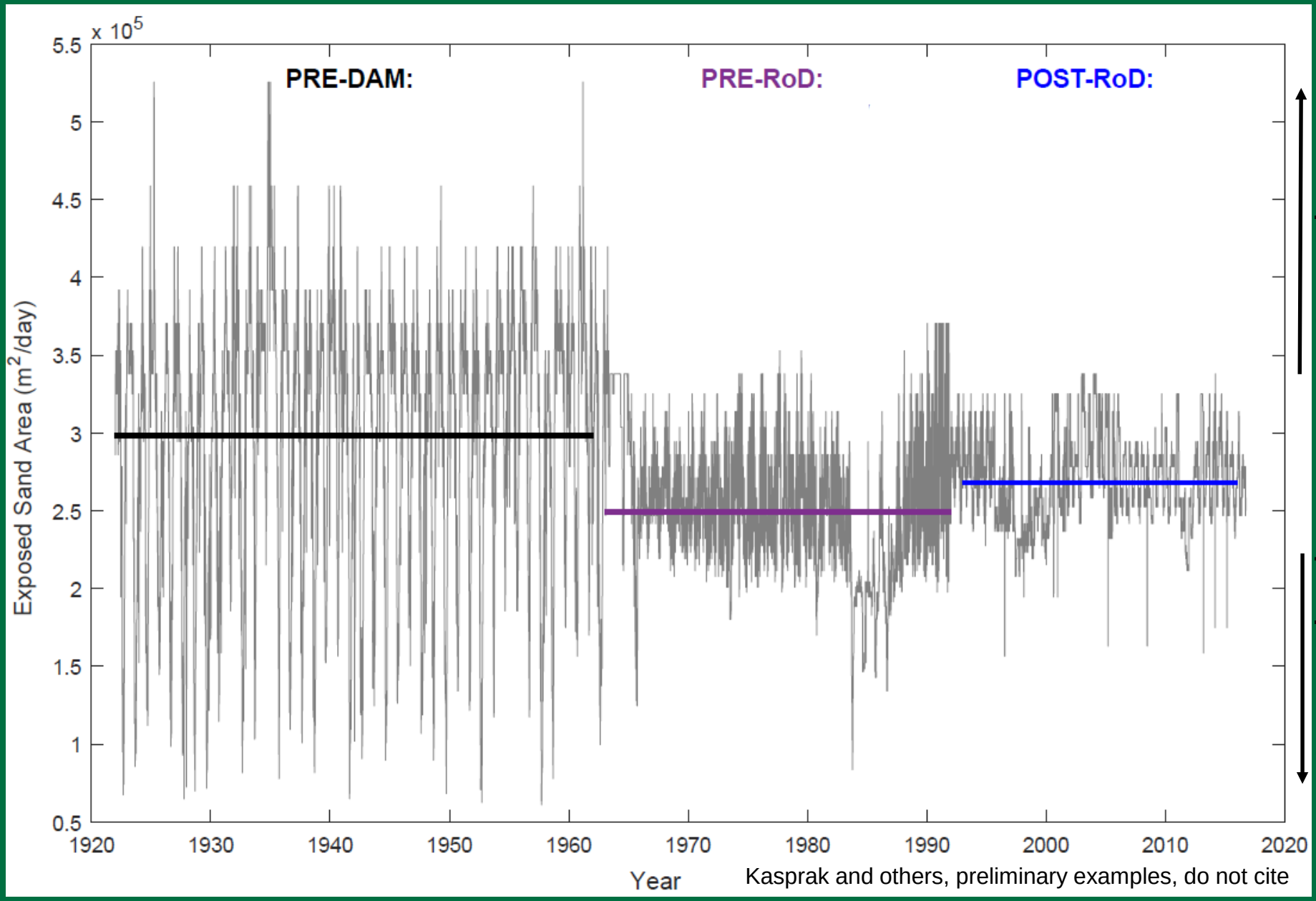
Path Forward

- The possible solutions to increase preservation potential for sand-dependent resources
  - Sediment-rich high flows above 45,000 CFS, and/or
  - Seasonal low flows below 8,000 CFS, and/or
  - Riparian vegetation removal

USGS

East et al., 2016 Professional Paper 1825

Path Forward – What are we doing in Project 4 to address possible solutions and provide science that is useful for river management?



