Sand resources and monitoring at archaeological sites in Glen and Grand Canyons: HFE effects

Glen Canyon Dam Adaptive Management Program
High Flow Experiment Workshop
February 27, 2015

Joel B. Sankey,

Brian Collins, Amy East, Helen Fairley

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

Project J: 2013-2014
Overview questions

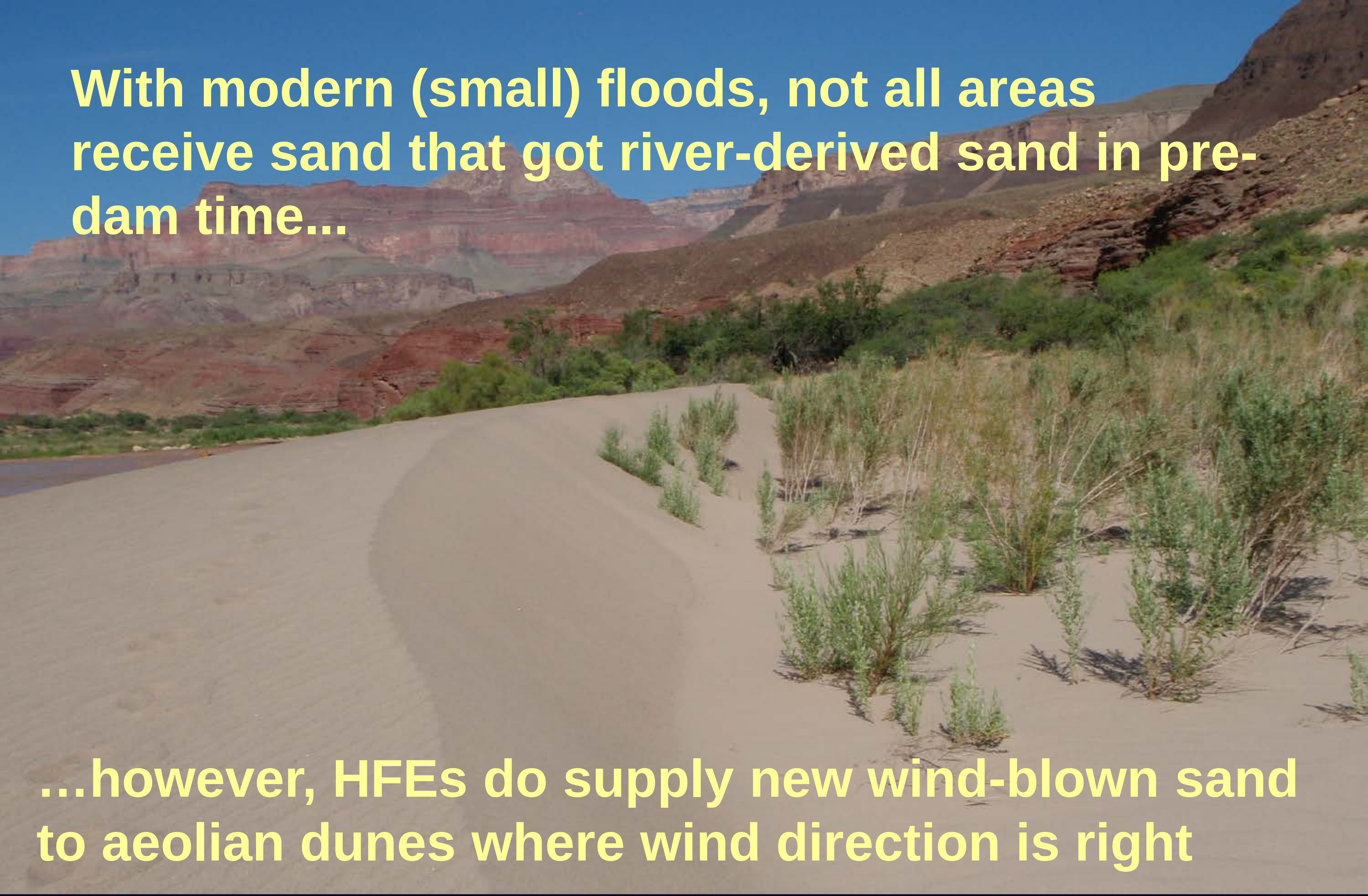
- ***Do cultural sites erode or change faster or in a significantly different manner than they would if dam operations were different?***

- ***How effective are HFEs at supplying aeolian sand to upland landscapes and archaeological sites?***

USGS

Aeolian landscapes form downwind of river sandbars: “source-bordering dunes”

