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Cultural Site Monitoring in Glen and Grand Canyons

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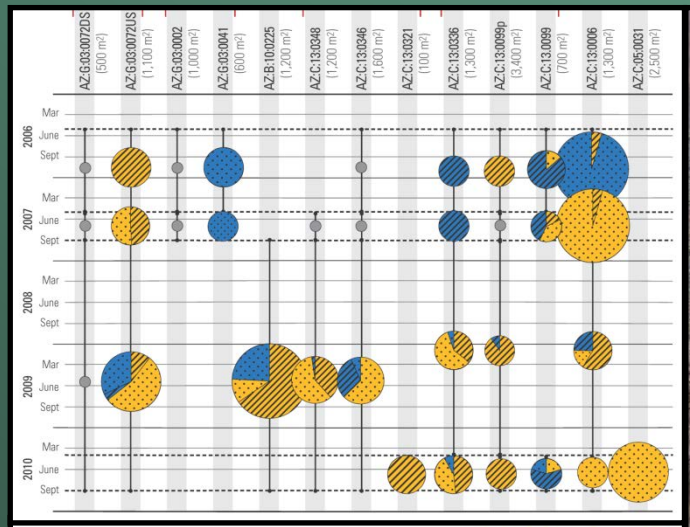
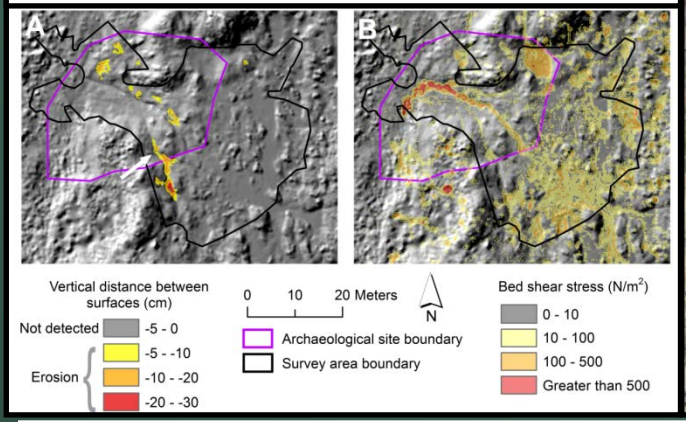
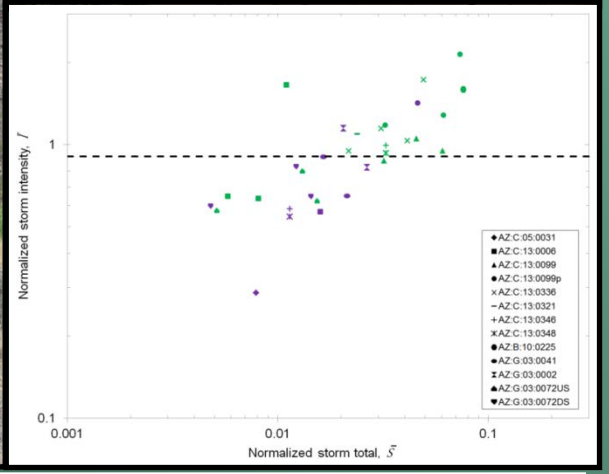
U.S. Department of the Interior
U.S. Geological Survey

What do we know about archaeological site change in Grand Canyon?







(Collins et al., in review)

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What do we know about archaeological site change in Grand Canyon? [2014]

- **Are cultural sites eroding or changing faster or in a significantly different manner than they would if Glen Canyon Dam was operated differently than it has been?**
  - **Are archaeological sites eroding?**
  - **If so, then how fast are archaeological sites eroding?**
  - **What does it take to cause erosion?**
  - **If discrete events cause erosion, then what is the frequency of these events?**
  - **Can meteorological effects be distinguished from dam operational effects?**
  - **Have HFEs impacted archaeological site erosion thus far?**

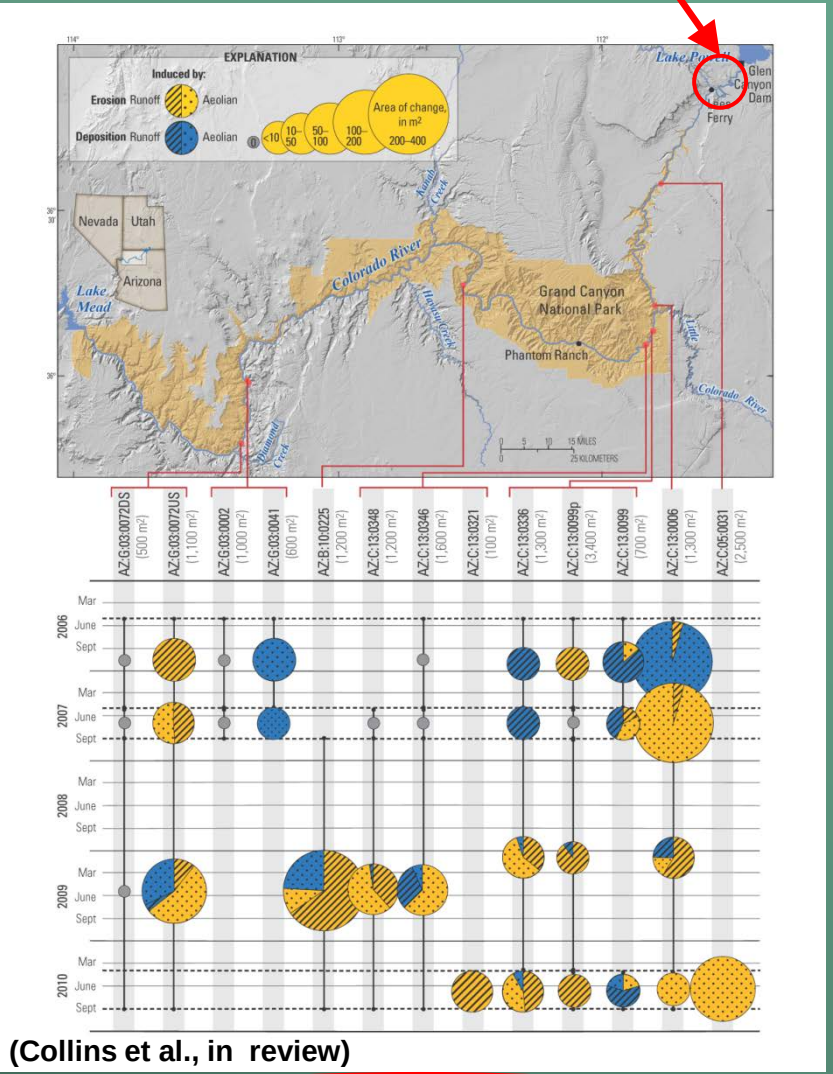
Cultural Monitoring Overview Questions [2015]

- **Are cultural sites eroding or changing faster or in a significantly different manner than they would if Glen Canyon Dam was operated differently than it has been?**
  - **Is the magnitude of aeolian transport to, and deposition at, sites from river sand bars sufficient to offset erosion, and thereby protect archaeological resources?**
  - **In areas with active aeolian deposition, do sites that are subjected to significant gullying (i.e., >30cm downcutting) undergo net topographic lowering such that the physical and informational integrity of archaeological resources are impacted?**
  - **Are archeological sites in Glen Canyon significantly more eroded (e.g. are gullies more incised) compared to those found downstream from Lee's Ferry where the fine-grained sediment supply is larger?**

Today

- Update on site specific studies
  - How do actual sites respond?
  - Do they confirm what we are learning at the landscape scale?
- Monitoring
  - Existing methods – terrestrial lidar
  - New methods in Glen Canyon – airborne lidar
- Glen Canyon
  - Geomorphologic analysis
  - Short-term change detection
  - Long-term gully erosion characterization
- Grand Canyon
  - Short-term change detection
  - Comparison to 7-yr trends