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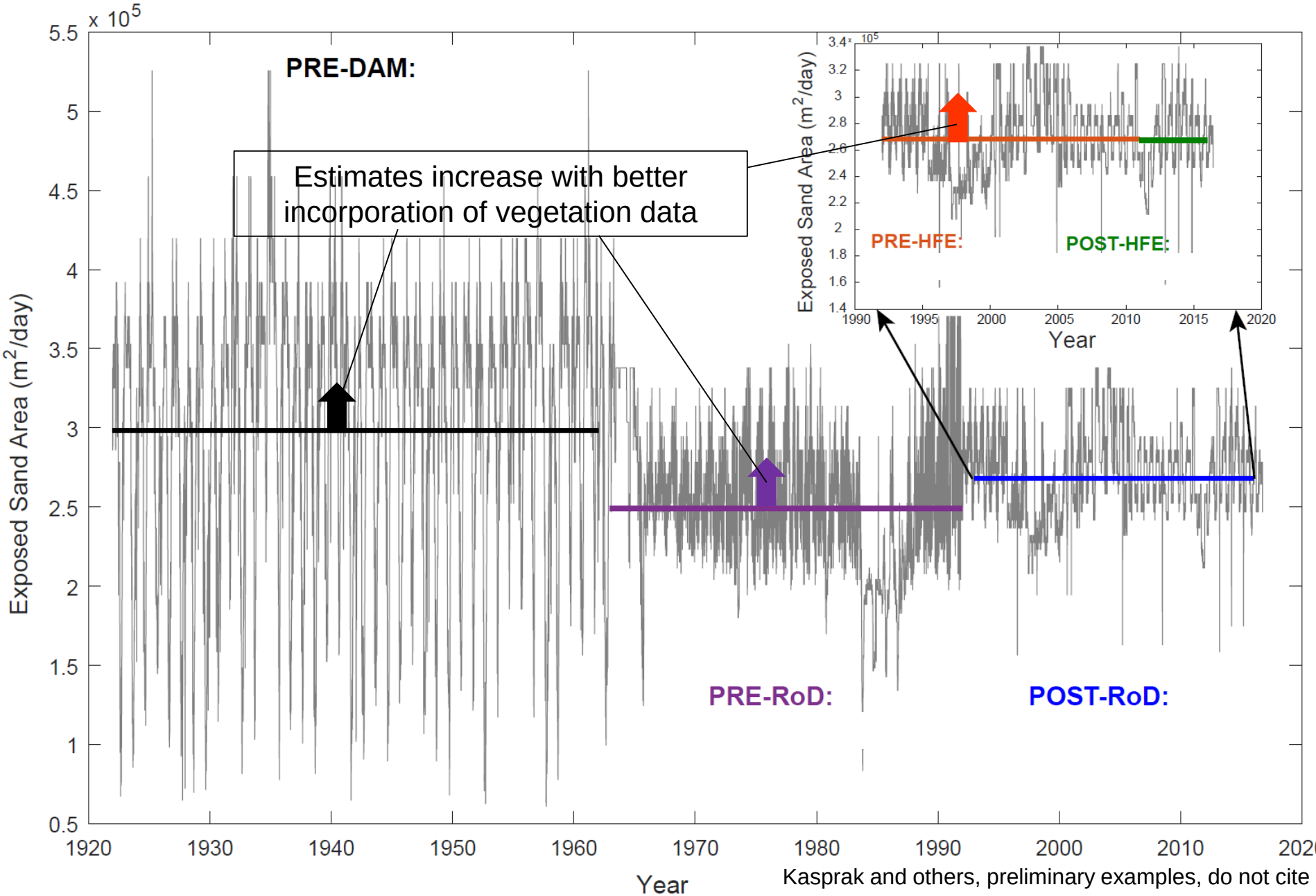