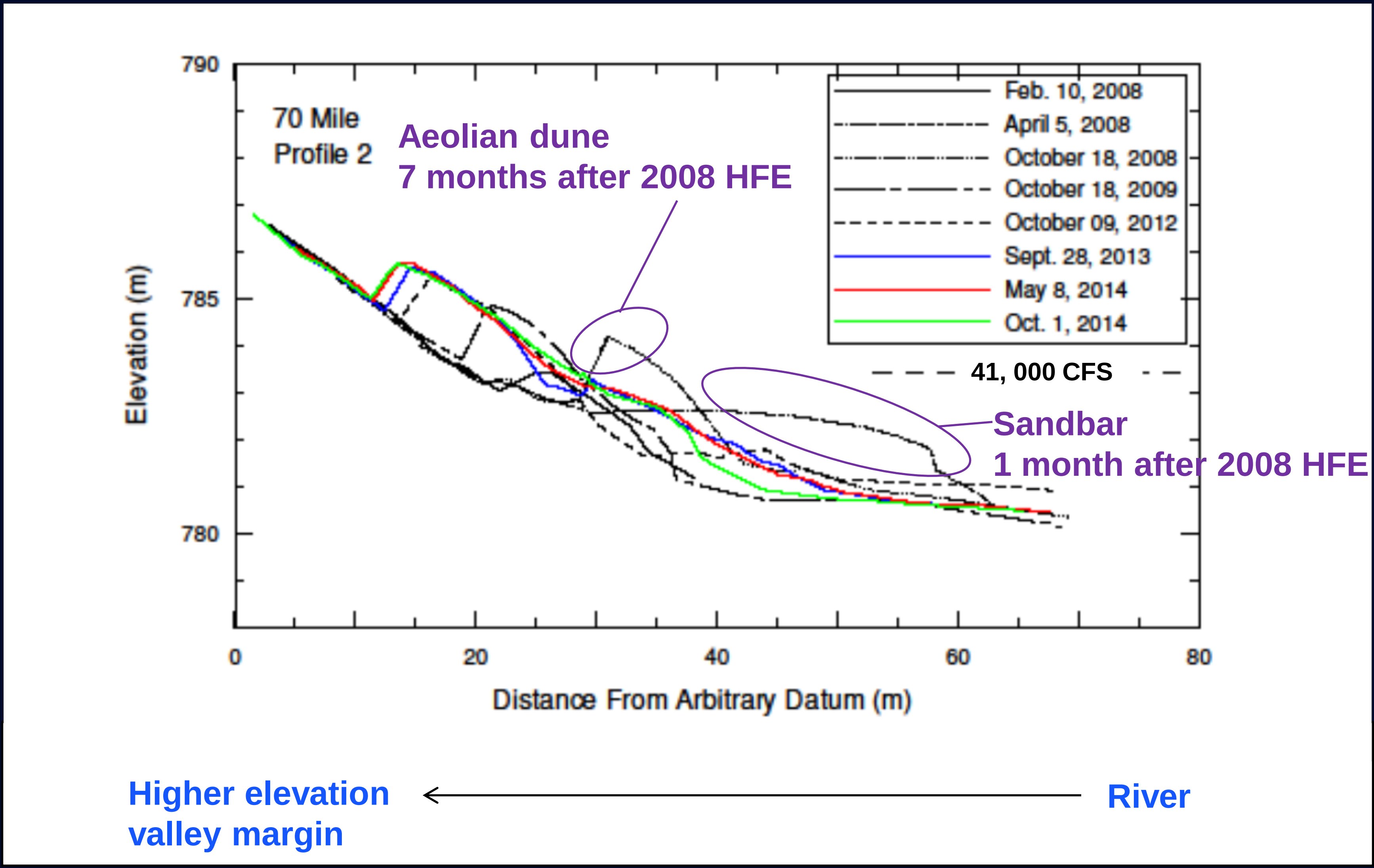
USGS



With modern (small) floods, not all areas receive sand that got river-derived sand in pre-dam time...

…however, HFEs do supply new wind-blown sand to aeolian dunes where wind direction is right

USGS



Joe Hazel, Northern Arizona University, unpublished data, do not cite

USGS

Project J: 2013-2014 Research questions

At landscape scale

- ***What number and proportion of archaeological sites potentially receive windblown sand from HFEs?***
- ***Role of aeolian sand in limiting gully erosion?***

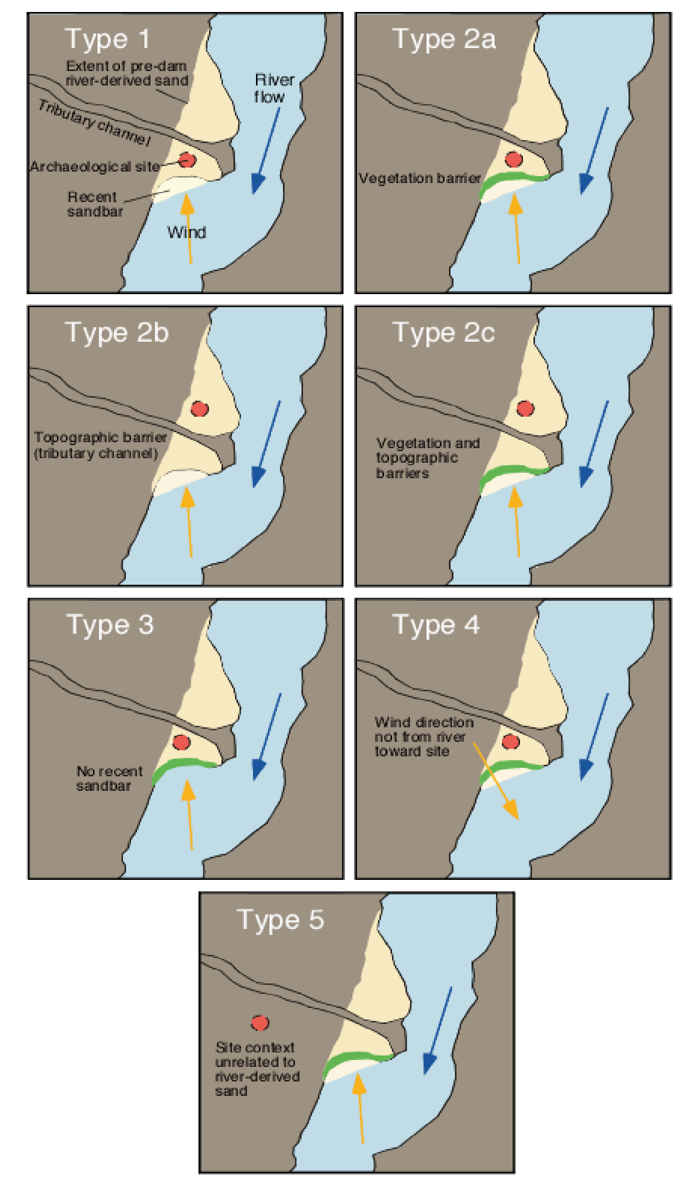
At site scale

- ***At sites that receive HFE sand, does aeolian deposition sufficiently outpace erosion by rainfall and gullying? How well does HFE sand preserve sites?***
- ***How do conditions in Glen Canyon compare with those in Marble-Grand Canyon?***

USGS

What number and proportion of sites potentially receive windblown sand from HFEs?

