USGS
science for a changing world

Summary of 2012 Accomplishments for Cultural Monitoring R&D Project, New Knowledge Gained, and Future Research Directions for FY2013-2014

Helen Fairley , Brian Collins, and Amy Draut (USGS)

Annual Reporting Meeting, Phoenix, AZ
January 23, 2012

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

Outline

- **Part I:** Review project background, describe FY2012 accomplishments, summarize new insights gained
- **Part 2:** Describe how knowledge gained from FY2006-2012 Cultural Monitoring R& D and previous research (e.g., Draut and Rubin, 2008) is being applied to new research effort in FY2013-2014 (Project J)

FY2012 Accomplishments

- **2012 Publications:**
  - Collins and others, 2012: “Topographic Change Detection at Select Sites in Grand Canyon National Park, Arizona, 2007-2010” USGS Scientific Investigations Report 2012-5133
  - Draut, 2012: “Effects of river regulation on aeolian landscapes, Colorado River, Southwestern USA” Journal of Geophys. Research-Earth Surface, vol. 117
- **2012 Fieldwork in Glen Canyon:**
  - Collected detailed topographic measurements from 4 sites
  - Planned/completed data collection for Nov. 2012 HFE
    - Repeat photography
    - Site visits to determine high flow level in relation to sites

USGS

Hypothesis linking dam operations, sand supply, wind/weather & archaeological site preservation

Erosion of cultural features tied to reduced sediment supply, lack of floods, increased vegetation → no flood deposits; fewer open, dry sand bars → less eolian sand to cover sites & backfill gullies → progressive deflation by wind, continuous down-cutting in gullies

River-level sandbar

Sand dunes above river

Deflating Arch. site

USGS

What is the fundamental question?

<u>Not</u> whether sites and associated high elevation terraces are eroding, but

Are sites and terrace deposits eroding faster or more extensively than they would if:

A) Glen Canyon Dam did not exist; and

B) Glen Canyon Dam was operated differently

USGS

Why is this question difficult to answer?

Our ability to answer this question has been constrained historically by a lack or shortage of:

- high quality site-specific geomorphic data
- reliable methods and appropriate tools for measuring past and current rates of change
- local measurements of key parameters (rainfall, wind conditions), topography, soil characteristics, cover
- pre-dam landscape/terrace condition data
- control data from comparable unregulated rivers

USGS

Cultural Monitoring R&D: Goals

Phase 1: Collect & evaluate basic data

1) evaluate geomorphic setting/characteristics of sites
2) develop and test low impact tools and methods for accurately detecting and measuring deposition/ erosion

Phase 2: Initiate pilot monitoring program
1) Apply new methods at random sample of sites to characterize systemwide condition & rates of change;
2) develop geomorphic model to explore linkages re: weather, sediment supply, flows.

Lidar and Archaeology

- Archaeology relies on 3-D mapping extensively
  - Context matters!
- Archaeologists quick to adopt lidar technology for:
  - Documentation (artifacts, architecture)
  - Mapping landscapes
  - Preservation tool
- Lidar efficient at collecting 3-D data w/ minimal impact

USGS

Why did we need R&D?

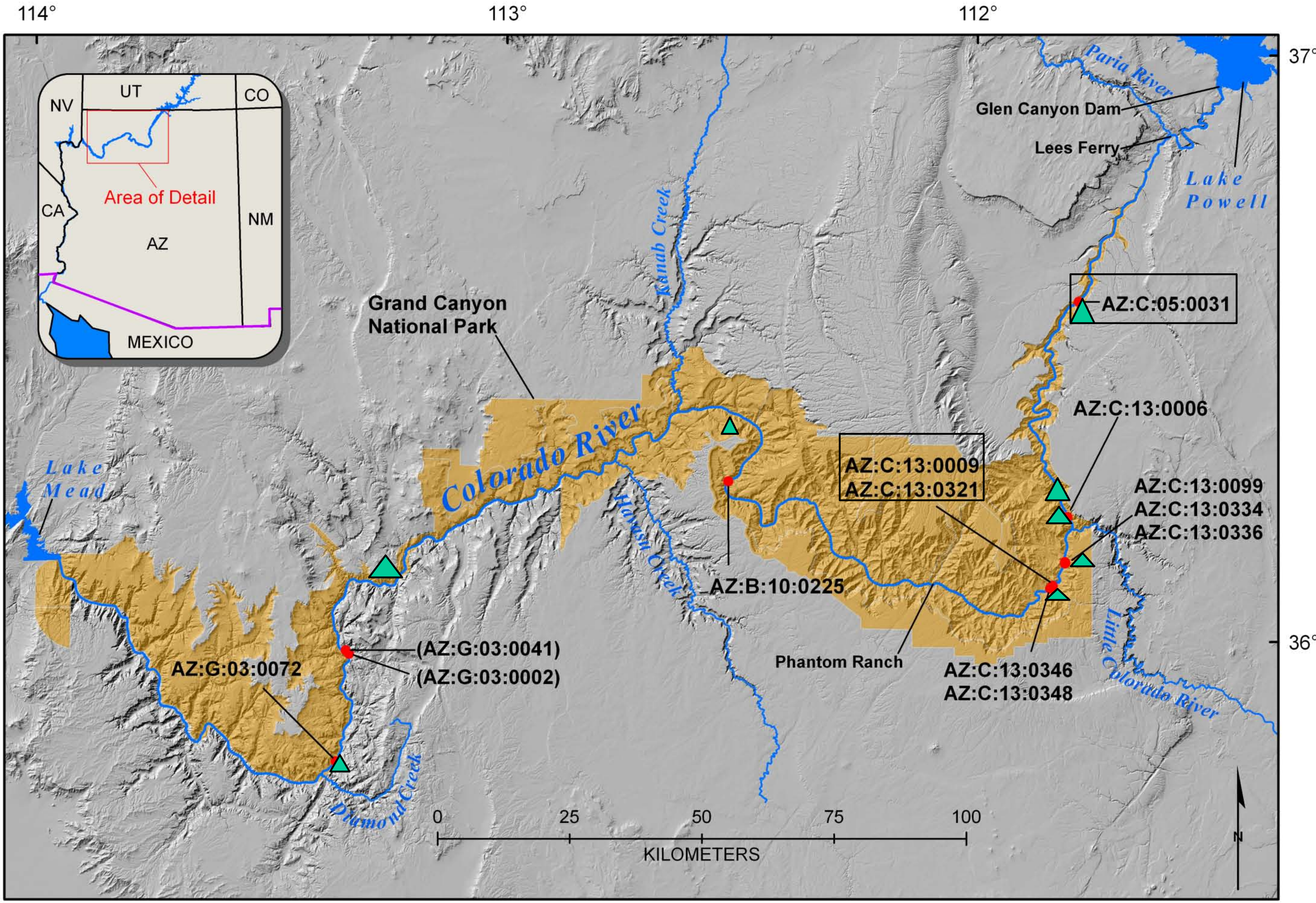
- Need to develop method for repeat mapping (monitoring) change at landscape scale
  - Rapidly evolving technology
  - Evaluate impacts
  - Evaluate errors
- Worked out "bugs" with new weather station technology
- Explore other tools & techniques (RTK GPS, thalweg surveys)

USGS

Cultural Monitoring R&D Project History

- August 2005: AMWG approved new direction for Cultural Resources Monitoring Program –multiphase project
  - 2-3 years R&D on tools/methods, followed by pilot program
- 2006-2007: <u>Phase 1 started</u>. GCMRC/USU/NPS collaborated.
  - develop baseline geomorphic data for 232 sites
  - initiate research on tools/methods for monitoring (lidar surveys)
  - Install weather monitoring stations near 9 sites
- 2008-2009: <u>Phase 1 field work stopped</u> (4 publications)
- 2010: <u>Phase 1 fieldwork resumed</u> (3 publications)
- 2011: <u>Phase 2 initiated, then terminated</u> (1 publication)
- **2012:** <u>Glen Canyon work initiated</u> (2 publications)

USGS



114°
113°
112°
37°
36°
NV
UT
CO
CA
AZ
NM
MEXICO
Area of Detail
Paria River
Glen Canyon Dam
Lees Ferry
Lake Powell
Kanab Creek
AZ:C:05:0031
Grand Canyon
National Park
Colorado River
Lake Mead
AZ:C:13:0006
AZ:C:13:0009
AZ:C:13:0321
AZ:C:13:0099
AZ:C:13:0334
AZ:C:13:0336
Havasu Creek
AZ:B:10:0225
(AZ:G:03:0041)
(AZ:G:03:0002)
AZ:G:03:0072
Phantom Ranch
AZ:C:13:0346
AZ:C:13:0348
Little Colorado River
Diamond Creek
0
25
50
75
100
KILOMETERS
N

Lidar Survey R&D Component

- **2006-2007**
  - Assess whether terrestrial lidar can be used for change detection in Grand Canyon
- **2010-2011**
  - Determine if cm-scale terrestrial lidar change detection is possible; error estimates
- **2012-2013**
  - Synthesize existing body of work (geomorph, weather, change detection data)
- **2013-2015 (Project J)**
  - Link site-scale measurements to landscape (use models to determine if current conditions match predicted conditions). Do site-specific changes vary systematically with local sediment supply?