4 new sites in Glen Canyon

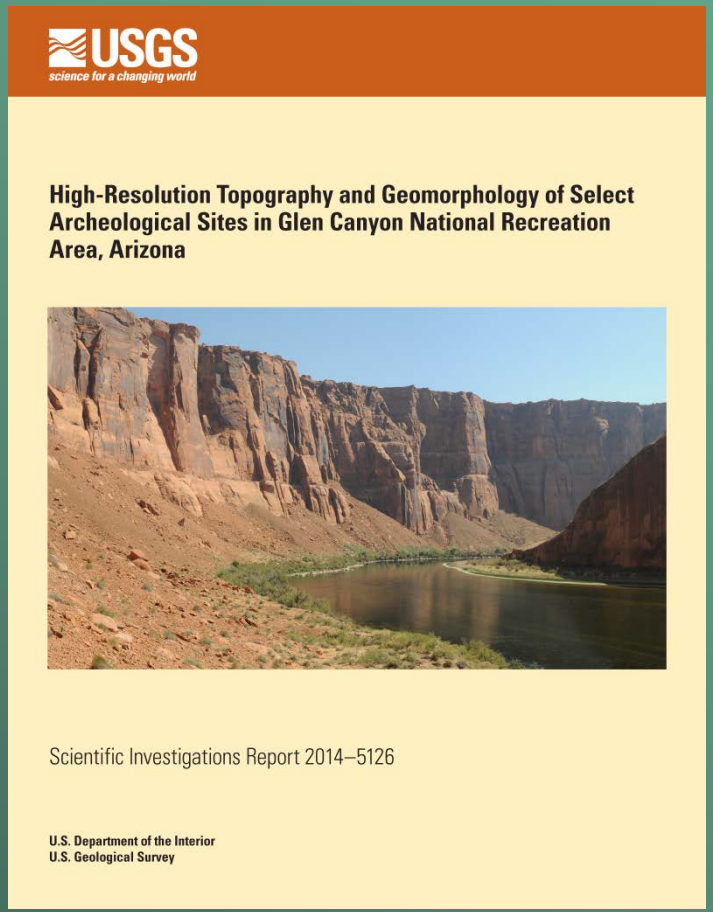


(Collins et al., in review)

New data from 2012, 2013, 2014

Geomorphological studies at archaeological sites in Glen Canyon

- Application and comparison of methods
  - Terrestrial lidar
  - Airborne lidar
  - Airborne photogrammetry
- Topography and geomorphology at 4 sites
  - Dual terrestrial-airborne gives unprecedented data coverage
- USGS SIR 2014-5126



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(Collins et al., 2014, High resolution topography and geomorphology at select archeological sites in Glen Canyon National Recreational Area, Arizona, *USGS Scientific Investigations Report 2014-5126*, 31p., http://dx.doi.org/10.3133/sir20145126)

Short-term changes in Glen Canyon

- Goal: Identify rates and causes of change at arch. sites
  - Put regional observations into context
- Sequential terrestrial lidar
  - High resolution change maps
  - Four sites
  - Sept. 2012 - Nov. 2013
    - Brackets November 2012 HFE

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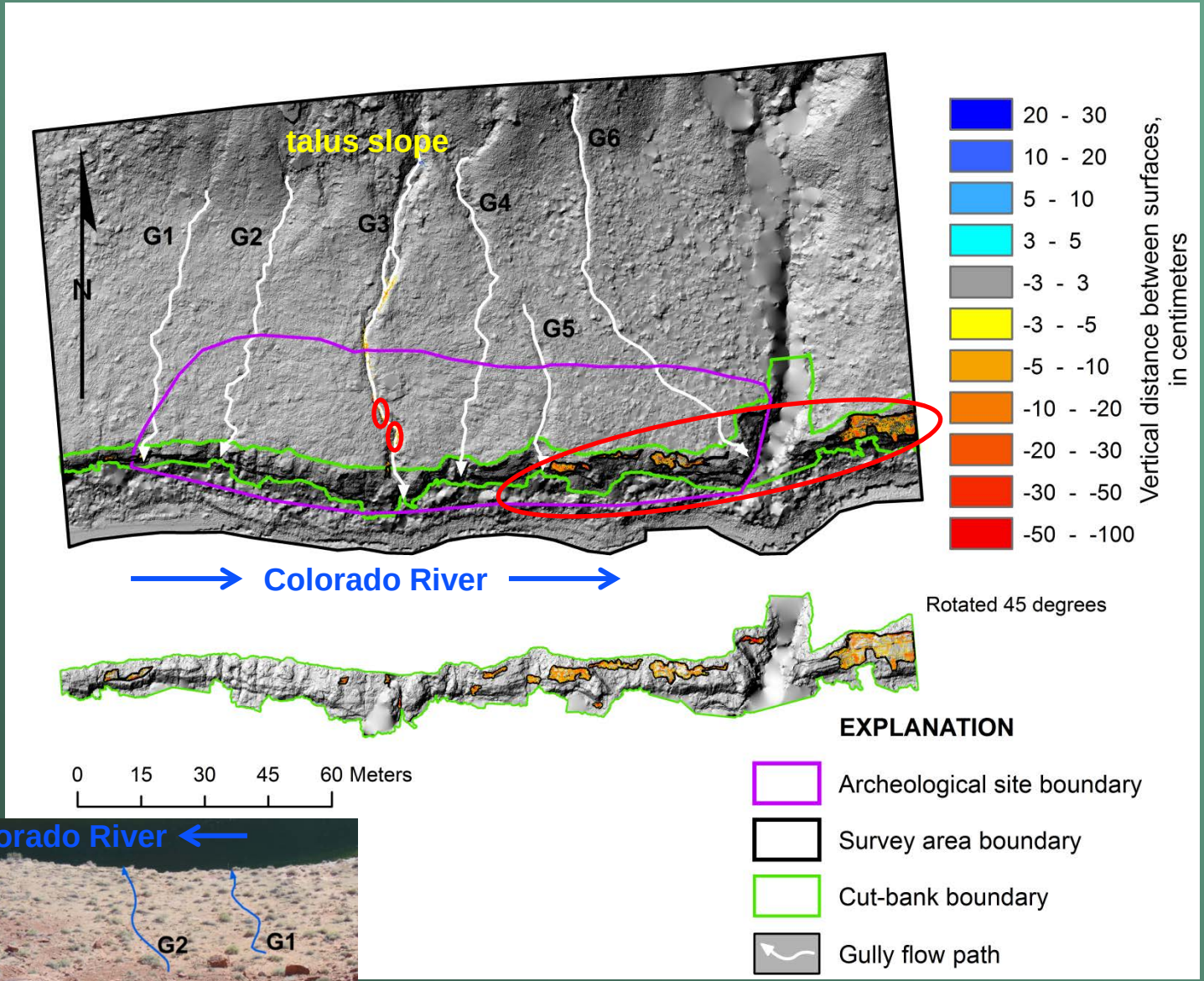
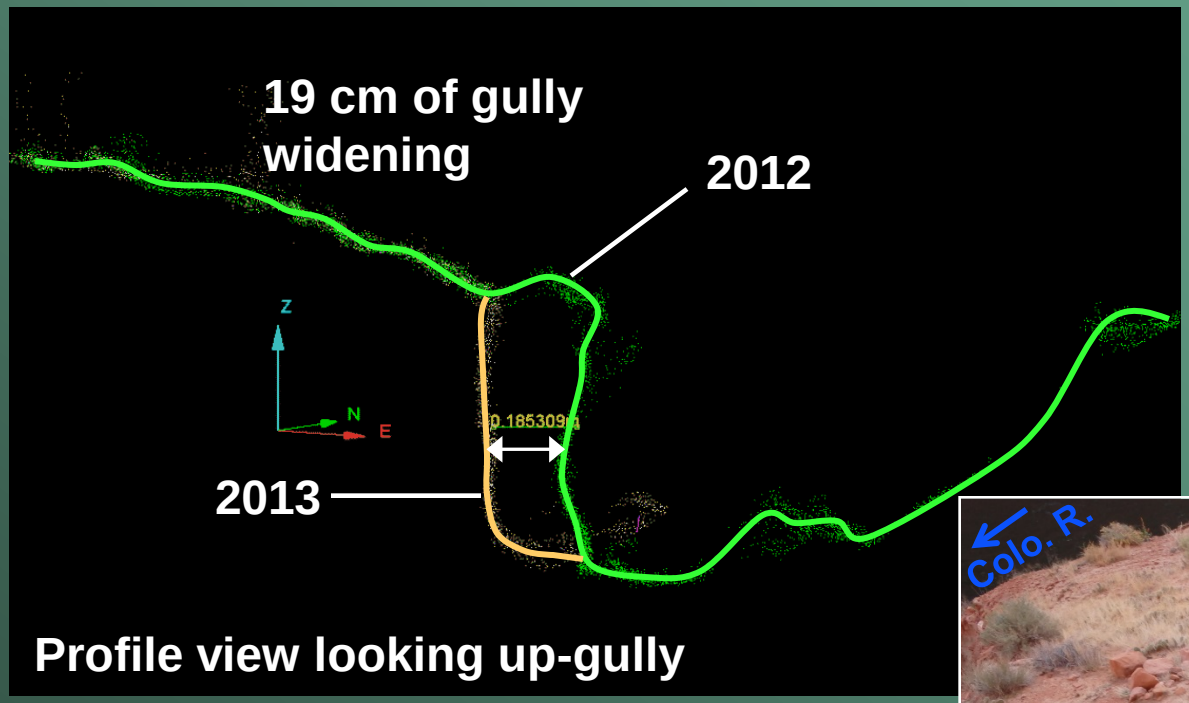
Topographic changes: AZ:C:02:0032