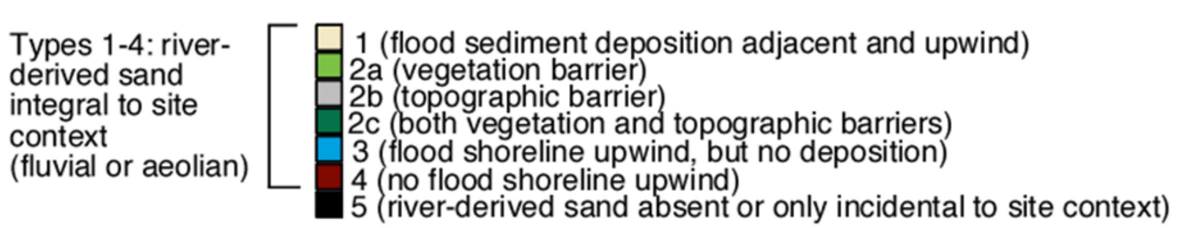
- 7-part classification system
- Evaluated 358 river-corridor arch sites, RM 0-240
- Types 1-4 have river-derived sediments as substrate
- Ranking means decreasing potential for aeolian sand supply from recent fluvial sandbars
- Modern evaluation from field data, 3 earlier time steps from aerial imagery

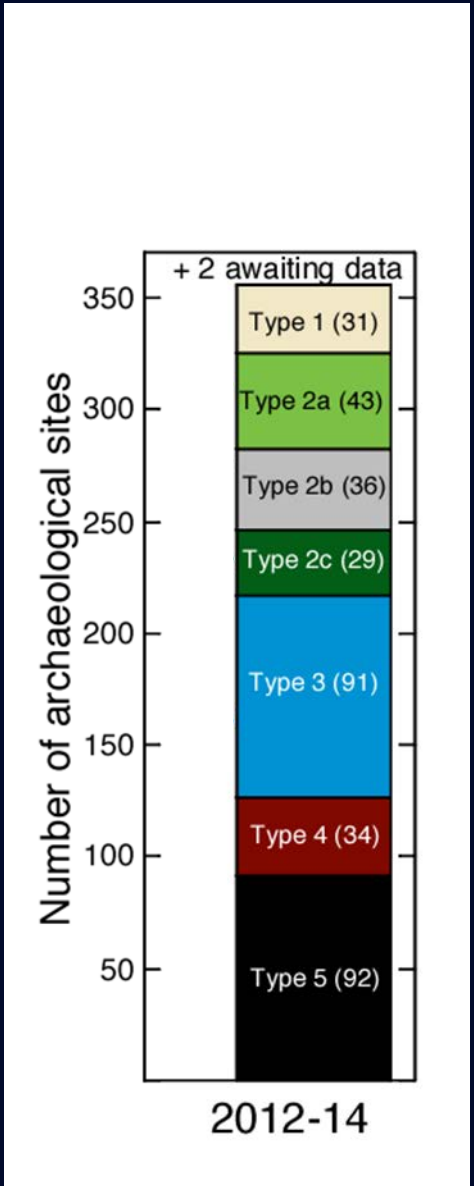


USGS

Preliminary results, do not cite (East et al., in prep.)

What number and proportion of sites currently have potential to receive windblown sand from HFEs?