USGS

Knowledge Gained re: Use of T-Lidar for Monitoring Topographic Changes

- 2006-2007
  - Terrestrial lidar has low impact; can be used effectively in Grand Canyon for monitoring topographic changes at archaeological sites

(USGS OFR 2008-1384)

(USGS SIR 2009-5116)

- 2010-2012
  - Terrestrial lidar has cm-scale monitoring capability (vertical error <3 cm)
  - Archaeological sites are dynamic; more erosion than deposition, but both occur

(USGS SIR 2012-5133)

- 2013 (in progress)
  - Weather data is being used to develop empirical thresholds for change
  - Numerical modeling underway; initial results show promise

(JGR-Earth Surf., in prep.)

USGS

Data Limitations

- **Phase 1 data collected for purpose of developing monitoring tools & protocols**
  - Test → evaluate → refine method
- **Current data NOT suitable for demonstrating trends**
  - Sites not random; not representative of system
  - Data collection dates disjointed (2006, 2007, 2010)
  - Existing data (2-5 data points from 13 non-random sites) can not be used to evaluate specific trends
  - Reliable trend data would require a long-term monitoring program

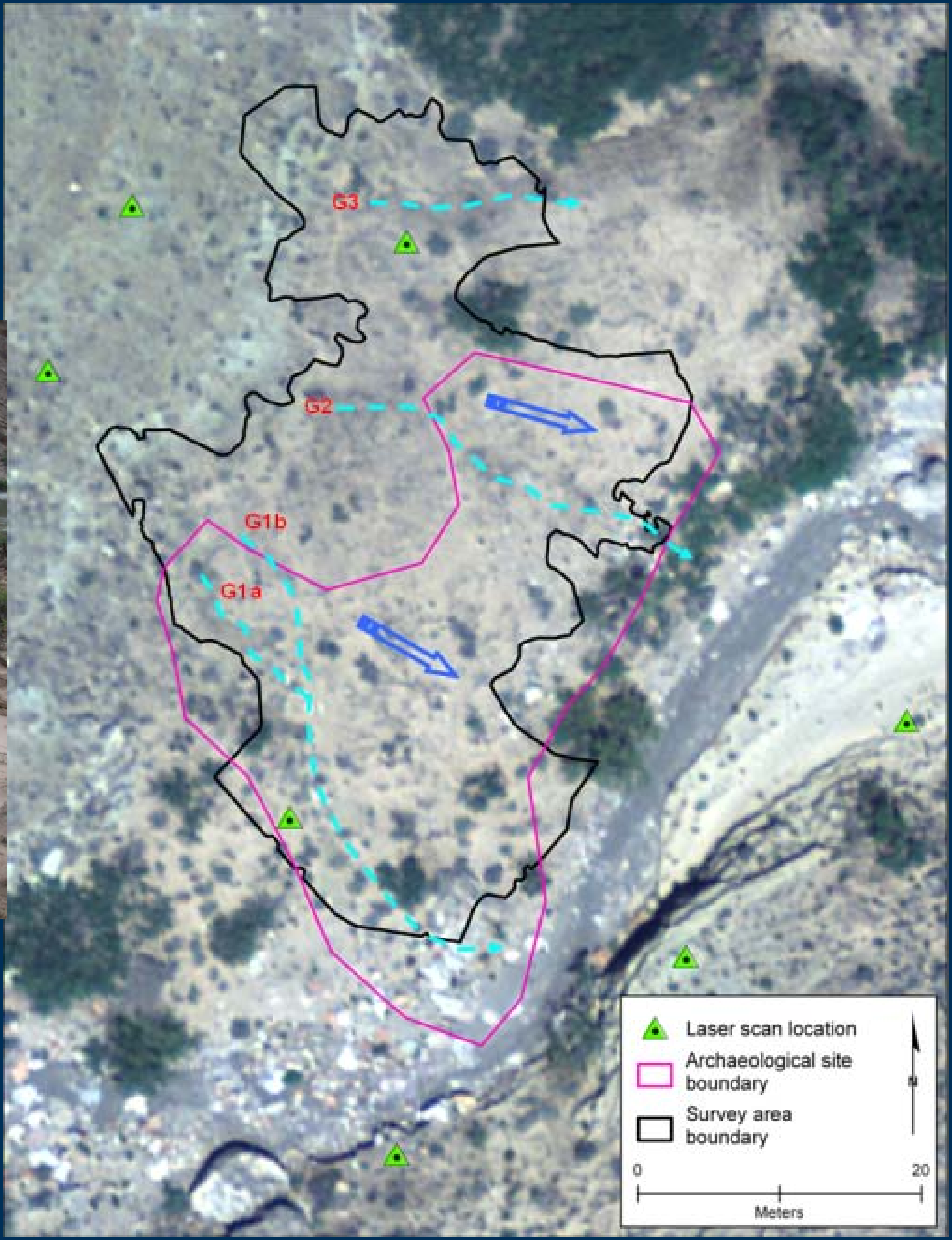
USGS

Knowledge Gained from Phase I Data (topographic change detection data)

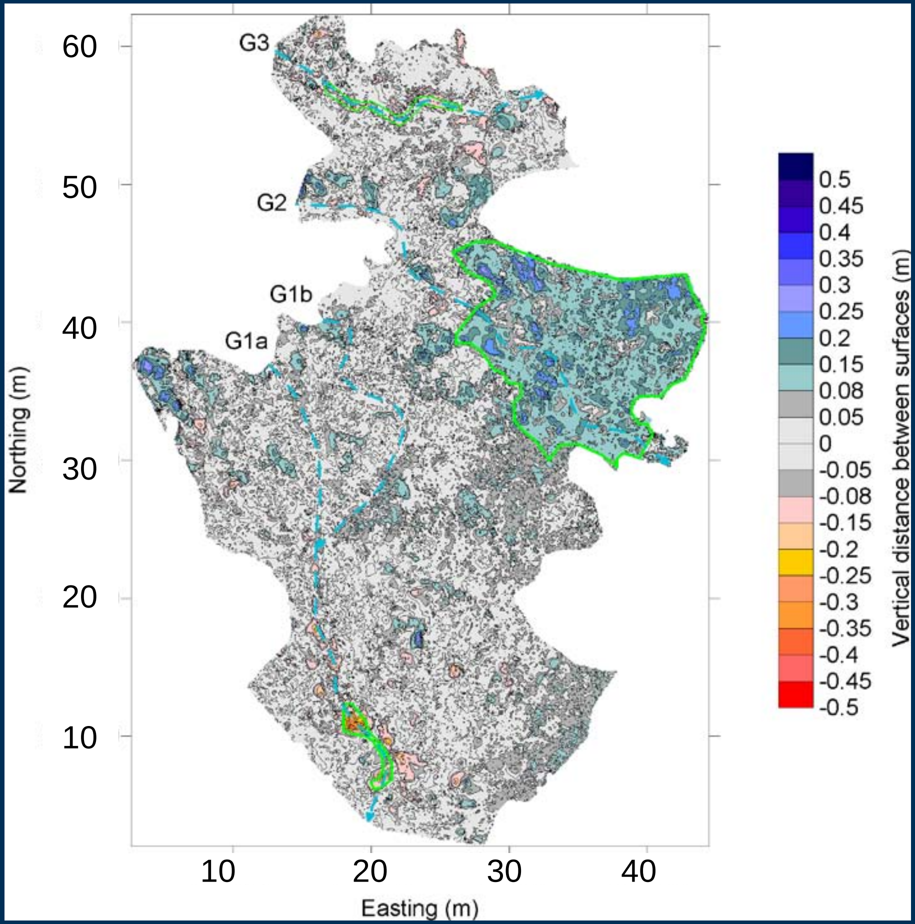
- Overall pattern at surveyed sites is erosive
- Erosion occurs primarily due to gullying and aeolian deflation; some human influence documented
- Gullying can be acute and deep; in one instance, severe gullying at a previously un-gullied location
- Aeolian deposition measurable with lidar surveys; deposition appears to limit/reduce gullying
- Aeolian erosion-induced changes (deflation) affect larger areas of the landscape than gullies