- 120 m^2 (1.5%) of surface change in arch. site
- Most (81%) from bank erosion
- Ave. change depth = -11 cm



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

AZ:C:02:0032 – gully bank erosion



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

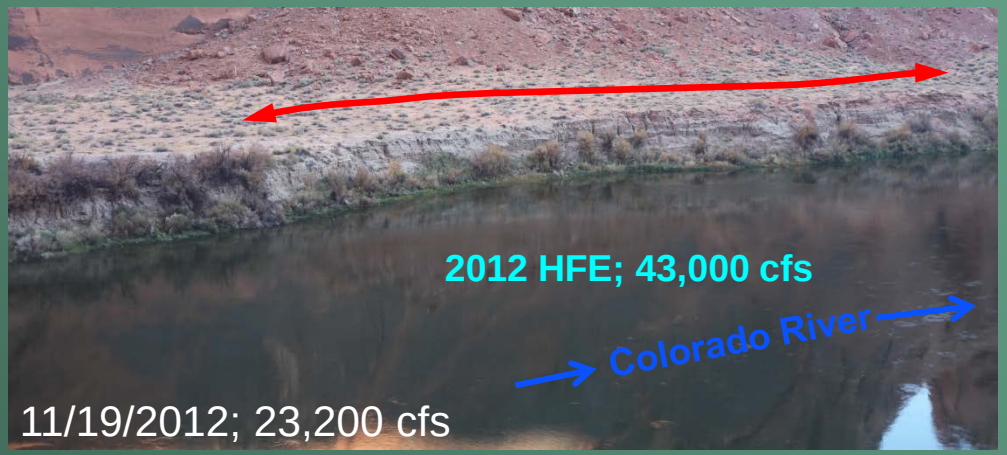
AZ:C:02:0032 – gully undercutting

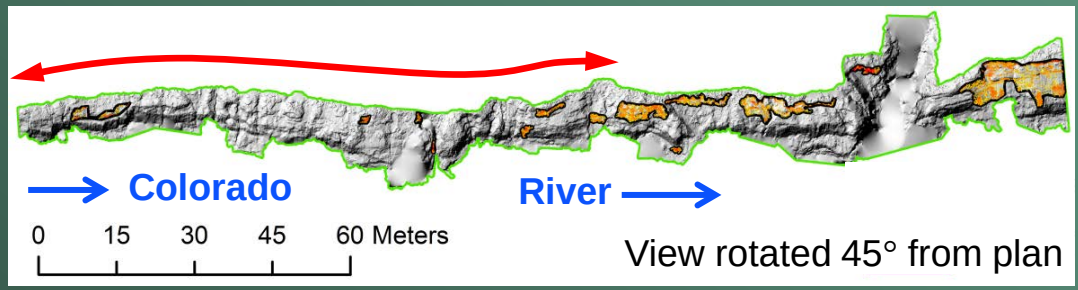
PRELIMINARY RESULTS – DO NOT CITE (Collins et al., in prep.)

AZ:C:02:0032 – dam operation effects

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

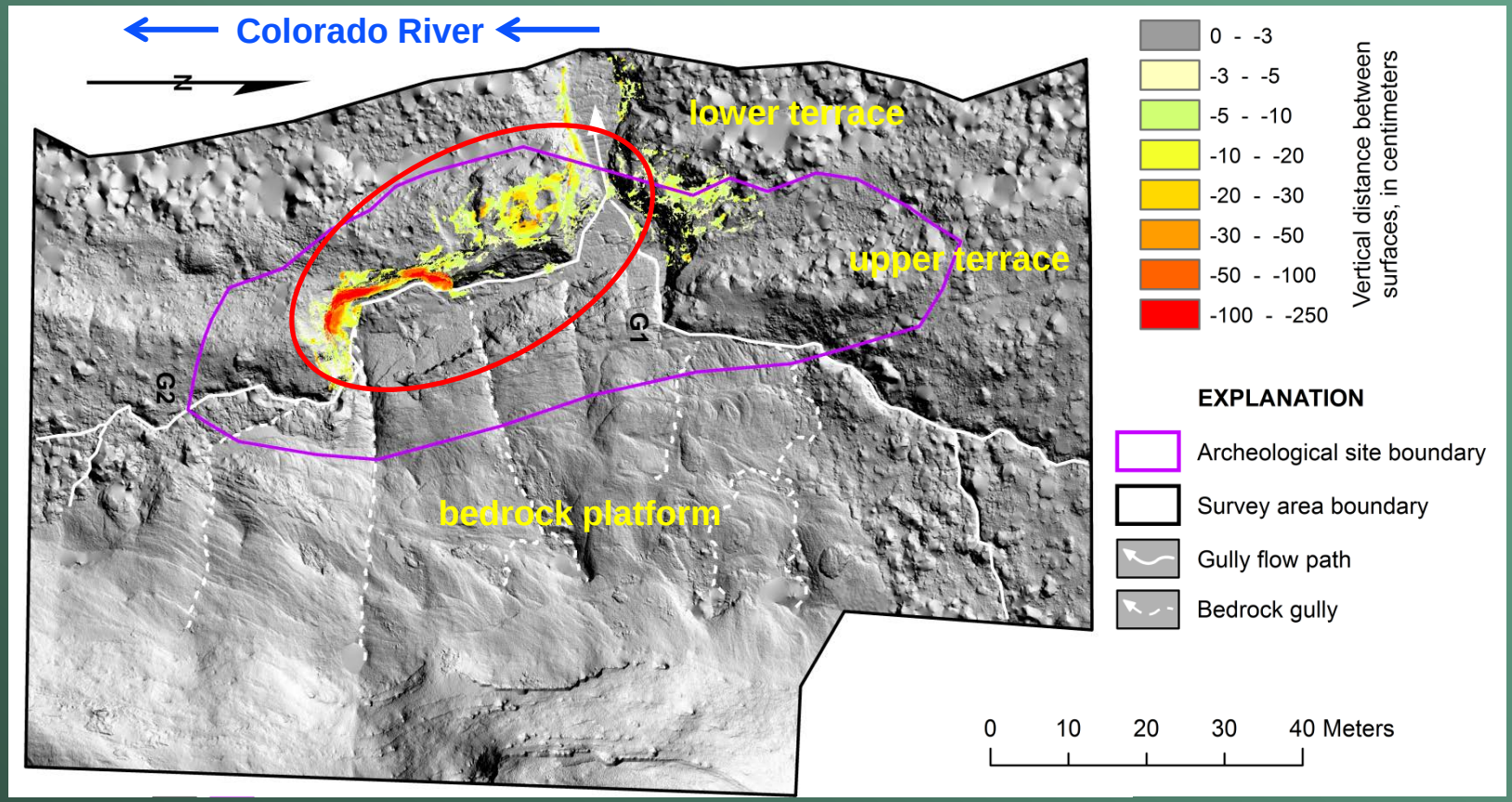
Oblique photos and flow interpretation courtesy of NPS - Mark Anderson and Thann Baker