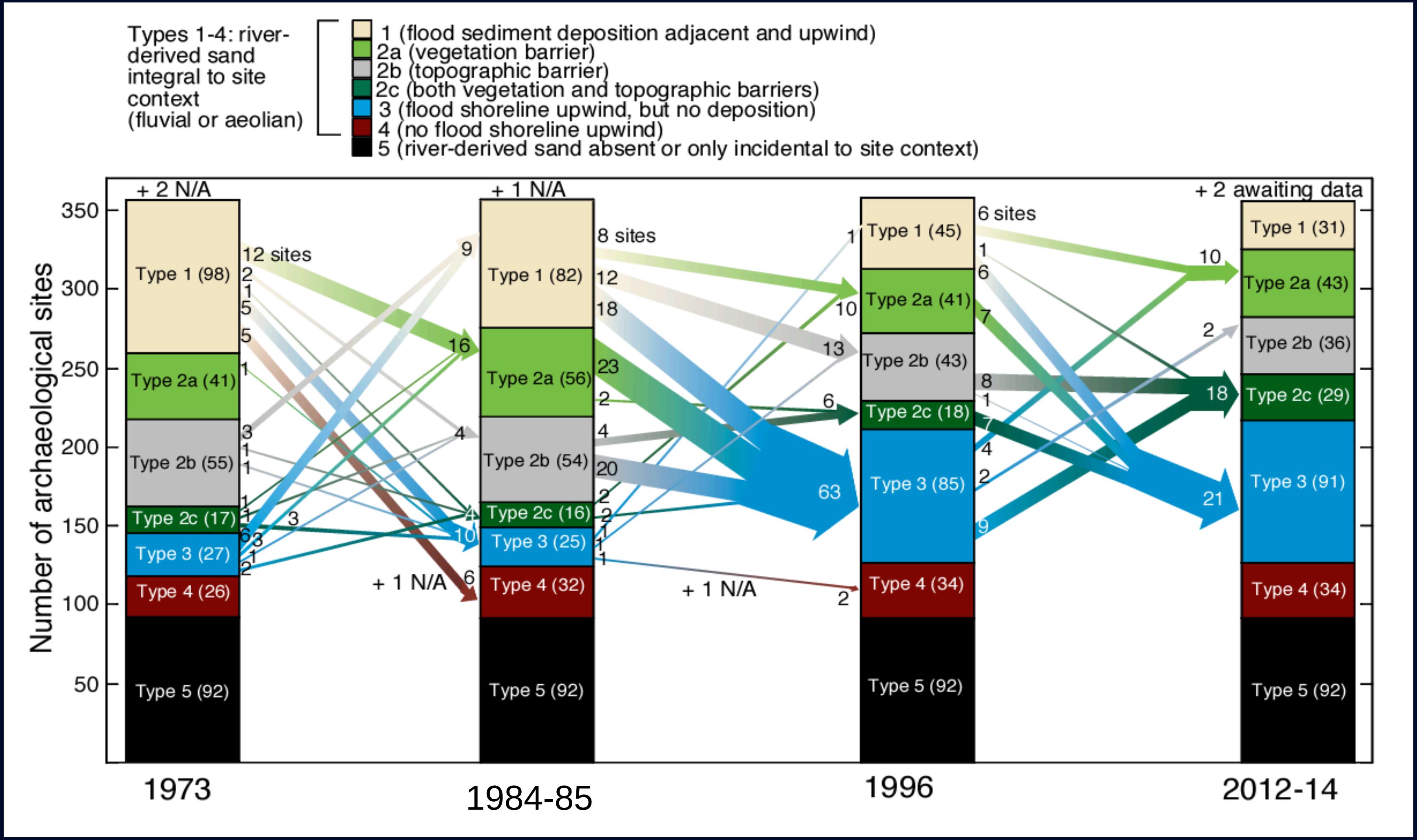




USGS

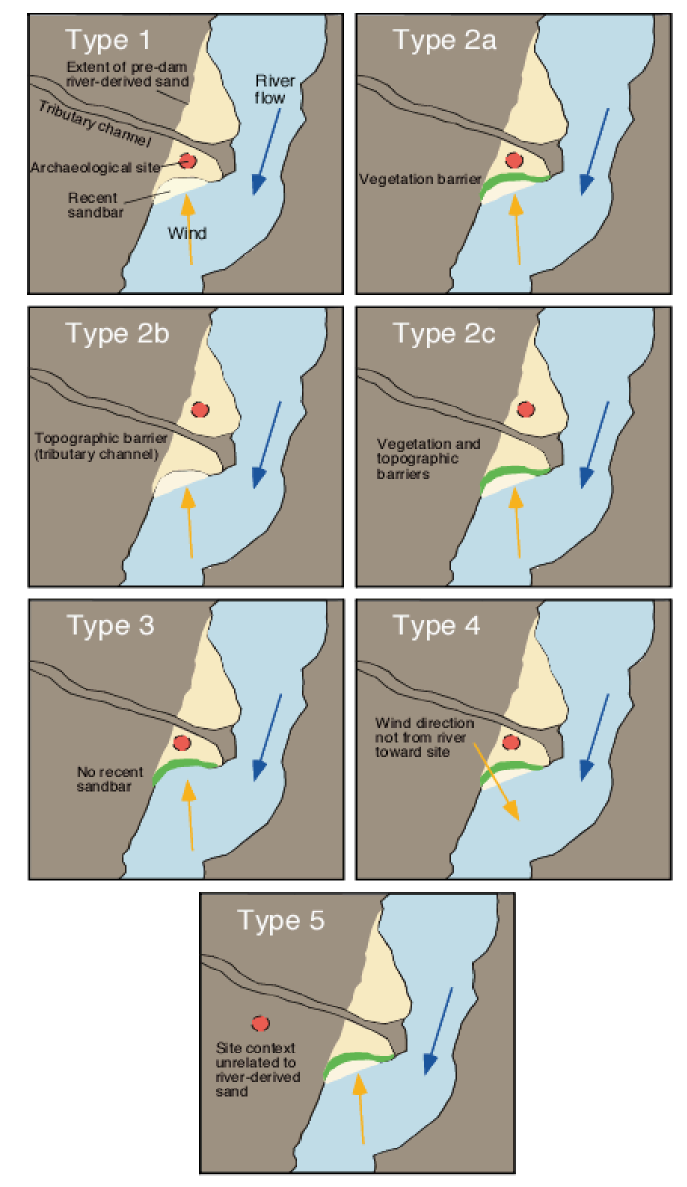
Preliminary results, do not cite (East et al., in prep.)

Site classifications are dynamic



Preliminary results, do not cite (East et al., in prep.)

What number and proportion of sites currently have potential to receive windblown sand from HFEs?



Takeaway points:

- **230 sites are Types 1-3 (65%) and are currently downwind of HFE shorelines (45k and less), so are potentially influenced by sandbars from flows of that magnitude**
- **31 sites are currently Type 1 and have greatest potential of getting windblown HFE sand**
- **Classes are dynamic over time:**
  e.g., from 1973-2014, total of Type 1 sites decreased from 98 to 31

Preliminary results, do not cite (East et al., in prep.)

Role of windblown sand in limiting gully erosion

- In active sand deposits, gullies occupy much less proportion of the area and are more likely to terminate (Sankey and Draut, 2014), so are more likely to anneal instead of becoming progressively larger
- HFE sand sources mean greater aeolian sand activity in dune fields immediately downwind of sandbars (Draut, 2012)
- So, HFEs can reduce gully extent in areas with upwind sandbars

USGS

Site-specific observations in Grand Canyon

- At Type 1 “best case scenario” sites in Grand Canyon that receive HFE sand
  - Does aeolian deposition sufficiently outpace erosion by rainfall and gullying?
  - How well does HFE sand preserve sites?

USGS

Observations at Type 1 sites in Grand Canyon

Site C:05:0031 - Gullies formed in monsoon season 2013

8/22/2013, 3 p.m.

8/23/2013, 7 a.m.

9/11/2013, 3 p.m.

9/12/2013, 7 a.m.