Kasprak and others, preliminary examples, do not cite

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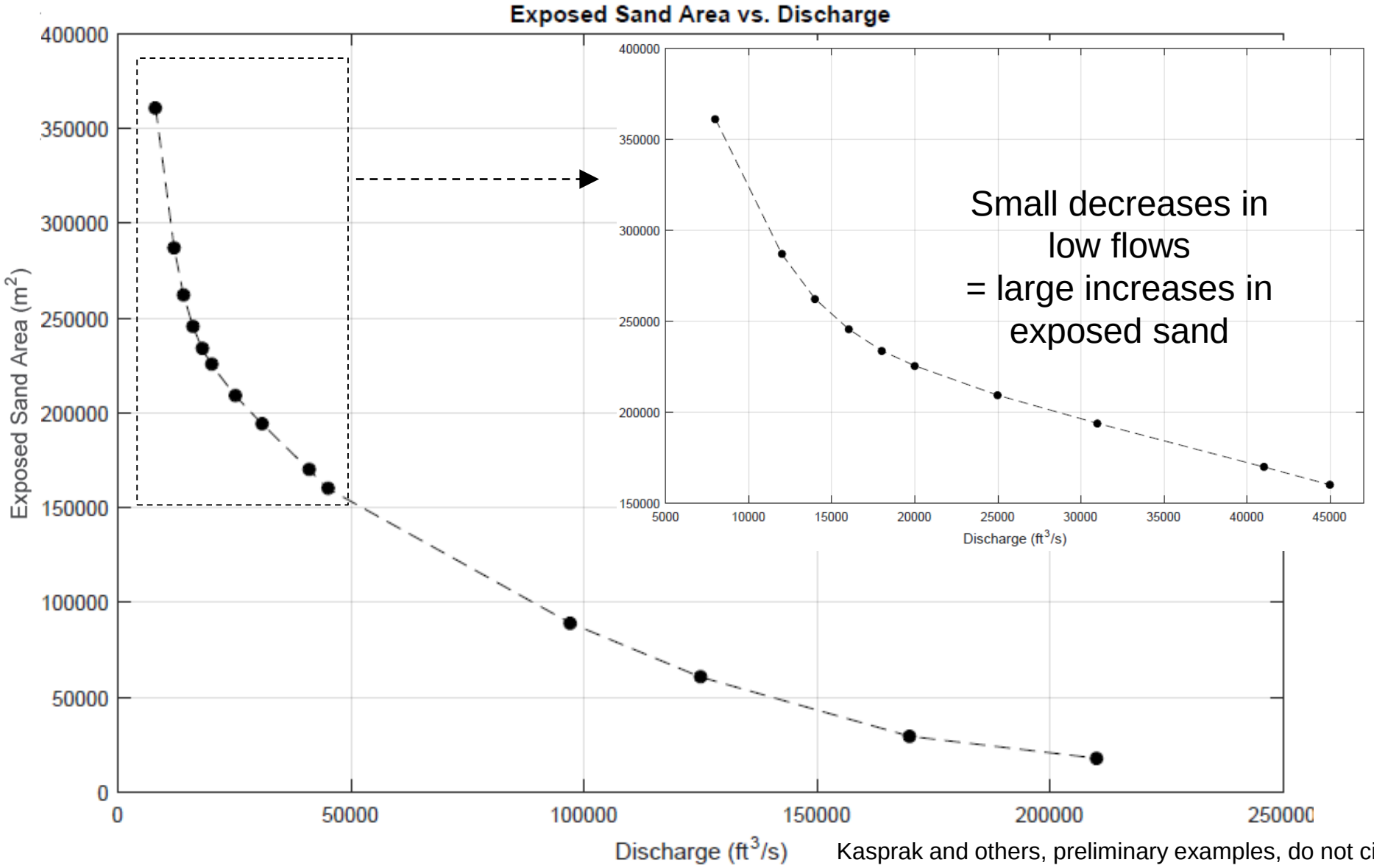