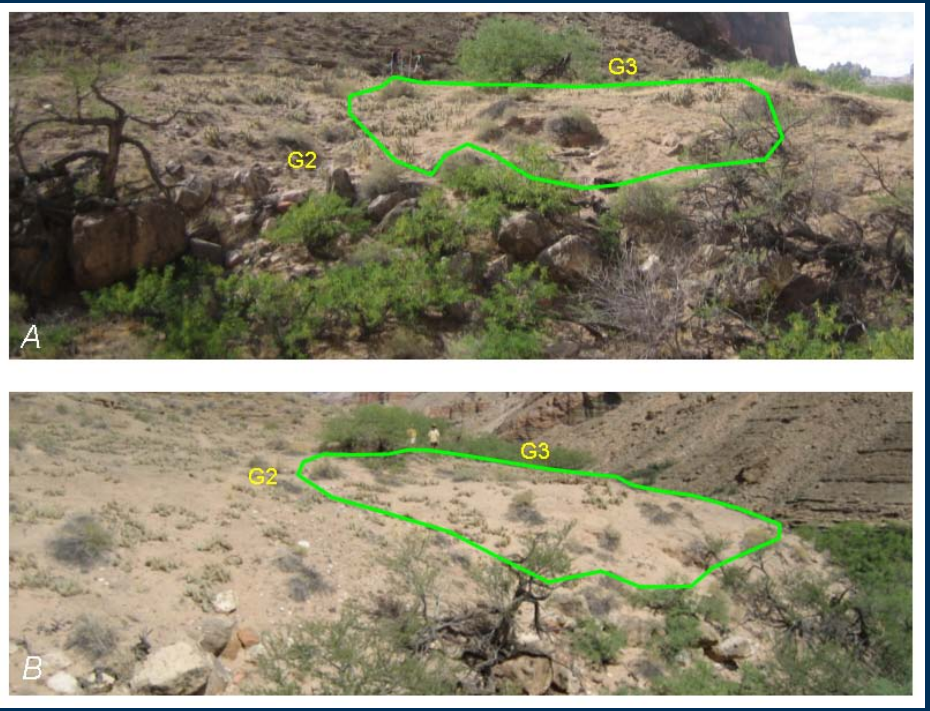
USGS

AZ C:13:0006


G3
G2
G1b
G1a
Laser scan location
Archaeological site boundary
Survey area boundary
N
0
20
Meters

AZ:C:13:0006: May 2006 – Sept 2007



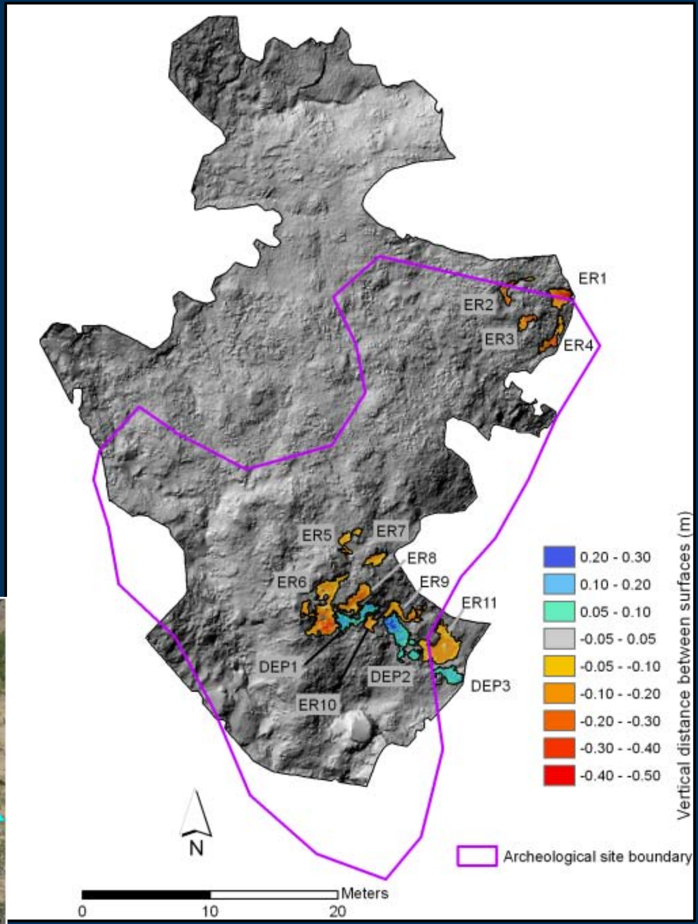


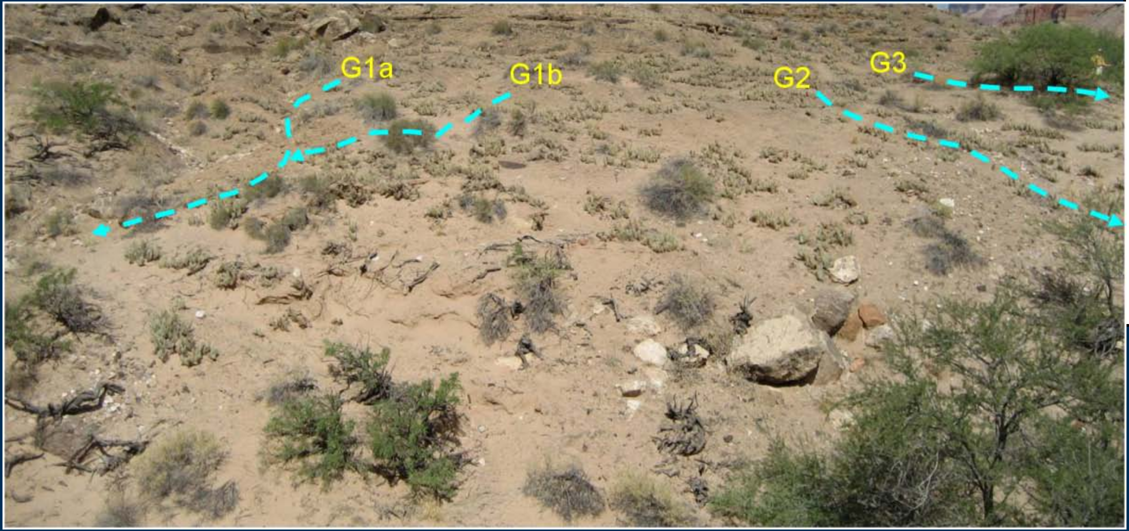
(A) May 2006 – (B) September 2007

USGS

AZ:C:13:0006 Site Change, 2007-2010

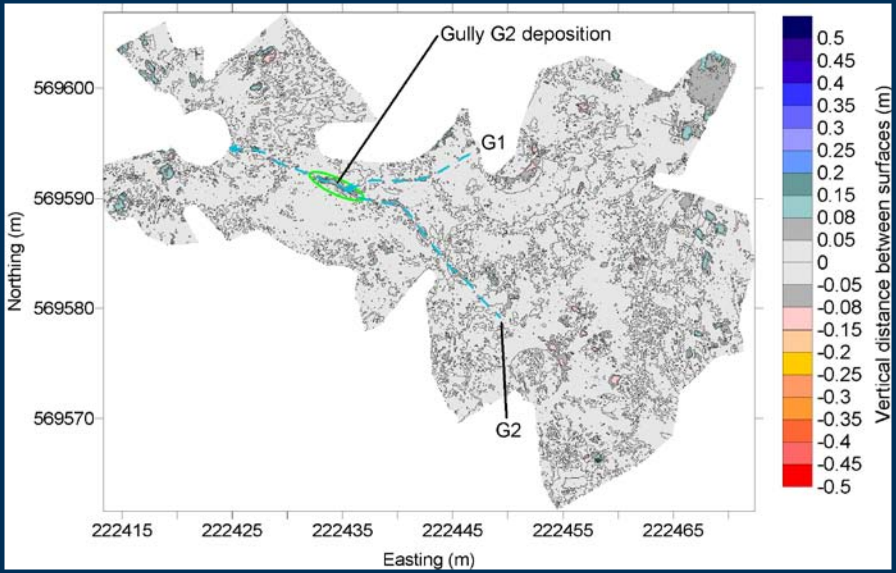
- Aeolian deposition near existing gully (G2) in 2006-07 limited gully erosion
- Gullying occurred outside depositional area (G1 and G3) during same period
- In 2010, additional erosion occurred; potential for further instability here.