USGS

Preliminary results, do not cite (J. Caster)

Observations at Type 1 sites in Grand Canyon

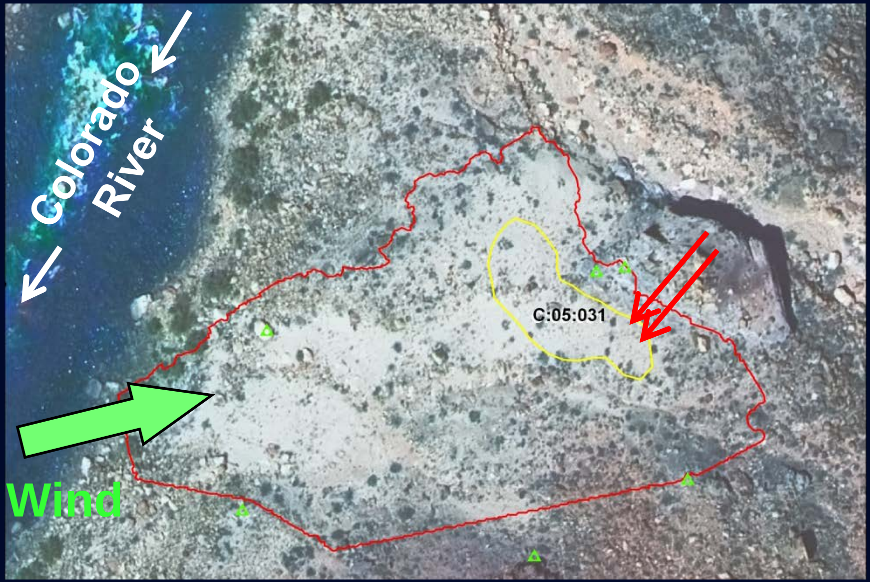
Site C:05:0031 - Gullies that formed in monsoon season 2013 partially annealed during the spring 2014 windy season.

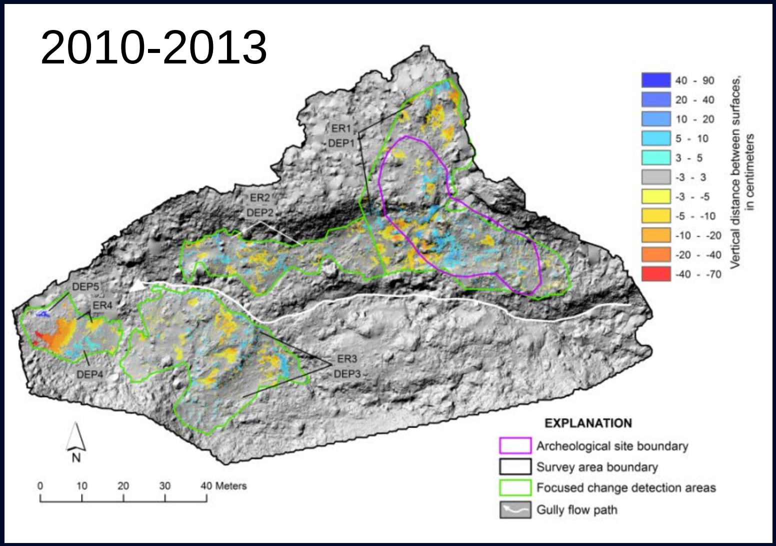
3/9/2014, 1 p.m.

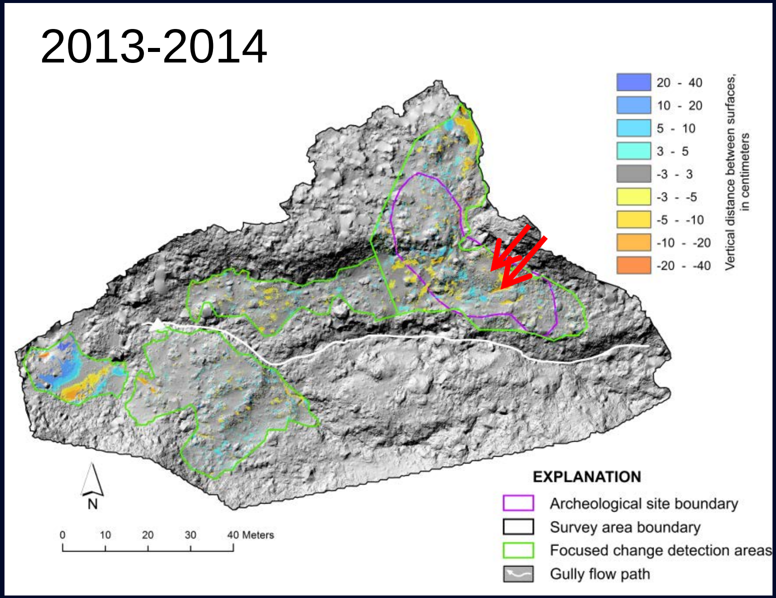
5/1/2014, 1 p.m.

Preliminary results, do not cite (J. Caster)

Observations at Type 1 sites in Grand Canyon
Topographic changes: AZ:C:05:0031







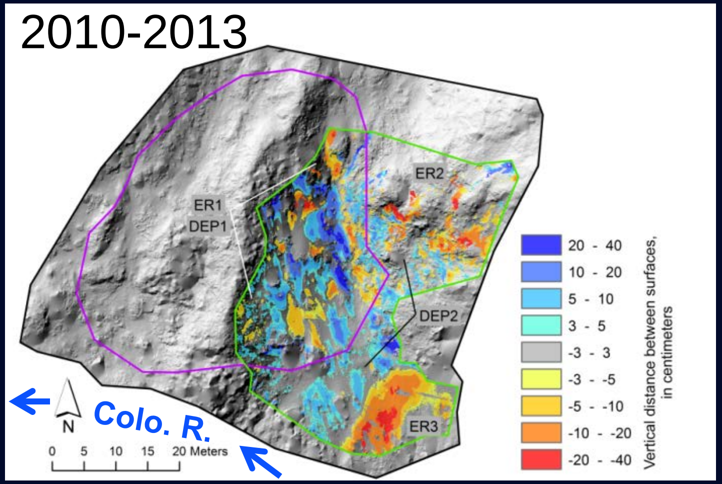
- Reworking of fluvial-sourced sand
- Favorable depositional wind trajectory
- Formation of two gullies in 2013
- 2010-2013
  - 20% of area changed w/ -3 cm ave. change depth
- 2013-2014
  - 14% of area changed w/ 0 cm ave. change depth