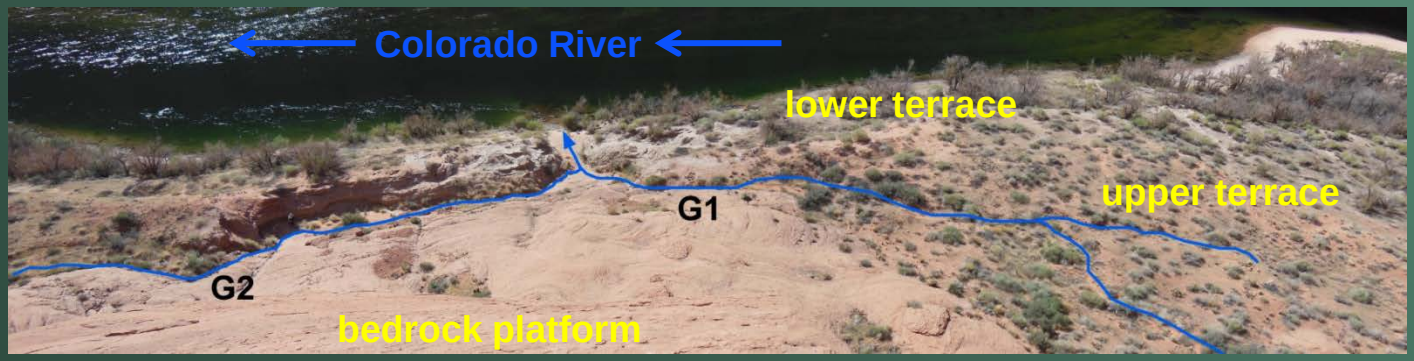




PRELIMINARY RESULTS – DO NOT CITE (Collins et al., in prep.)

Topographic changes: AZ:C:02:0075

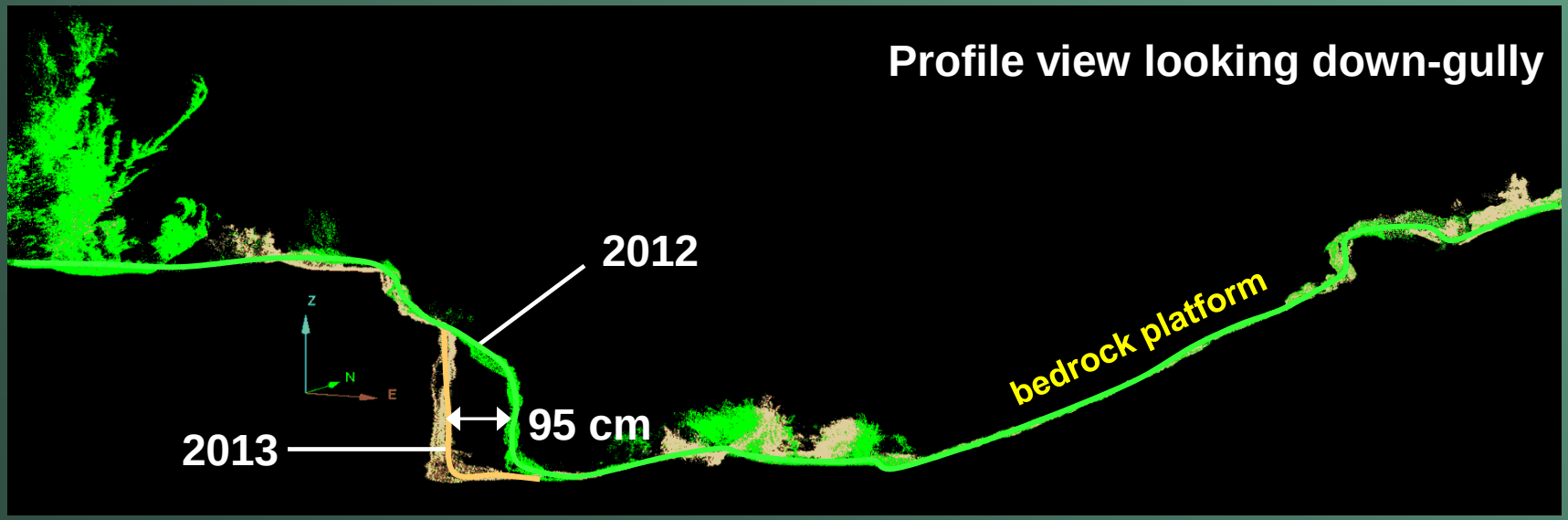




- 212 m^2 (10%) of surface change in arch. site
- Gullying bank collapse and possible aeolian erosion
- Ave. change depth = -19 cm

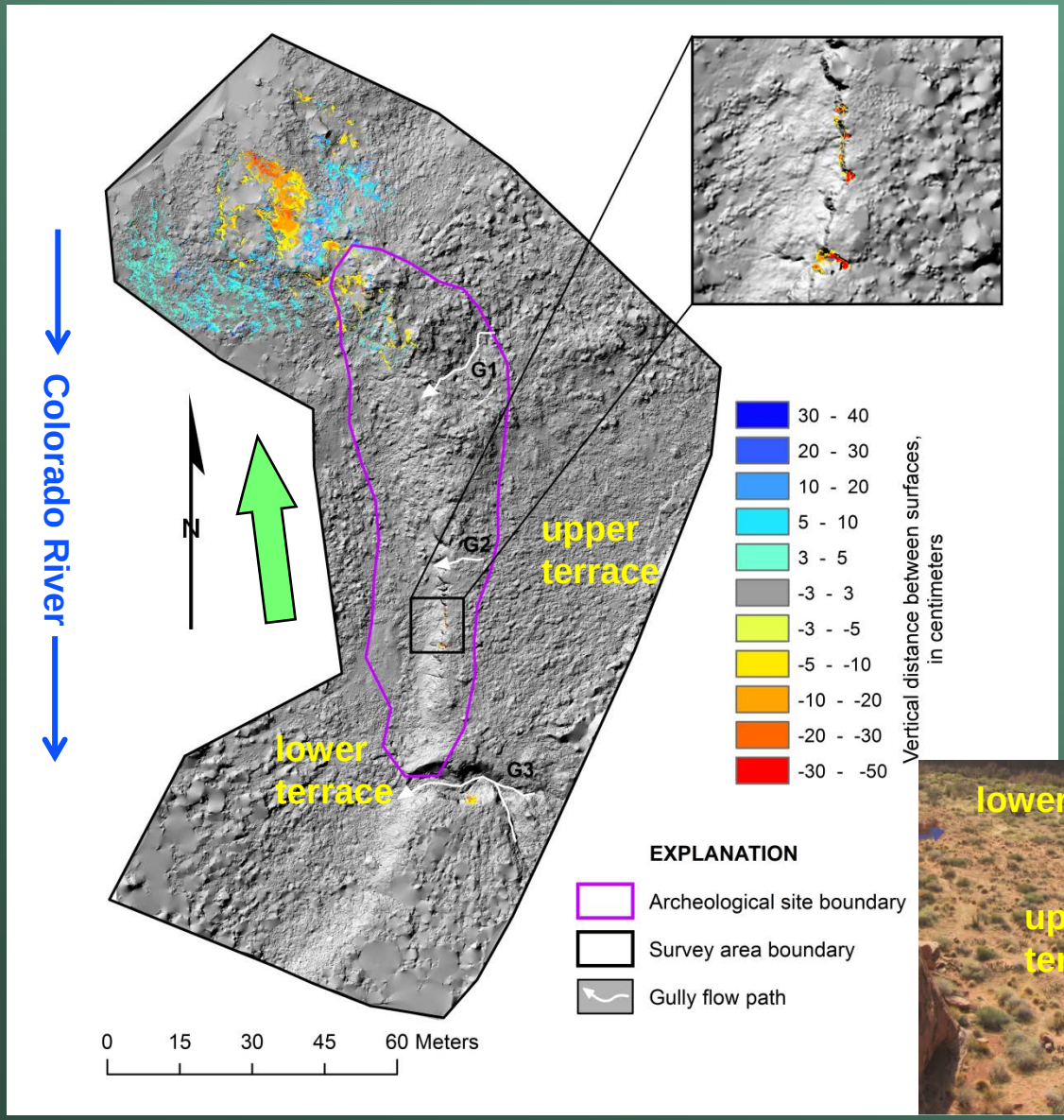
PRELIMINARY RESULTS – DO NOT CITE (Collins et al., in prep.)