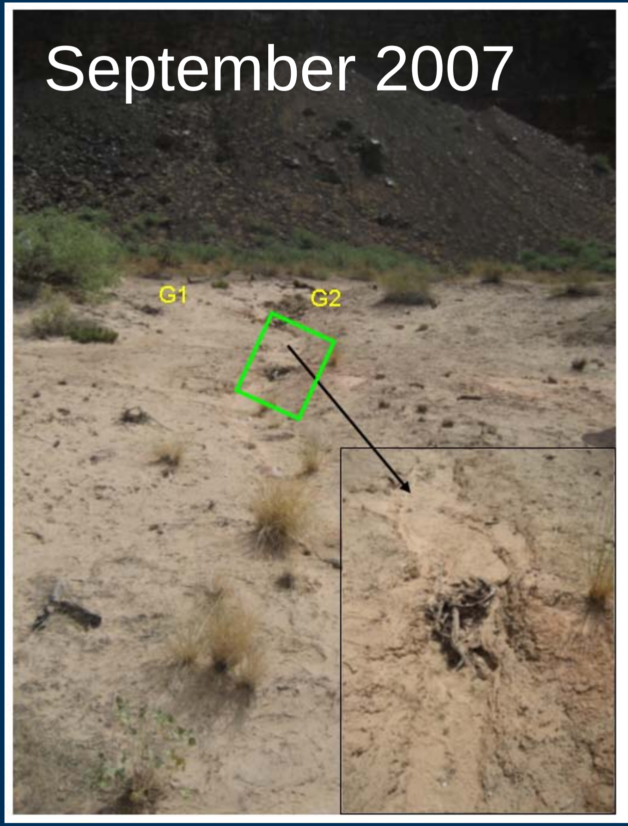


AZ C:13:0336 – Palisades Area

- **Alluvial terrace overlain by dune sands; cut by several gullies.**
- **Gully infilling document at check dam during 2006-2007**



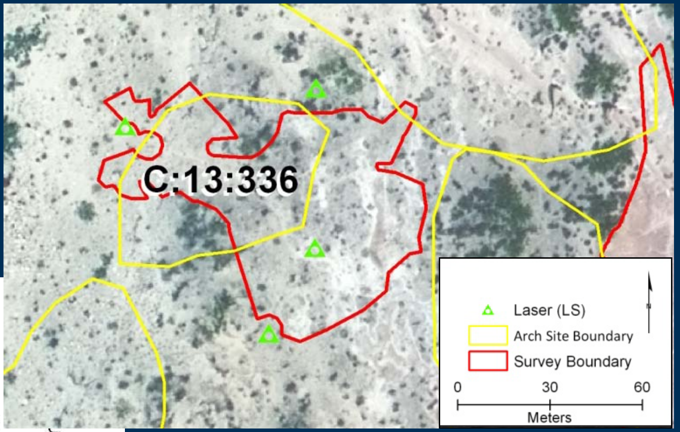
May 2006 – September 2007

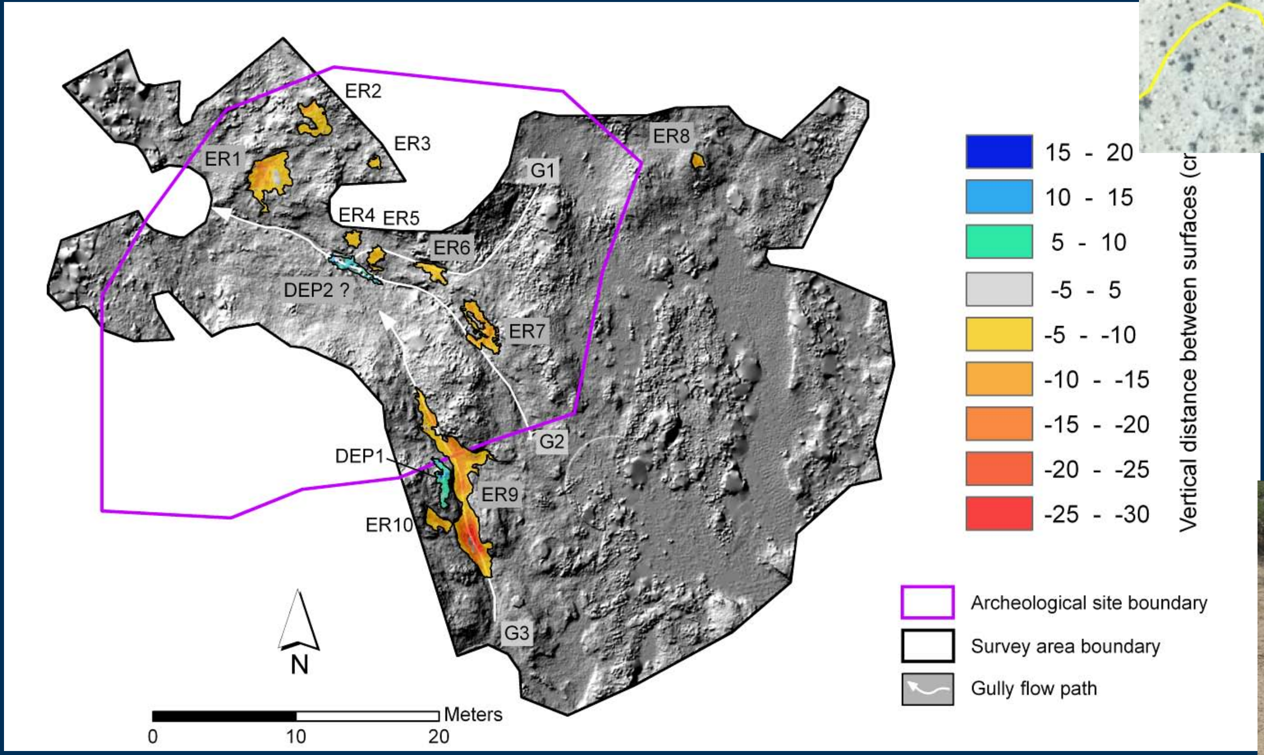


USGS

AZ C:13:0336 – Palisades Area

- Gully erosion (>8 cm) from 2007-2010: erosion affected upper gully in 2010
- Main geomorphic process is overland flow; possibly following a human trail