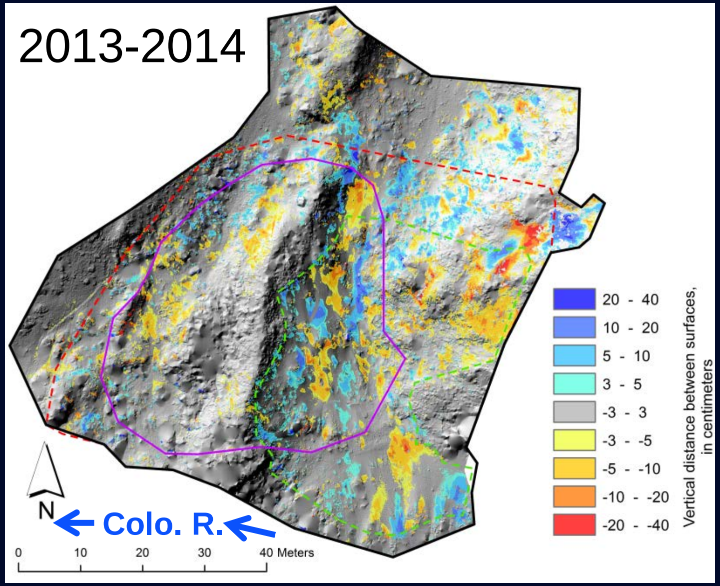
USGS

PRELIMINARY RESULTS – DO NOT CITE (Collins et al., in prep.)

Observations at Type 1 sites in Grand Canyon

Topographic changes: AZ:C:13:0321





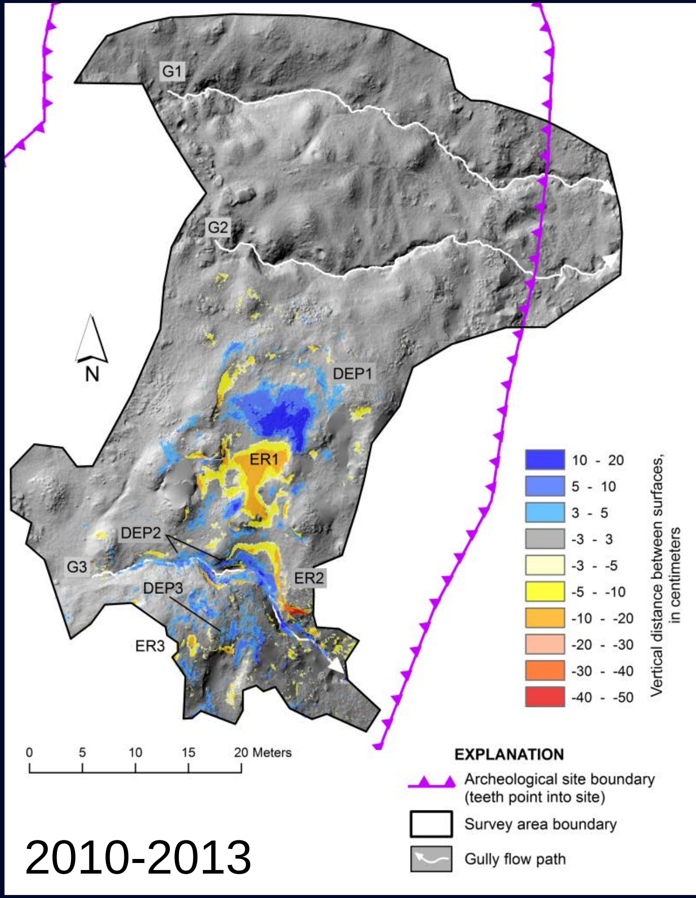
- Reworking of fluvial-sourced sand
- Favorable depositional wind trajectory
- 2010-2013
  - 40% of area changed w/ -3 cm ave. change depth (+4 cm in arch. site)
- 2013-2014
  - 23% of area changed w/ -1 cm ave. change depth