AZ:C:02:0075 – aeolian and gully bank erosion

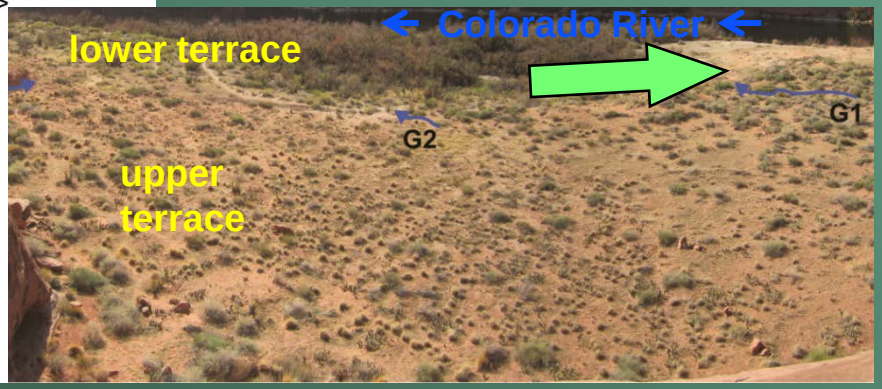


PRELIMINARY RESULTS – DO NOT CITE (Collins et al., in prep.)

Topographic changes: AZ:C:02:0077



- 1 m^2 (0.04%) of surface change in arch. site
- Terrace edge gullying erosion
- Ave. change depth = -17 cm
- 425 m^2 of change area in adjacent parts – mostly aeolian



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

Summary: short-term changes in Glen Canyon

- All sites show measurable changes
- Steep terrace banks subject to HFE impacts
- Gullying is active on terraces and causing site changes
- Aeolian processes also active, but minimal: little expectation for gully annealing (no widespread source of sand)

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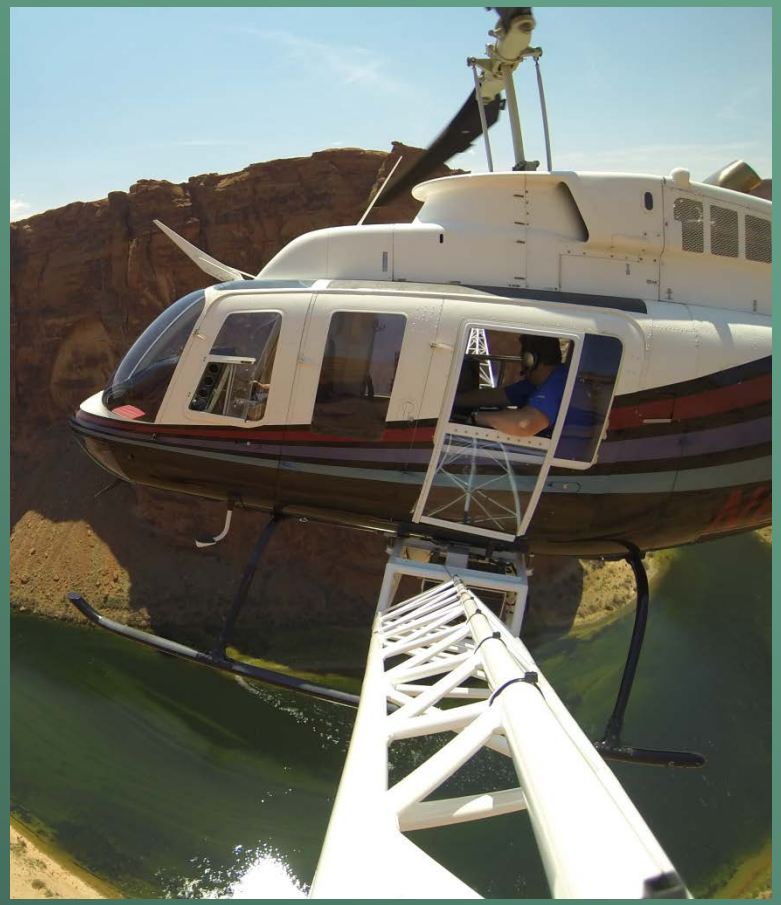
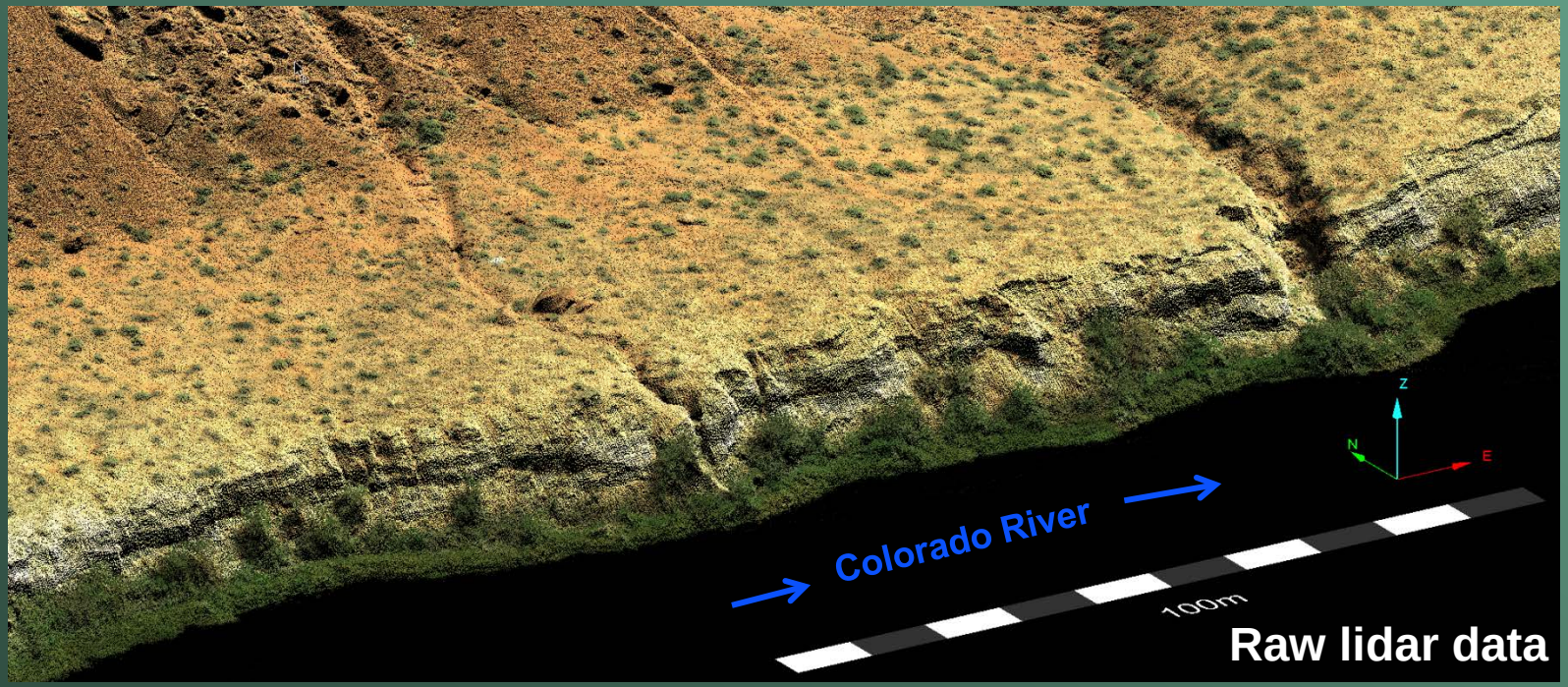
Long-term changes in Glen Canyon