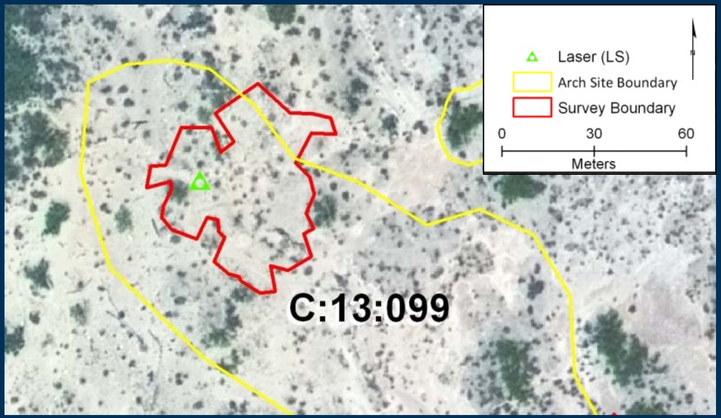
May 2007 – April 2010

Implication is that check dam may be locally effective, but gullying continues

USGS

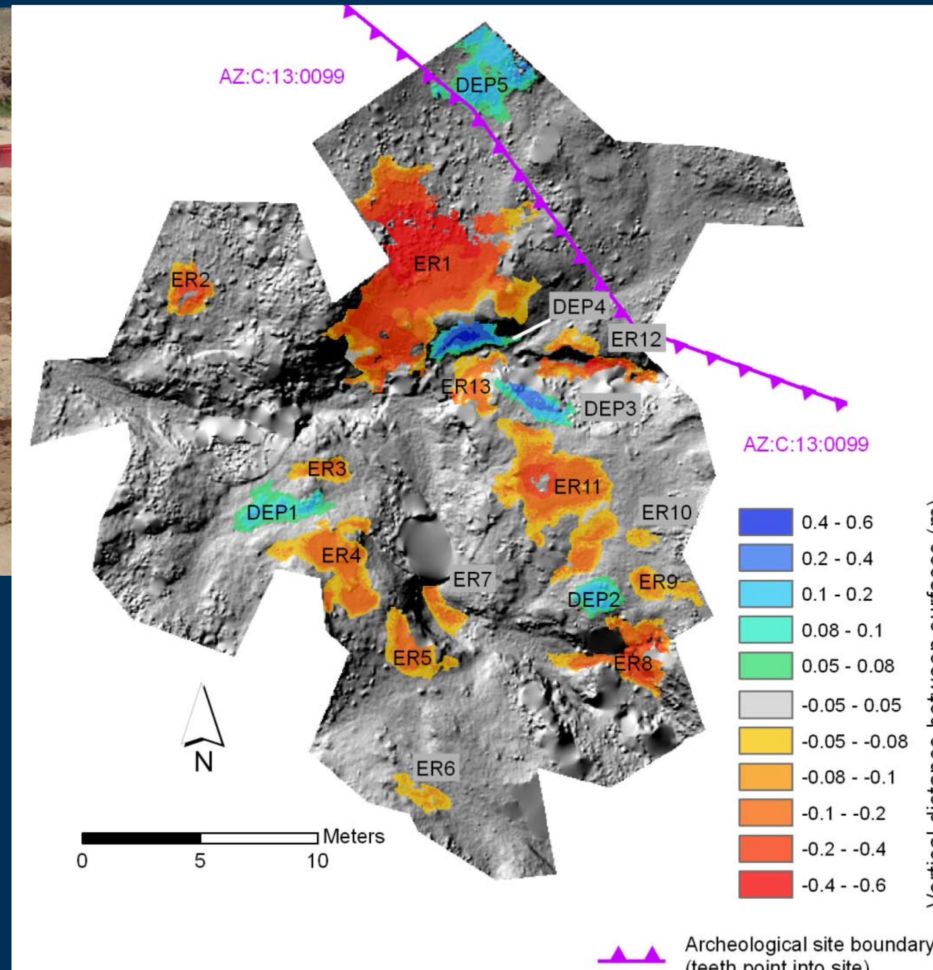
AZ C:13:0099 – Palisades Area

- **Alluvial terrace overlain by dune sands and cut by several gullies.**
- **Gully sidewall and sand dune erosion, and gully bottom infilling during 2006-2007.**