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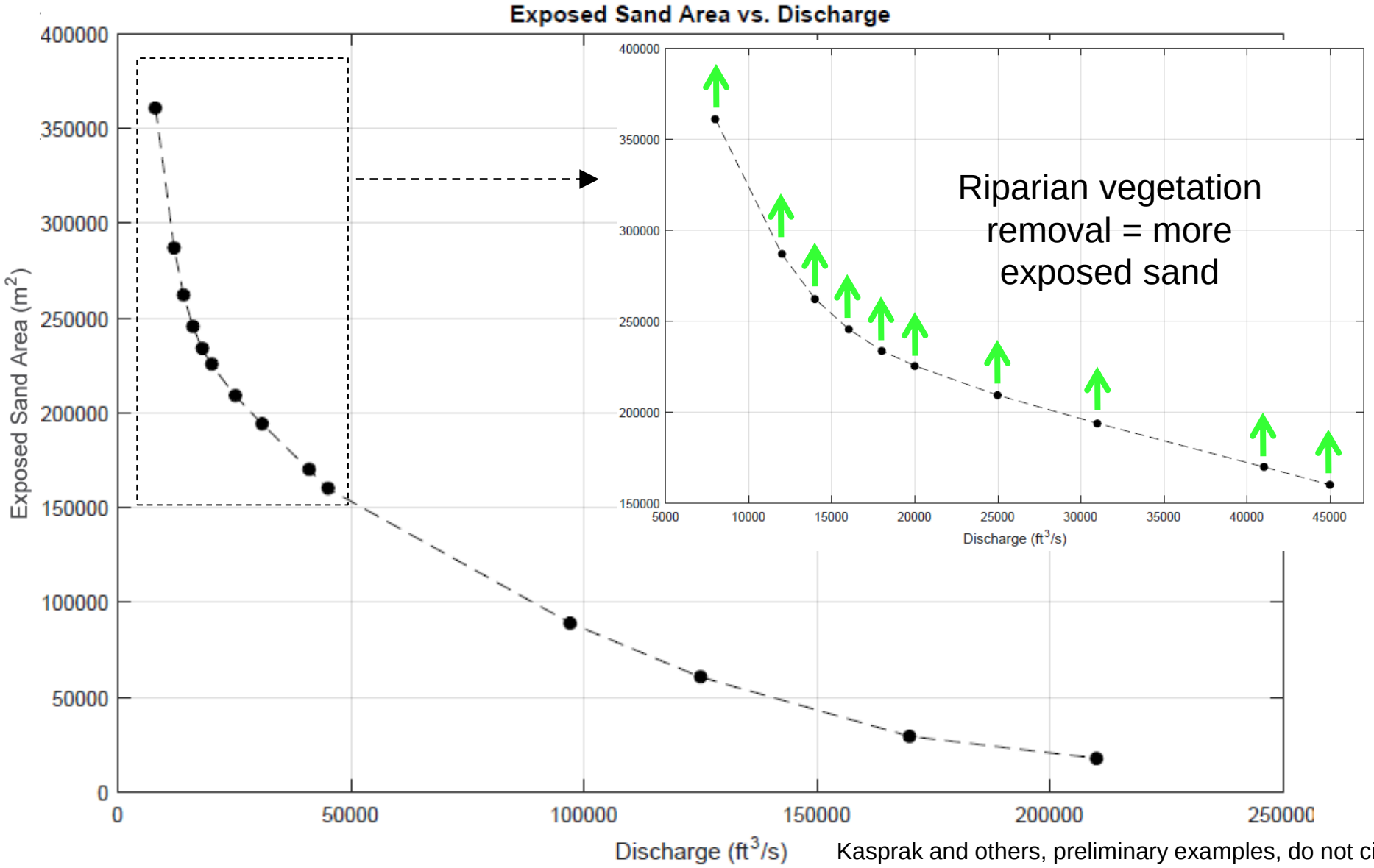


Kasprak and others, preliminary examples, do not cite

Path Forward – What are we doing in Project 4 (TWP) to address possible solutions and provide science that is useful for river management?

DRAFT

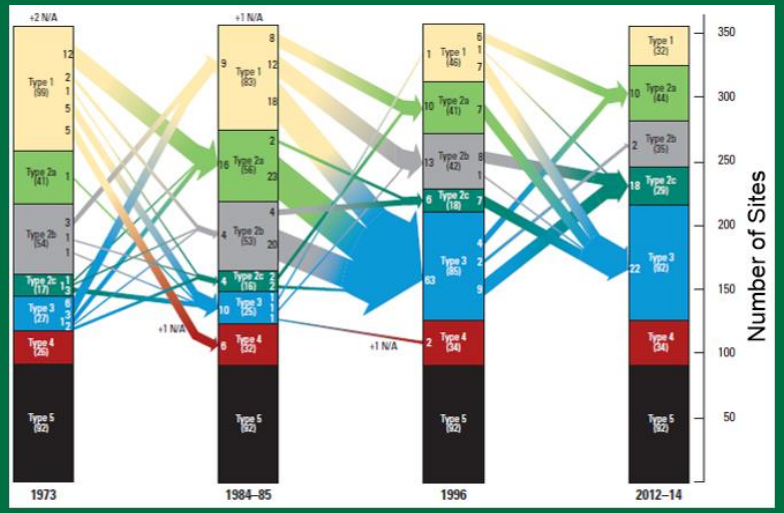
Draft plan for monitoring effects of geomorphic processes at archaeological sites in Grand & Glen Canyon

Draft prepared as originally proposed in: Project Element 4.2. of the Glen Canyon Dam Adaptive Management Program Triennial Budget and Work Plan—Fiscal Years 2015–2017

Draft date:
1/15/2016

Prepared by:

Joel B. Sankey, USGS, Grand Canyon Monitoring and Research Center
Helen Fairley, USGS, Grand Canyon Monitoring and Research Center
Joshua Caster, USGS, Grand Canyon Monitoring and Research Center
Amy East, USGS, Pacific Coastal and Marine Science Center