- Goal: characterize the overall state of gully erosion (Are arch. sites more eroded here than in Grand Canyon?)
- Focus on terrace-based gullies
- Airborne lidar of 8.5 river miles
  - Helicopter-based platform
  - July 2013
- Analysis of 400+ drainage paths



Results: gully characterization

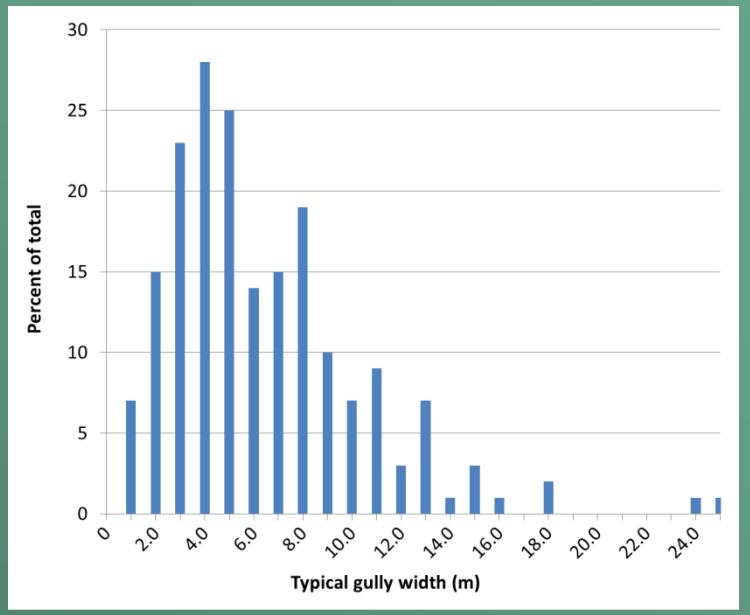
- 192 incised gullies (>20 cm) over 8.5 river miles (~23 gullies/mile)
- 8% cross known arch. sites
- 79% cross sand/terrace deposits

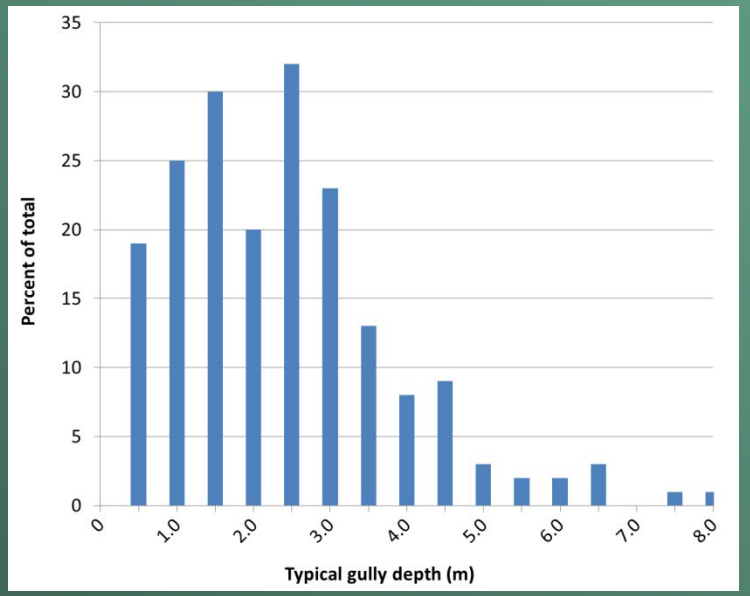


PRELIMINARY RESULTS – DO NOT CITE (Collins et al., in prep.)

Glen Canyon gully geometry

- Mean gully width = 5.9 m
- Mean gully depth = 2.2 m
- Insightful for characterizing the current state of erosion in Glen Canyon
- Work in progress
  - Compare to measured annual rates.
  - Compare to Grand Canyon.





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

Short-term changes in Grand Canyon

- Goal: Identify if Type 1 sites are responding as hypothesized to aeolian sand supply
- Four sites
- Sequential terrestrial lidar
  - September 2010 - May 2013
    - Brackets November 2012 HFE
  - May 2013 - May 2014
    - Brackets November 2013 HFE
- Adds to existing change analyses
  - 5 other data sets, May 2006 - September 2010

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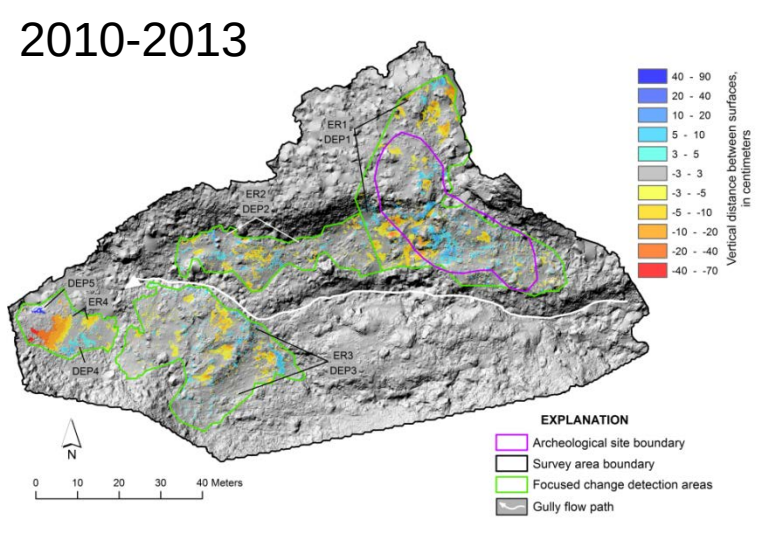
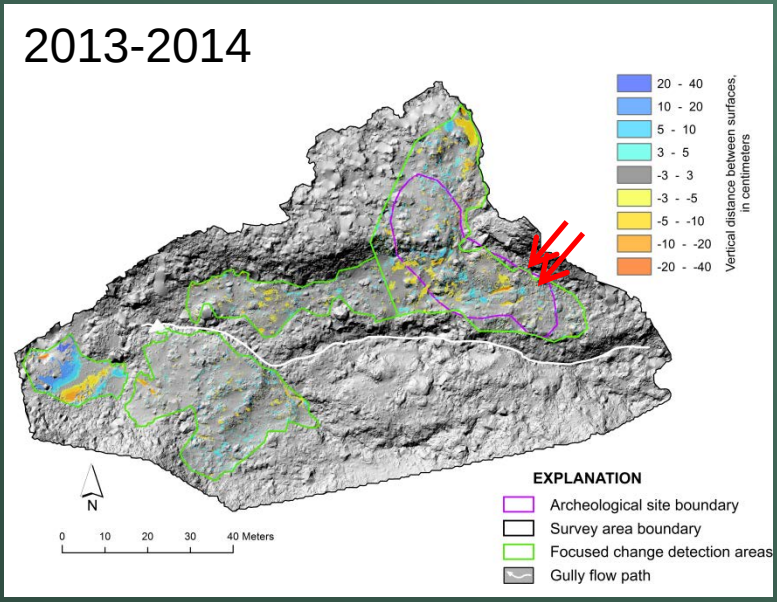
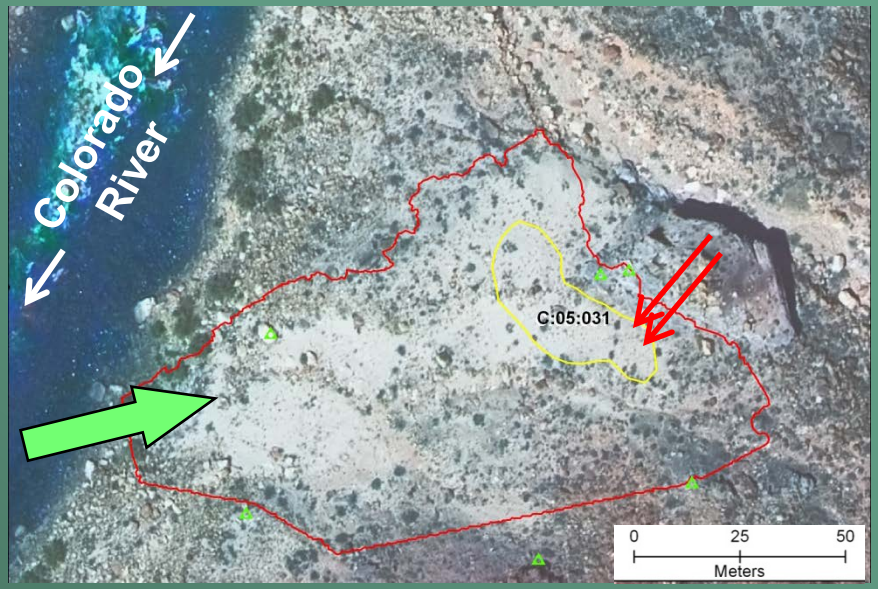
Topographic changes: AZ:C:05:0031