USGS May 2006 – Sept. 2007

AZ C:13:0099 – Palisades Area



NARY

Major erosion/ deposition during 2007-2010

2008 excavations primary source of change

Additional gully widening between 2007-2010

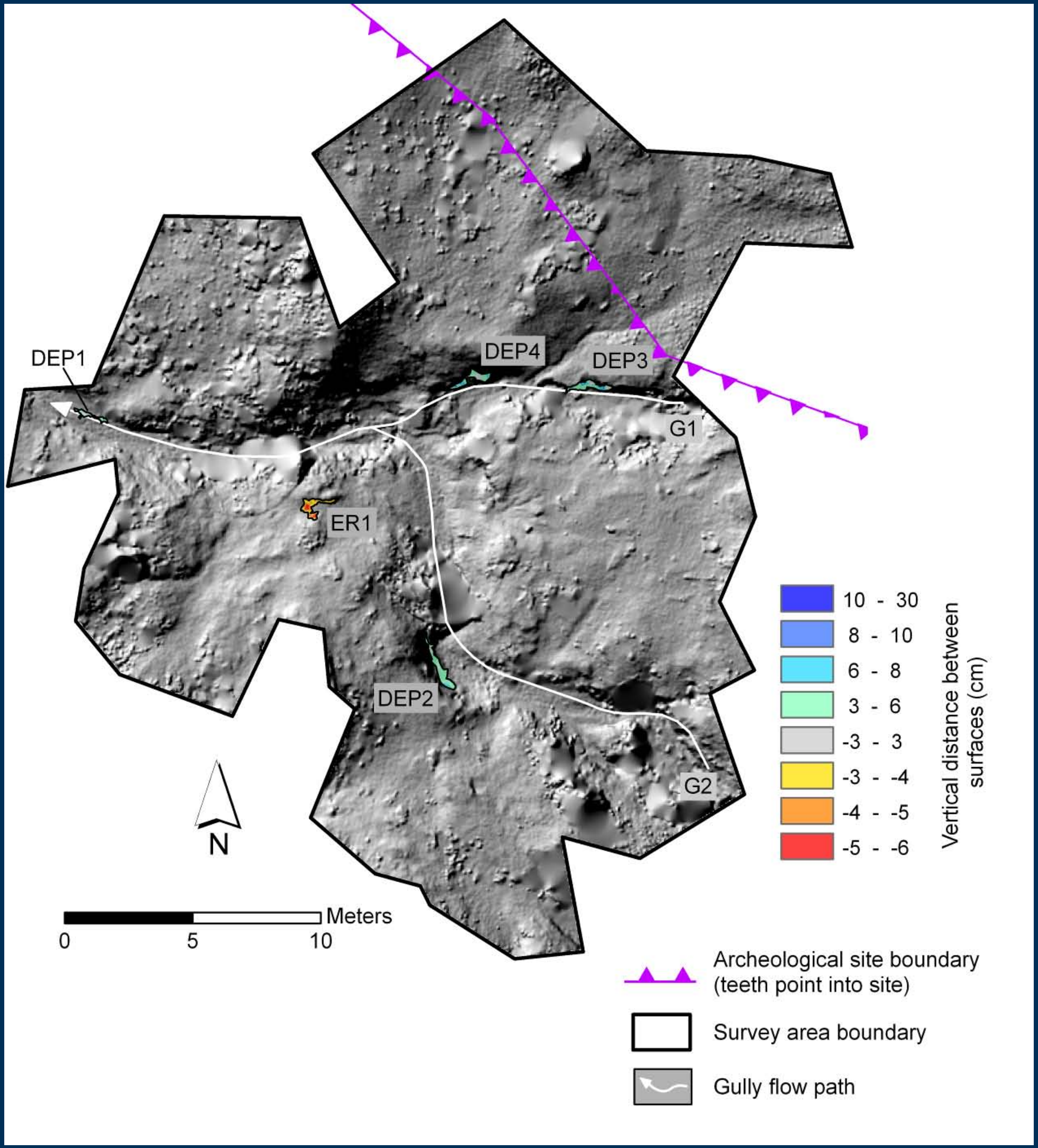
Sept. 2007 – April 2010

USGS

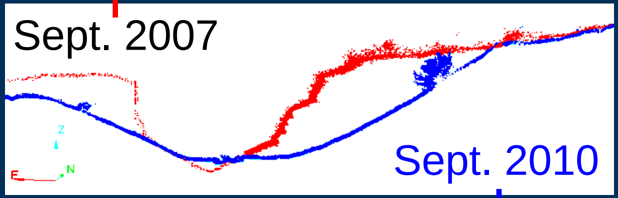
AZ C:13:0099

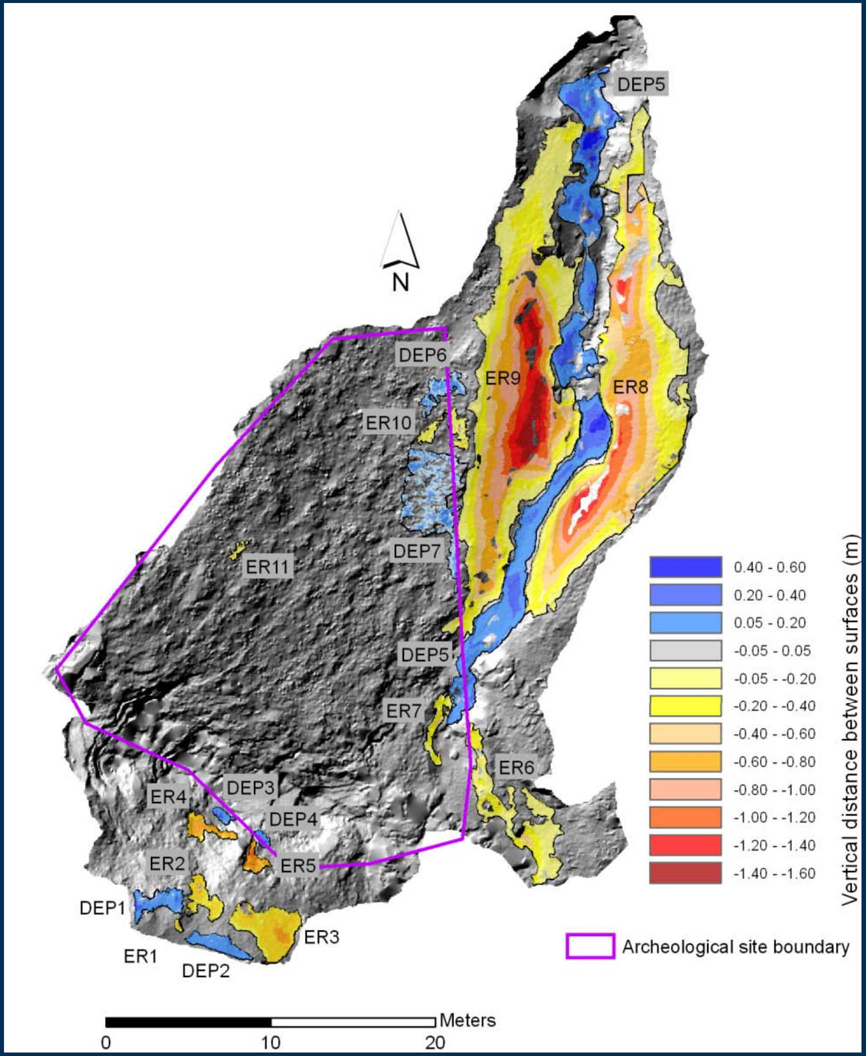
April-Sept. 2010

Minimal Change Detected



AZ B:10:0025 – Middle Granite Gorge

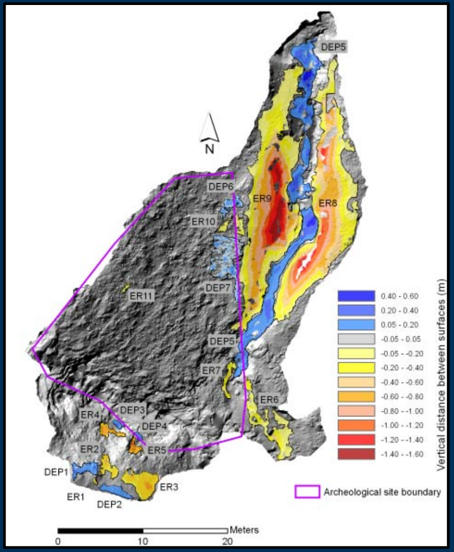


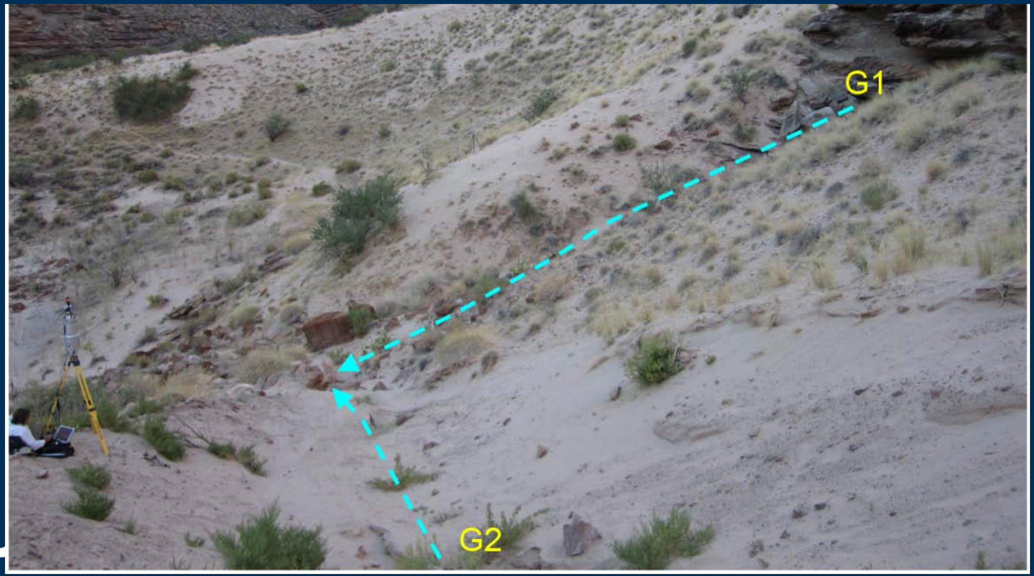


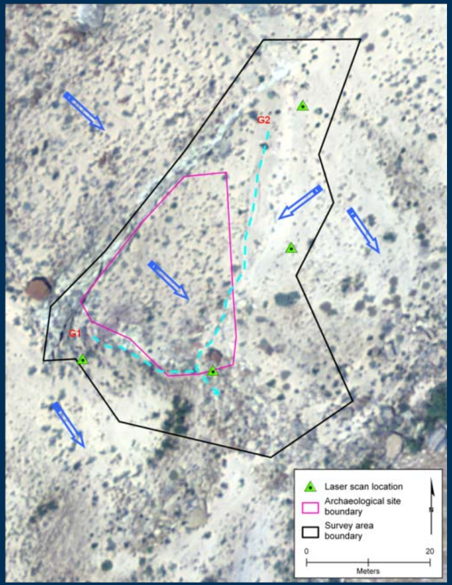
September 2007 – September 2010

Site change (AZ:B:10:0225)

- Massive gully erosion in 2007-2010 (120 m^3 sediment removed, averaging 52 cm deep)
- Additional aeolian infilling following this period (11 m^3)
- Potential for overall site lowering?
- Potential for additional aeolian infilling?