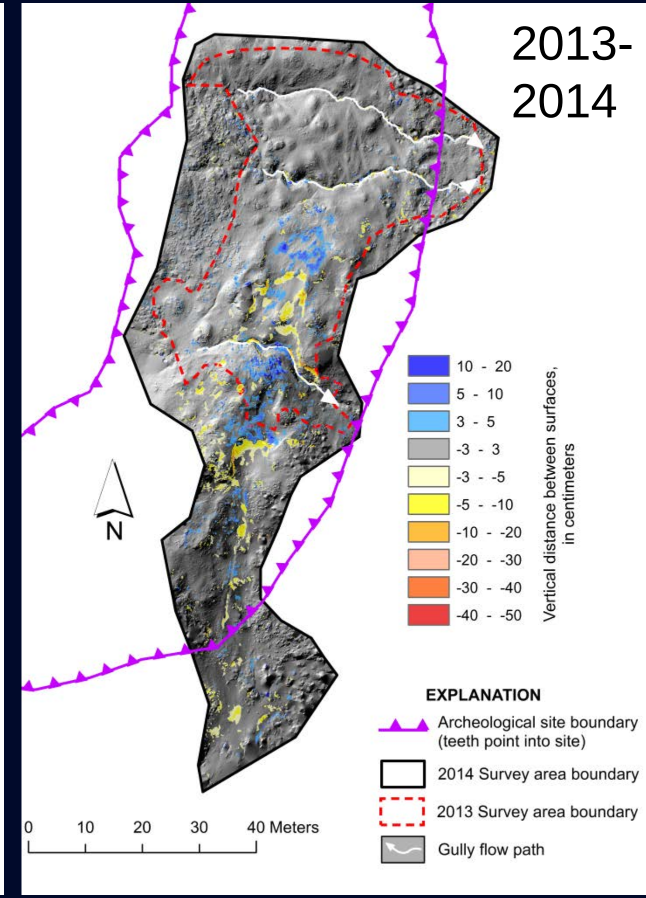
USGS

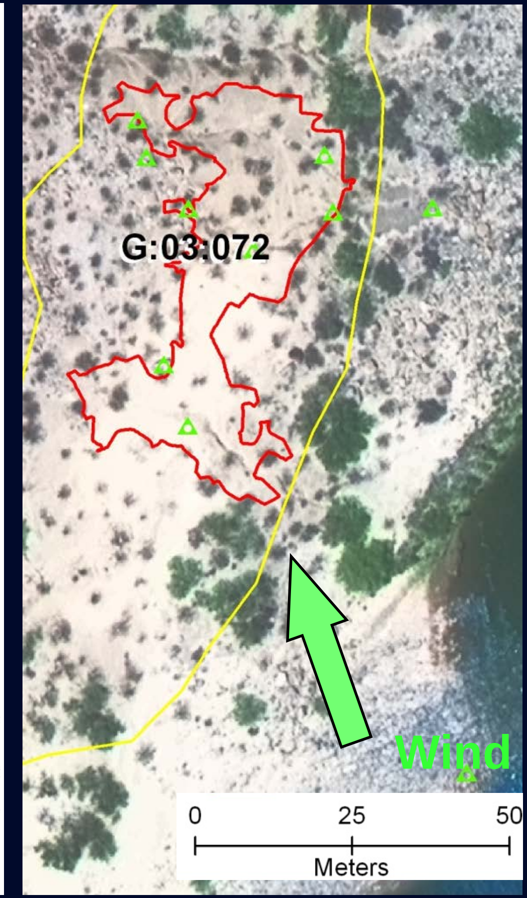
PRELIMINARY RESULTS – DO NOT CITE (Collins et al., in prep.)

Observations at Type 1 sites in Grand Canyon

Topographic changes: AZ:G:03:0072US







- Aeolian reworking of (originally) fluvial-sourced sands
- Some gullying, but partially annealed
- Connectivity between river and arch. site over 100+ meters
- 2010-2013: 6% of area changed w/ +3 cm ave. change depth
- 2013-2014: 8% of area changed w/ -1 cm ave. change depth

USGS

PRELIMINARY RESULTS – DO NOT CITE (Collins et al., in prep.)

Site-specific observations in Glen Canyon

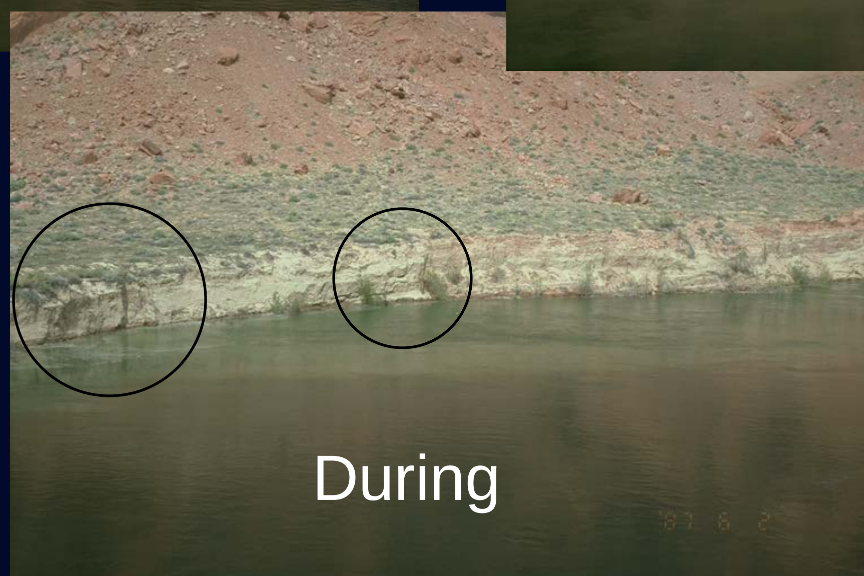
Sequential terrestrial lidar

- High resolution change maps
- September 2012 – November 2013
- Brackets 2012 HFE

Imagery from Google Earth (May, 2013)