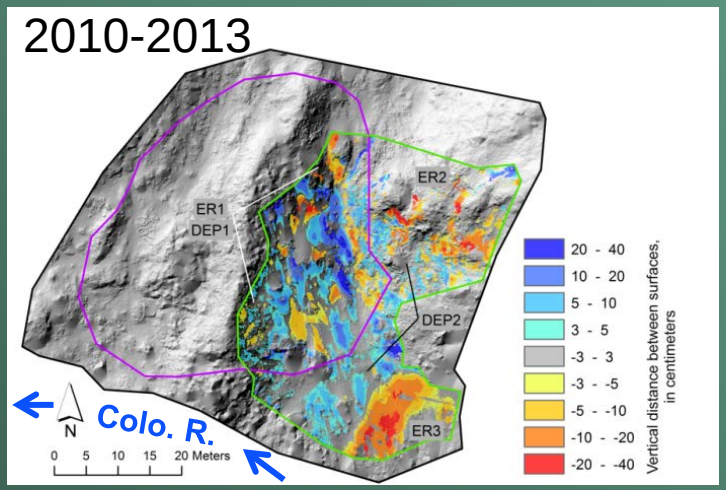


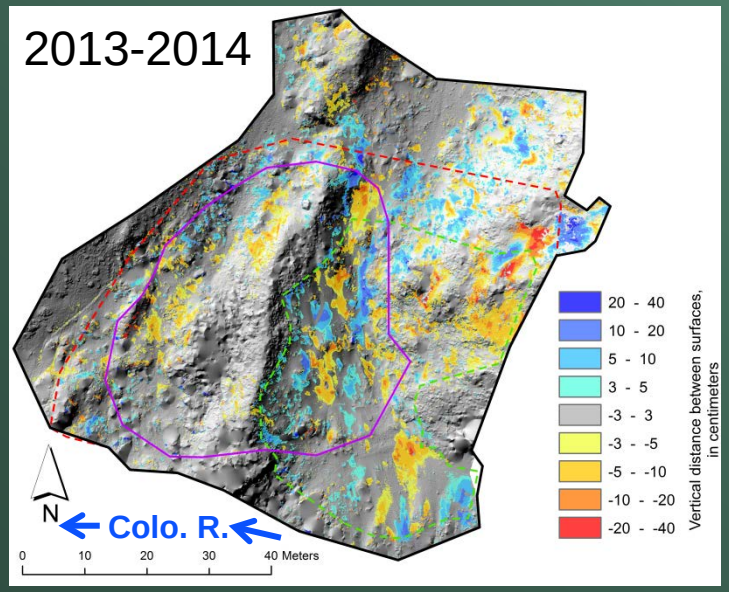


- Reworking of fluvial-sourced sand
- Favorable depositional wind trajectory
- Formation of two gullies in 2013
- 2010-2013
  - 20% of area changed w/ -3 cm ave. change depth
- 2013-2014
  - 14% of area changed w/ 0 cm ave. change depth

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

Topographic changes: AZ:C:13:0321

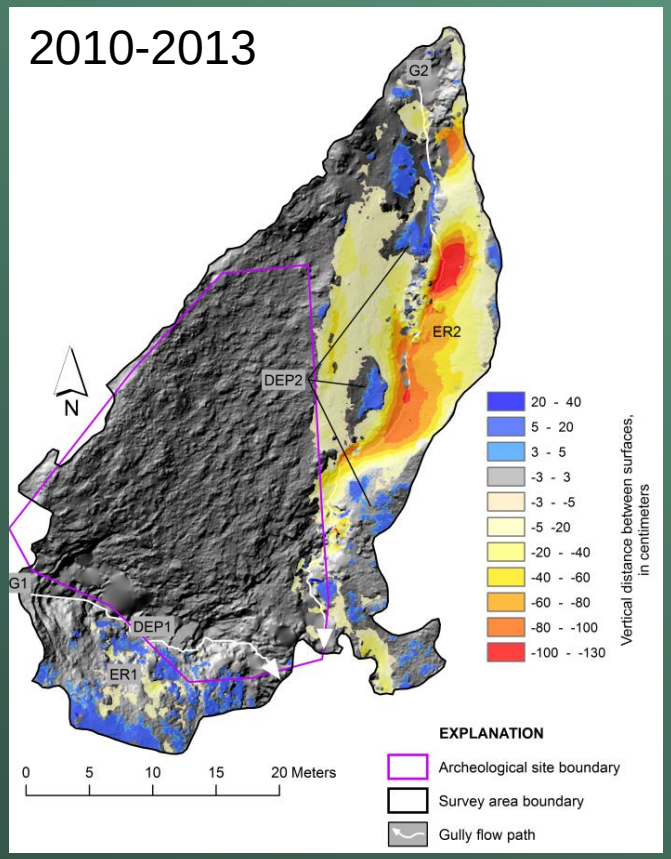


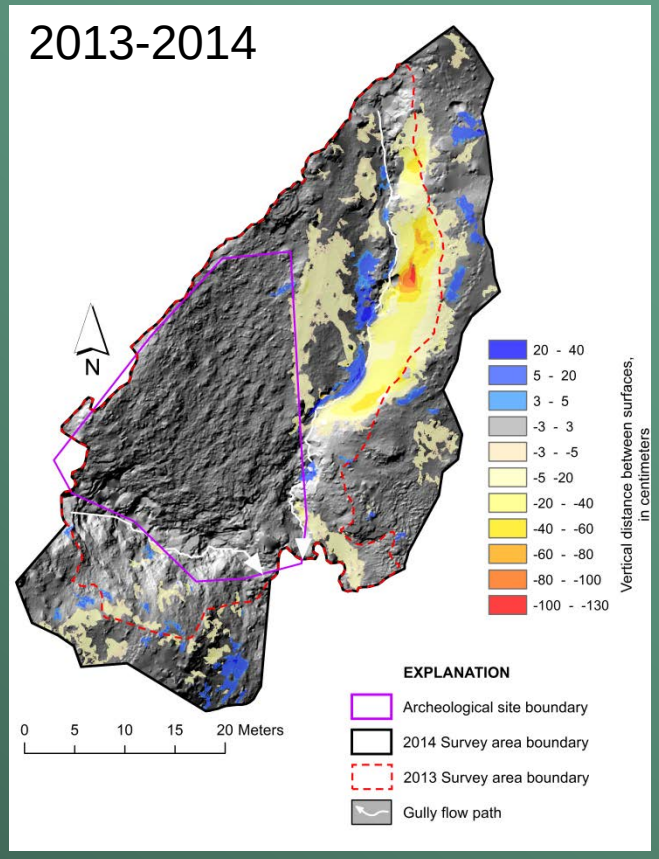


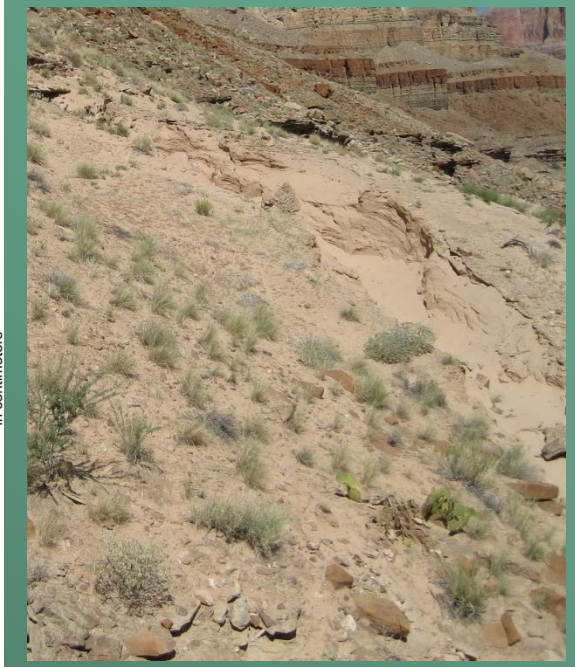
- Reworking of fluvial-sourced sand
- Favorable depositional wind trajectory
- 2010-2013
  - 40% of area changed w/ -3 cm ave. change depth (+4 cm in arch. site)
- 2013-2014
  - 23% of area changed w/ -1 cm ave. change depth

