Cultural Site Monitoring in Glen and Grand Canyons

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

(Collins et al., in review)
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 gullyng (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

*(Collins et al., in review)*

4 new sites in Glen Canyon

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

(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
Topographic changes: AZ:C:02:0032

- 120 m² (1.5%) of surface change in arch. site
- Most (81%) from bank erosion
- Ave. change depth = -11 cm

**EXPLANATION**
- Archeological site boundary
- Survey area boundary
- Cut-bank boundary
- Gully flow path

PRELIMINARY RESULTS – DO NOT CITE (Collins et al., in prep.)
AZ:C:02:0032 – gully bank erosion

Profile view looking up-gully

19 cm of gully widening

2012

2013

Preliminary results – Do not cite (Collins et al., in prep.)
AZ:C:02:0032 – gully undercutting

2012

2013

PRELIMINARY RESULTS – DO NOT CITE (Collins et al., in prep.)
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 m² (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

Profile view looking down-gully

2012

bedrock platform

2013

bedrock platform

95 cm

PRELIMINARY RESULTS – DO NOT CITE (Collins et al., in prep.)
Topographic changes: AZ:C:02:0077

- 1 m² (0.04%) of surface change in arch. site
- Terrace edge gullying erosion
- Ave. change depth = -17 cm
- 425 m² 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)
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
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 with -3 cm average change depth
- 2013-2014
  - 14% of area changed with 0 cm average change depth

PRELIMINARY RESULTS – DO NOT CITE (Collins et al., in prep.)
Topographic changes: AZ:C:13:0321

- **2010-2013**
  - 40% of area changed with -3 cm average change depth (+4 cm in arch. site)

- **2013-2014**
  - 23% of area changed with -1 cm average change depth

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

PRELIMINARY RESULTS – DO NOT CITE (Collins et al., in prep.)
Topographic changes: AZ:B:10:0225

2010-2013
- 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

2010-2013

• 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