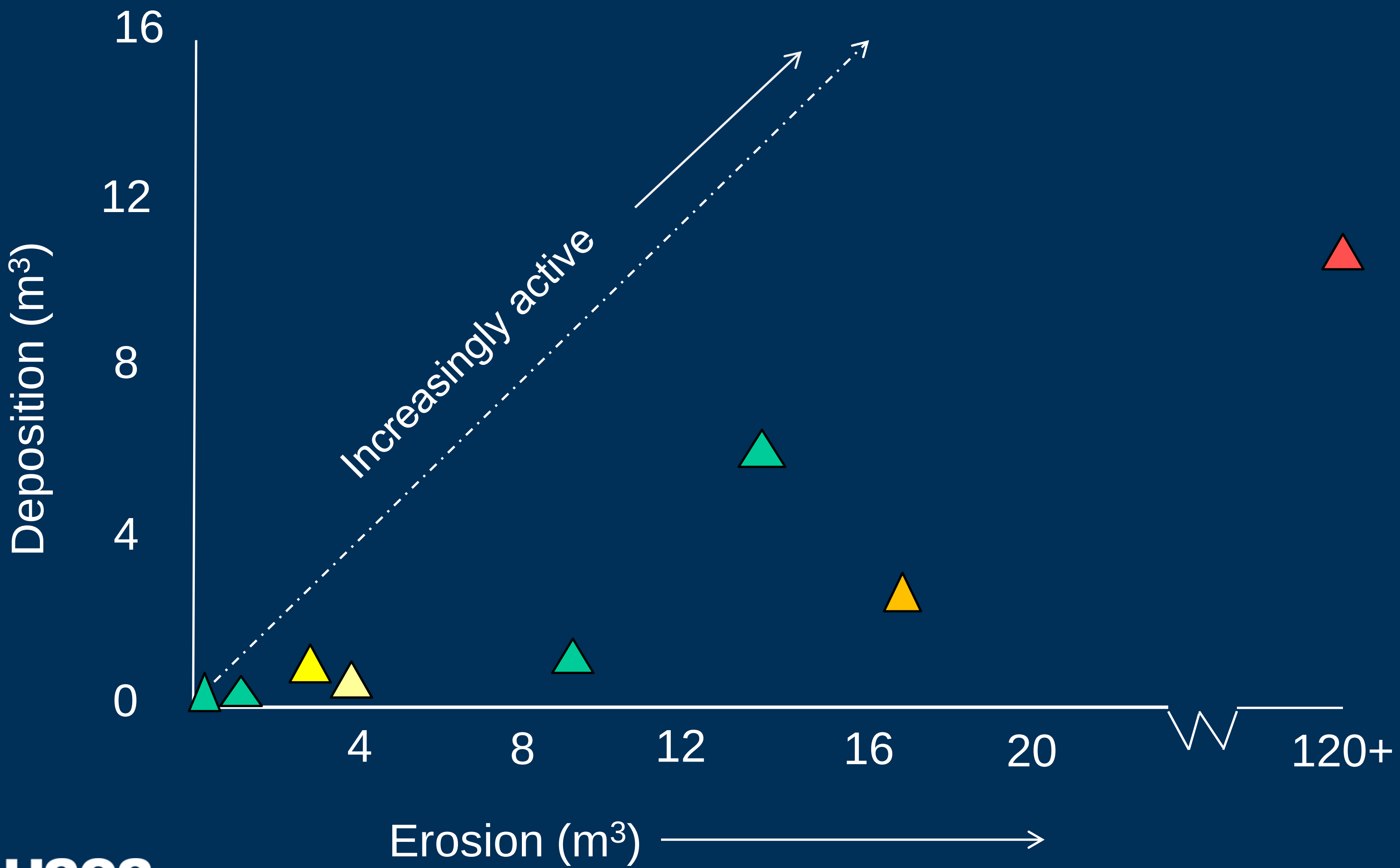


Measured Topographic Changes Sept. 2007 – Sept. 2010

Site number (Sept. 2007- 2010 monitoring period)	Area w/ measured erosion (m^2)	Area w/ measured deposition (m^2)	Total area modeled w/ change (percent)	Average (max.) height of erosion (cm)	Average (max.) height of deposition (cm)	Approx. volume of erosion (-) (m^3)	Approx. volume of depositio n (+) (m^3)
AZ:C:13:0006	27.0	8.8	2.8	15 (33)	9 (22)	-3.3	+0.8
AZ:C:13:0336	39.1	2.2	2.9	7 (27)	7 (15)	-3.6	+0.2
AZ:C:13:0099	103.0	22.5	19.6	12 (63)	12 (59)	-17.3	+2.8
AZ:C:13:0099 playa	3.6	0.4	0.1	7 (13)	6 (7)	-0.2	+0.02
AZ:C:13:0348 and AZ:C:13:0346	85.3	21.2	3.5	9 (28)	7 (13)	-8.6	+1.3
AZ:B:10:0225	254.2	81.3	28.7	22 (160)	13 (55)	-120.3	+11.2
AZ:G:03:0072 US	92.1	50.8	11.8	11 (52)	16 (60)	-13.8	+6.4
AZ:G:03:0072 DS	0	0	0	0 (0)	0 (0)	0	0