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

Topographic changes: AZ:B:10:0225



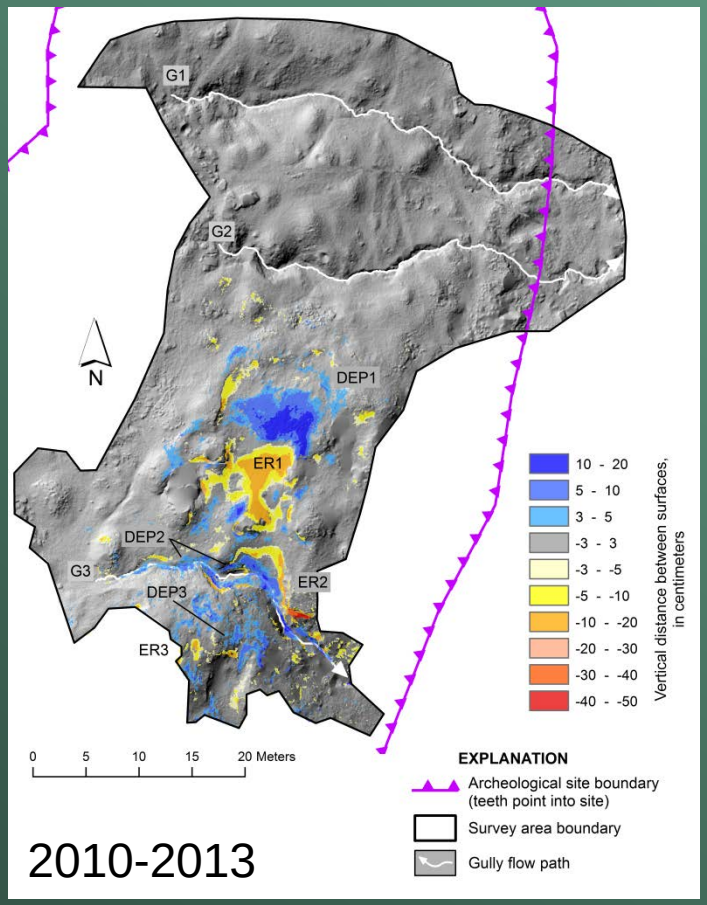


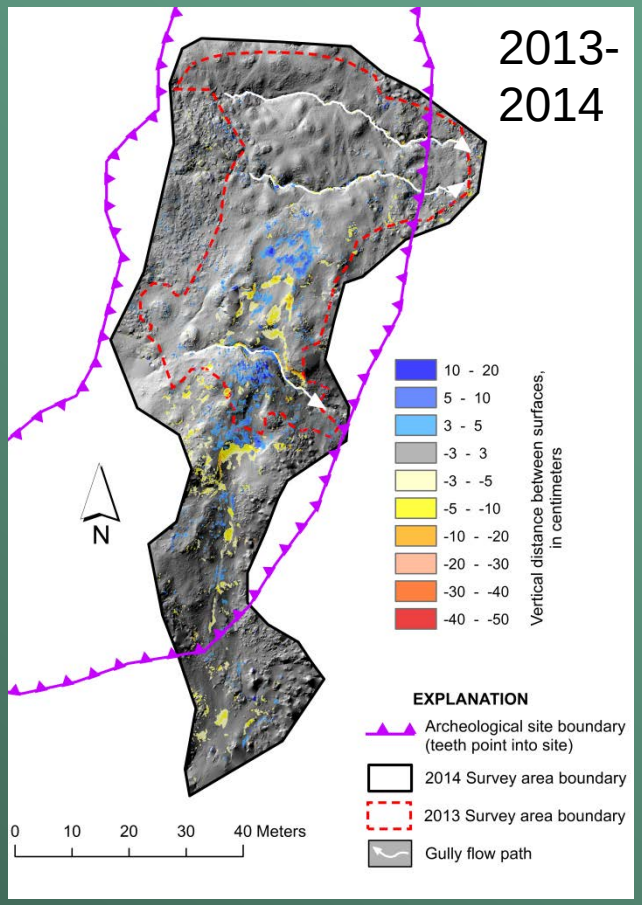


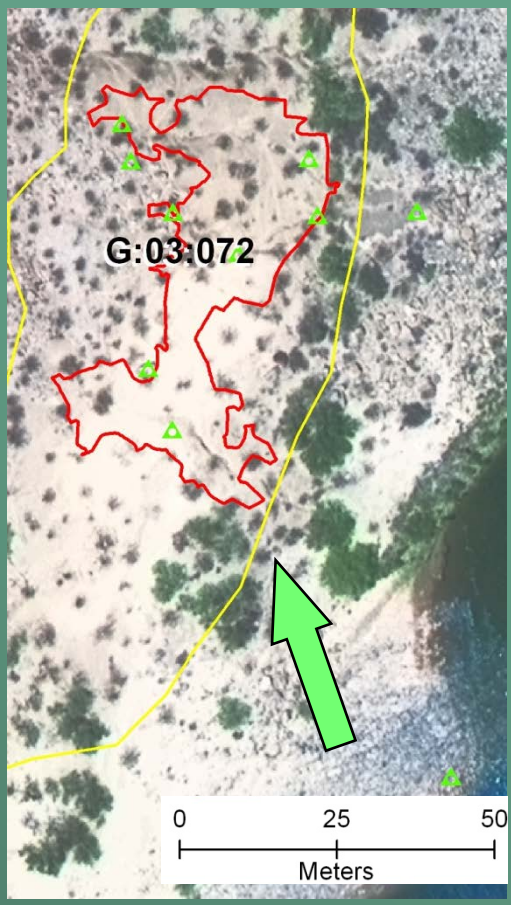
- Massive gullying with aeolian reworking (favorable wind trajectory)
- Gully with steep drainage pathway borders site
- Small changes to arch. site, but significant potential
- 2010-2013
  - 30% of area changed w/ -25 cm ave. change depth
- 2013-2014
  - 22% of area changed w/ -12 cm ave. change depth

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

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

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

Summary: short-term changes in Grand Canyon

- All sites show measurable changes
- General patterns of short-term sediment transport are maintained
- Gullying is active and causing site changes
- Aeolian processes are active and responsible for gully annealing

Cultural Monitoring Overview Questions

- **Are cultural sites eroding or changing faster or in a significantly different manner than they would if Glen Canyon Dam was operated differently than it has been?**
  - In some cases, the answer is yes (sites within direct impact of high water line; sites receiving HFE sand)
- Is the magnitude of aeolian transport to, and deposition at, sites from river sand bars sufficient to offset erosion, and thereby protect archaeological resources?
  - Yes – but all examples are in Grand Canyon.
- In areas with active aeolian deposition, do sites that are subjected to significant gullying (i.e., >30cm downcutting) undergo net topographic lowering such that the physical and informational integrity of archaeological resources are impacted?
  - Thus far, only minor evidence of this process - additional monitoring necessary.
- Are archeological sites in Glen Canyon significantly more eroded (e.g. are gullies more incised) compared to those found downstream from Lee's Ferry where the fine-grained sediment supply is larger?
  - Analysis is ongoing – we now know quantitative overall degree of erosion in Glen Canyon.

Thank you