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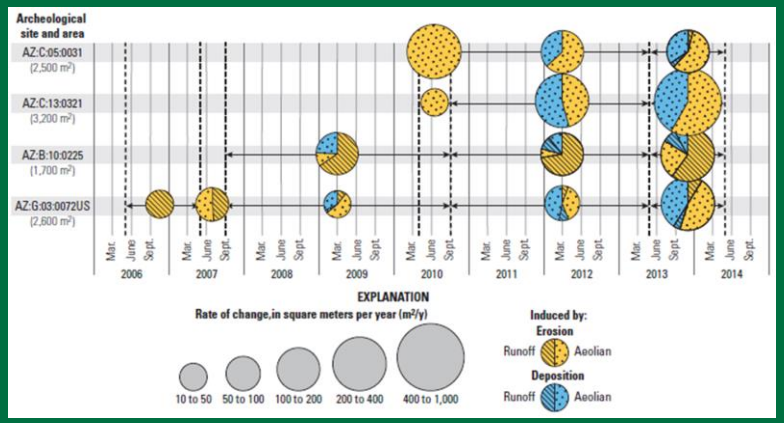

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Time

Professional Paper 1825 Acknowledgements

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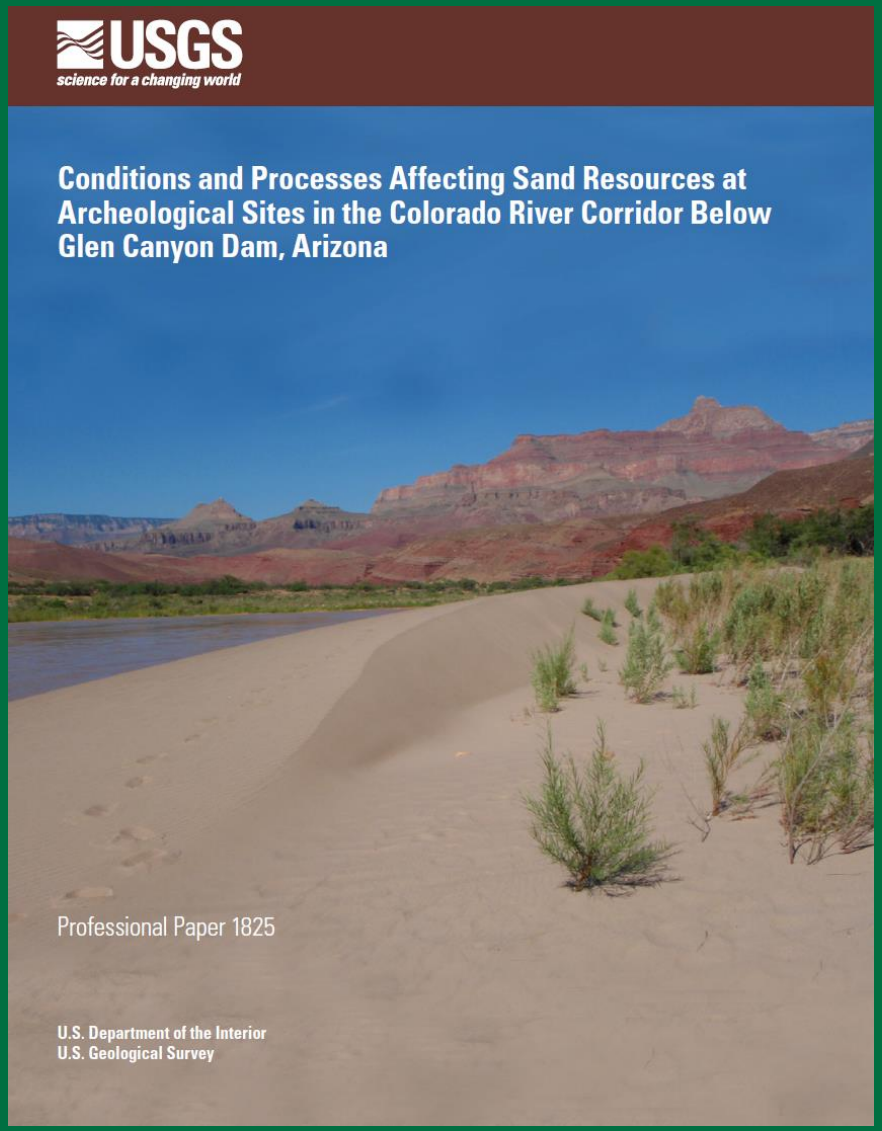
East, A.E., Collins, B.D., Sankey, J.B., Corbett, S.C., Fairley, H.C., and Caster, J., 2016, Conditions and processes affecting sand resources at archeological sites in the Colorado River corridor below Glen Canyon Dam, Arizona: U.S. Geological Survey Professional Paper 1825, 104 p., http://dx.doi.org/10.3133/pp1825.



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