1996 HFE (Stationary Cameras)

Before



During

After

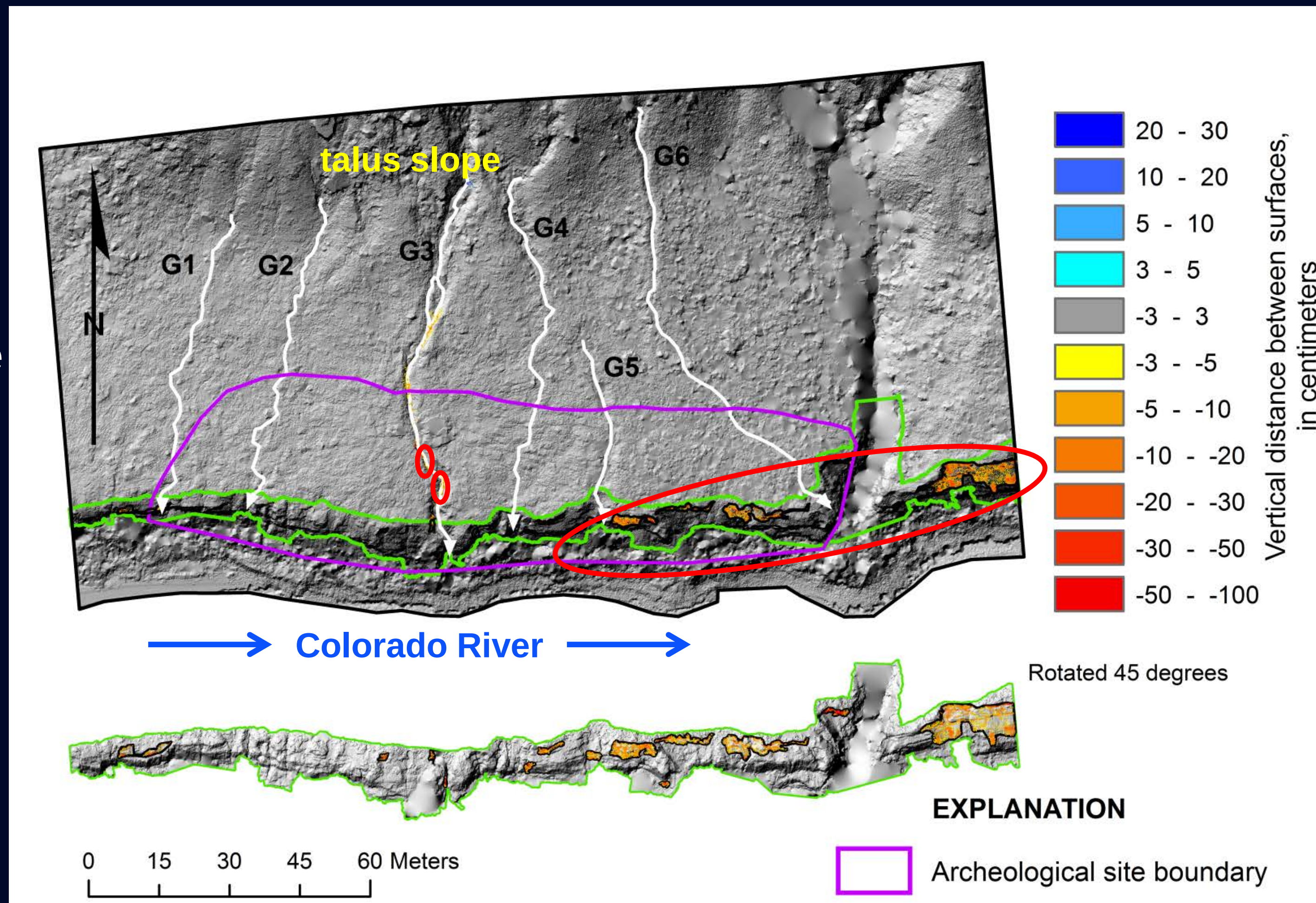
USGS

Photos and interpretation courtesy of NPS – Mark Anderson and Thann Baker

Glen Canyon
Topographic changes: AZ:C:02:0032

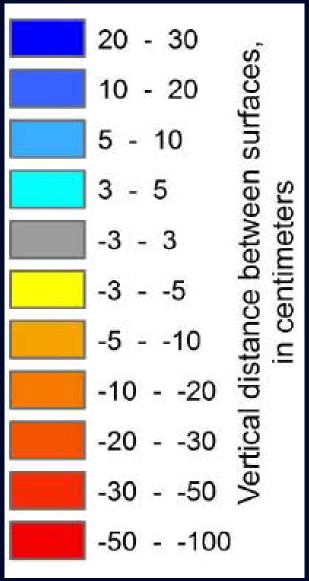
- Ave. change depth = -11 cm
- Most (81%) of surface change in archaeological site from bank erosion
- ~ 11 m^3 of bank erosion in site (~ 20 m^3 within surveyed area)

PRELIMINARY RESULTS – DO NOT CITE (Collins et al., in prep.)

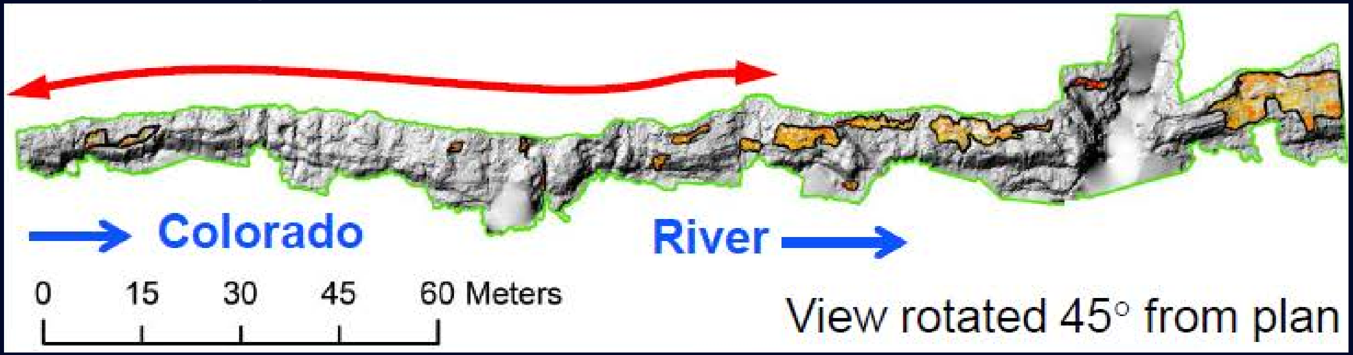


USGS

Glen Canyon
Topographic changes: AZ:C:02:0032



Rise and fall of water level leads to gravitational terrace bank instability and erosion



USGS

Change From September 2012 to November 2013

PRELIMINARY RESULTS – DO NOT CITE (Collins et al., in prep.)


Thank you for listening