

**GRAND CANYON HOLOCENE
GEOMORPHOLOGY SYMPOSIUM
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CONCLUDING OBSERVATIONS**

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GRAND CANYON GEOMORPHOLOGY: KEY ISSUES

- **Long-Term Evolution: Geomorphic Setting**
- **Post-Dam Channel Bed Changes**
- **Holocene Landscape Evolution: Terraces**
- **Erosion of the Holocene Record: Gullies**

LONG-TERM LANDSCAPE EVOLUTION

THE GEOMORPHIC CONTEXT

WHAT DO WE KNOW?

- Long-term (10^5 - 10^6 years) incisional trend recorded by flight of Pleistocene terraces
- Well-defined variations in valley morphology, and corresponding preservation of depositional records, in the downstream direction correlate with lithology and structure
- Long profile details are controlled by balance between debris-flow inputs and their reworking by the trunk stream
- Clear contrasts in fluvial processes and style between the glacial and interglacial river

LONG-TERM LANDSCAPE EVOLUTION THE GEOMORPHIC CONTEXT

WHAT DO WE REALLY NEED TO KNOW?

- **A better understanding of the initial conditions for the Holocene, and the archaeological record: when did the river reach its present level?**
 - **Has it flowed at a lower level?**
 - **Is this its lowest elevation or depth of incision?**

POST-DAM CHANGES IN CHANNEL MORPHOLOGY AND PROCESS

WHAT DO WE KNOW?

- Solid understanding of sediment routing in the channel, especially the coupling between tributary influx and the main stem
- Solid understanding of the major changes in sediment supply due to dam construction, especially the loss of fine sediment
- Reasonable understanding of relations between short-term deposition along the channel margin and flow modulation - we know how to build a beach

POST-DAM CHANGES IN CHANNEL MORPHOLOGY AND PROCESS

WHAT WE KNOW - CONT.

- Deposition and erosion of fine vs. coarse sediments have a different trajectory
- The dam-proximal reach has degraded significantly
- Farther downstream, there has been no net change, or even slight aggradation, of the channel bed
- The channel bed has, however, been transformed from a mixed gravel-sand system to a highly enhanced pool-riffle channel

POST-DAM CHANGES IN CHANNEL MORPHOLOGY AND PROCESS

WHAT DO WE REALLY NEED TO KNOW?

- How do we disentangle the effects of the dam from the inherited trajectory of channel change due to an ever changing climate?
 - This may be a fundamentally unresolvable issue, but we should try.
- We need to know more about the natural coupling between climate and fluvial processes.
- How do we preserve a beach? What sequence of flows, what level of sediment supply are needed?

HOLOCENE LANDSCAPE EVOLUTION: THE TERRACES

WHY IS THIS IMPORTANT?

- **Holocene terraces correspond to the time period of human occupation, and represent the repository for cultural resources and dateable material**
- **Holocene terraces record human-landscape interactions, and the nature of the environment at particular points in time**
- **The Colorado River integrates surface processes over a large area of the American West. Holocene terraces are the best record of fluvial activity, and changes in fluvial activity through time in response to climate change and other factors**

HOLOCENE LANDSCAPE EVOLUTION: THE TERRACES

WHAT DO WE KNOW?

- Reasonably agreed-upon sequence of depositional events
- Deposits are well-mapped (lines on the maps are very good) in many areas, including the culturally-relevant areas
- Deposits consist of overbank fluvial, colluvial, and eolian facies of varying proportions
- At any one reach where mapping has been completed, deposits are reasonably well-dated

HOLOCENE LANDSCAPE EVOLUTION: THE TERRACES

WHAT WE ARE LESS CERTAIN ABOUT

- How deposits precisely correlate from reach to reach, and between Grand Canyon and other areas
- Genetic origins of these landforms and deposits:
 - Depositional environments and relative proportions of fluvial, eolian, and colluvial inputs
 - Splitting vs. lumping of units....which way is best?
 - Origin and position of basal erosional surface and its implications for river incision history
 - Role of “extreme” vs. “normal” floods
- How much of the record is missing - particularly the early to middle Holocene? What are the implications for geological and archaeological interpretations?
- How is the terrace record coupled to external forcing?

EROSION OF THE HOLOCENE RECORD: THE GULLIES

WHY IS THIS IMPORTANT?

- Thought to be the primary short-term mechanism for loss of cultural resources
- Has been proposed to be, at least partially, a result of operations of Glen Canyon Dam

EROSION OF THE HOLOCENE RECORD: THE GULLIES

WHAT DO WE KNOW?

- Fluvial landscapes are in a constant state of revision, and for any given flood stage, there are locations of erosion, deposition, and subsequent modification
 - Gully erosion happens, and the only reason the issue is *front-burner* here is the proposal that accelerated erosion is due to dam presence and/or dam operations, and the associated mandate to preserve archaeological resources
 - Gullies always grow in the headward direction, and tend to be initiated at some break in slope
- Reasonable evidence exists that accelerated gully erosion corresponds to the post-dam period

EROSION OF THE HOLOCENE RECORD: THE GULLIES

WHAT DO WE KNOW - CONT.

- The post-dam period corresponds to one of the wettest periods in the historical record
- We see no clear evidence that gullies are initiated by dam-related processes
- Flood sediments can fill gully mouths, and can persist for years to exert short-term influences on the lower reaches of gully networks (to the first nickpoint?)
- We see no clear evidence that deposition of flood sediments in gully mouths will heal existing gullies, permanently stem gully erosion, or have much effect on the long-term evolution of gully systems
- The supply of sand for eolian transport, and potential healing of gullies, has decreased due to dam presence

EROSION OF THE HOLOCENE RECORD: THE GULLIES

WHAT WE ARE LESS CERTAIN ABOUT

- Exact links between gully erosion and “base level” are not well understood
 - If gullies are graded to the low flow channel, then base level has been raised due to dam presence
 - If gullies are graded to sand bars, then in some cases base level has been lowered due to dam presence
 - How does something called base level relate in any way to gullies on the upper terraces?
- What are the precise controls on gully initiation vs. gully propagation vs. gully healing (senescence)
- What are the longer-term effects of gully mitigation, especially the “unintended consequences”?

WHERE TO FROM HERE?

- **Develop a true, fully integrated interdisciplinary perspective and methodological approach to Grand Canyon archaeological and human ecological research**
- **Given the dynamic nature of the landscape, and limited budgets, all archaeological resources should not be considered of equal significance and value**
- **Develop a rational strategy to maximize return on public investment by driving archaeological and human ecological research with fundamental questions**
 - **Comprehensive evaluation of sites relative to present geomorphic setting and paleolandscapes**
 - **Clear understanding of the archaeological significance of “at risk” and non at-risk sites, and what questions can be answered from each**

WHERE TO FROM HERE?

- At the ***gully scale***, build on past and current research to develop fully predictive physical models of erosion potential and site vulnerability
- At the ***landscape scale***, undertake a new generation of detailed and integrated studies that focus on the coupling of the archaeological record and Holocene landscape evolution:
 - Process-based studies of Holocene framework to more fully understand origin and genetic significance of main stem landforms and deposits
 - Geochronology needs to be more fully developed through creative and extensive use of techniques such as ^{14}C , OSL, and cosmogenic nuclides
 - How do records of landscape evolution link to local vs. regional vs. global climate and climate change