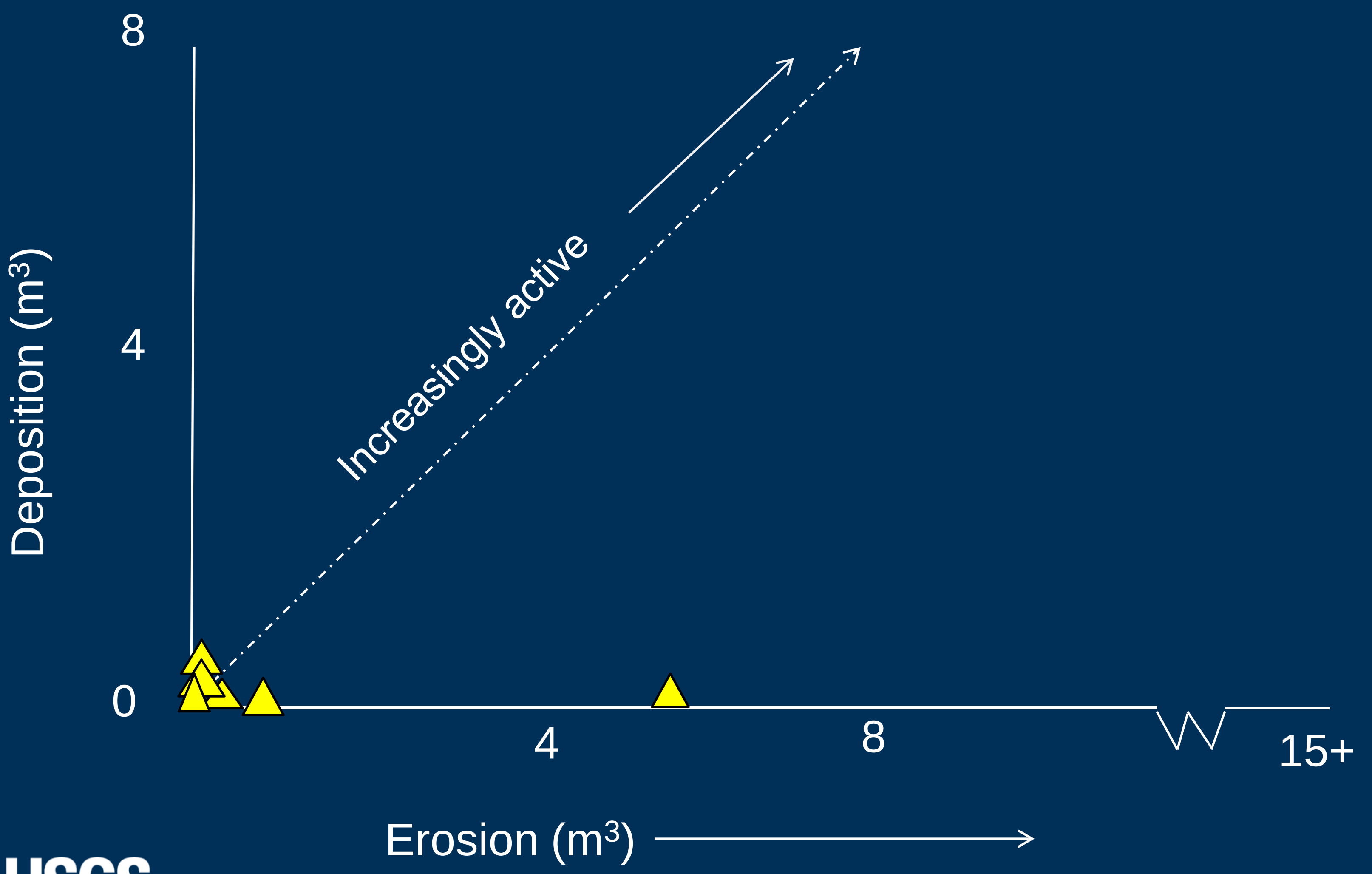
USGS

Volumetric Change : 2007-2010



USGS

Volumetric Change : Apr-Sept 2010



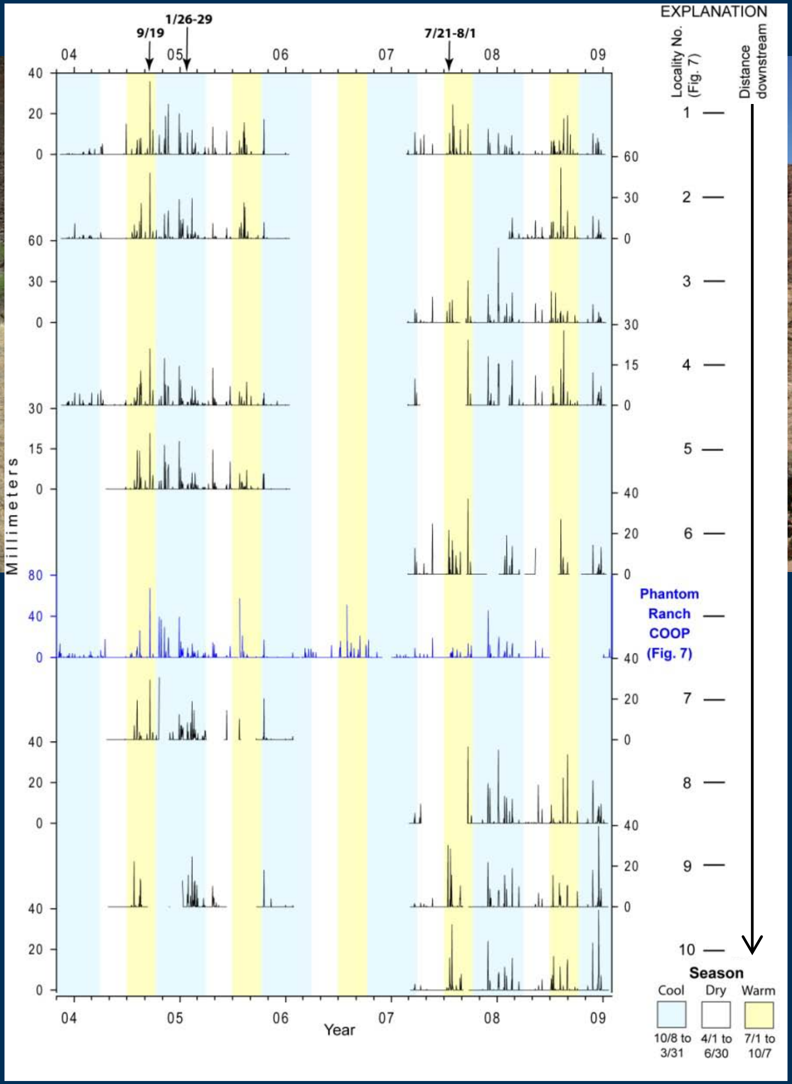
USGS

Measured Topographic Changes April 2010 – September 2010

Site number (April-Sept. 2010 monitoring period)	Area w/ measured erosion (m^2)	Area w/ measured deposition (m^2)	Total site area modeled w/change (percent)	Average (max.) height of erosion (cm)	Average (max.) height of deposition (cm)	Approx. volume of erosion (-) (m^3)	Approx. volume of deposition (+) (m^3)
AZ:C:05:0031	134.9	0	5.4	4 (30)	0 (0)	-5.7	0
AZ:C:13:0006	2.2	0	0.2	6 (16)	0 (0)	-0.1	0
AZ:C:13:0336	16.5	1.5	1.3	3 (9)	3 (5)	-0.6	+0.1
AZ:C:13:0099	0.4	2.3	0.4	4 (6)	5 (9)	-0.02	+0.1
AZ:C:13:0099 playa	0.02	0	0.001	5 (6)	0 (0)	-0.001	0
AZ:C:13:0321	13.9	0	10.0	4 (14)	0 (0)	-0.6	0

USGS

Phase I included R&D re: Weather (Tools & Methods; local variability)

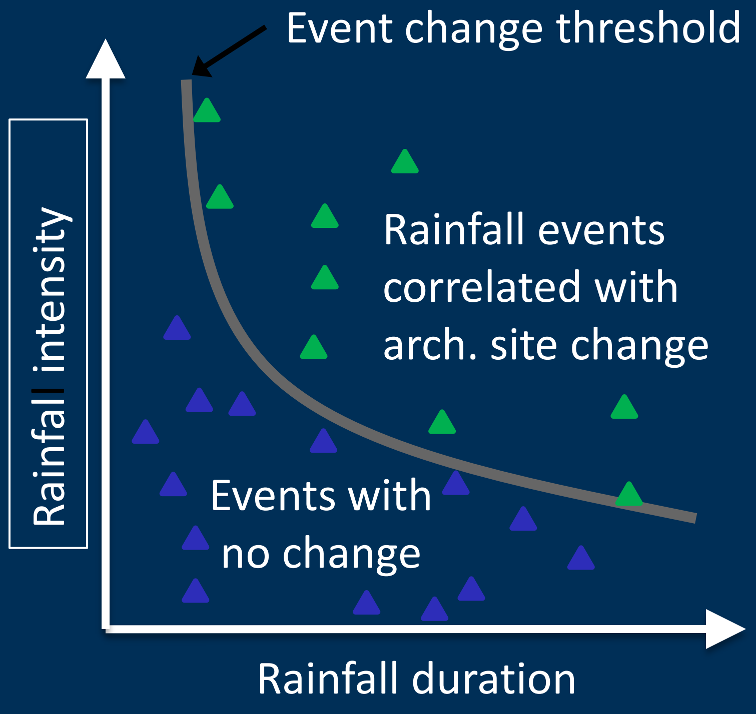


2007-2008:
Resolved technical issues
2008-2010:
Annual Data Reports
2011-2012:
Additional analysis

USGS

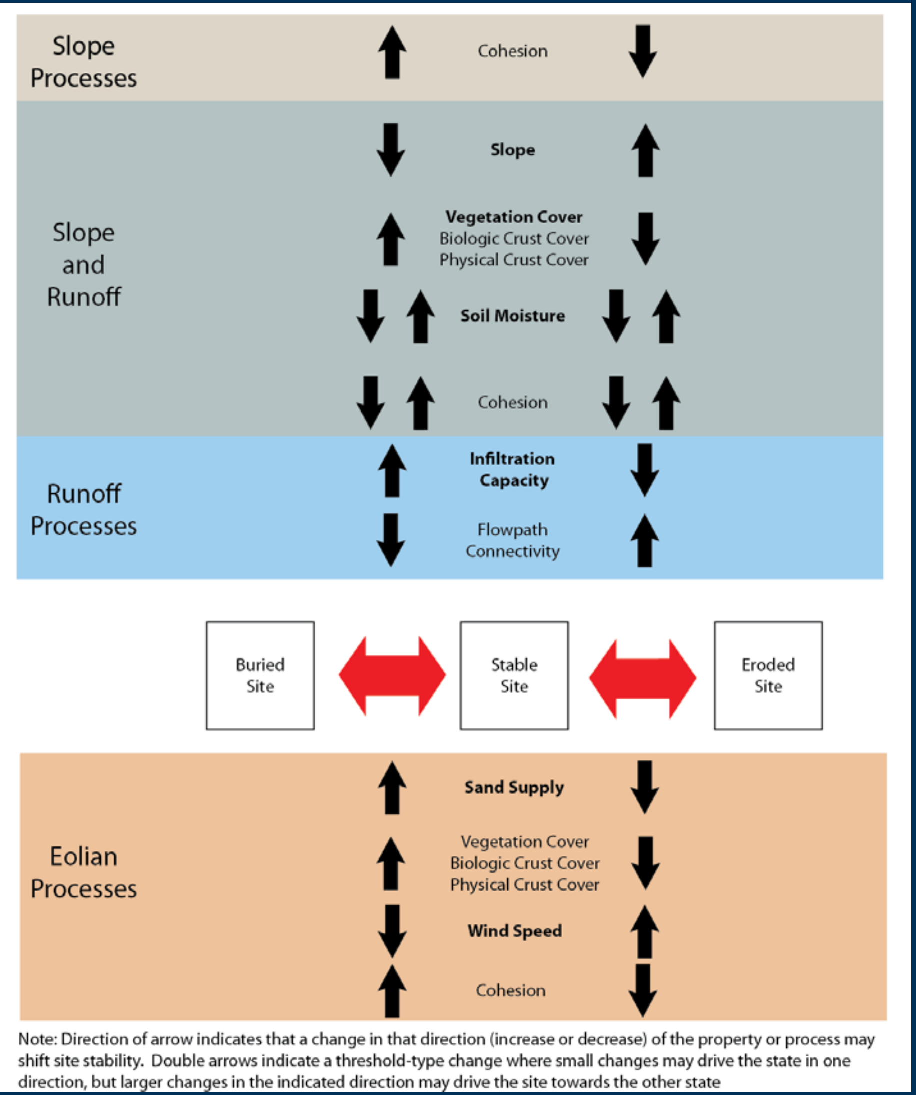
Development of empirical thresholds

- Combine weather and change detection data
- Develop plot of observed change with respective rainfall events
- This establishes background climatic event thresholds for arch. site change
- Thresholds are required to put potential dam effects in perspective



Next Steps re: Cultural R & D project

- Analyze measured change in relation to documented weather events (ongoing)
- Construct numerical geomorphological model using available data (lidar/ topographic, weather, soil infiltration data) (Ongoing)
- Use empirical data to calibrate model; evaluate model predictions relative to current conditions (ongoing)



FY2012 Work in Glen Canyon

FY2012 Glen Canyon Work Summary

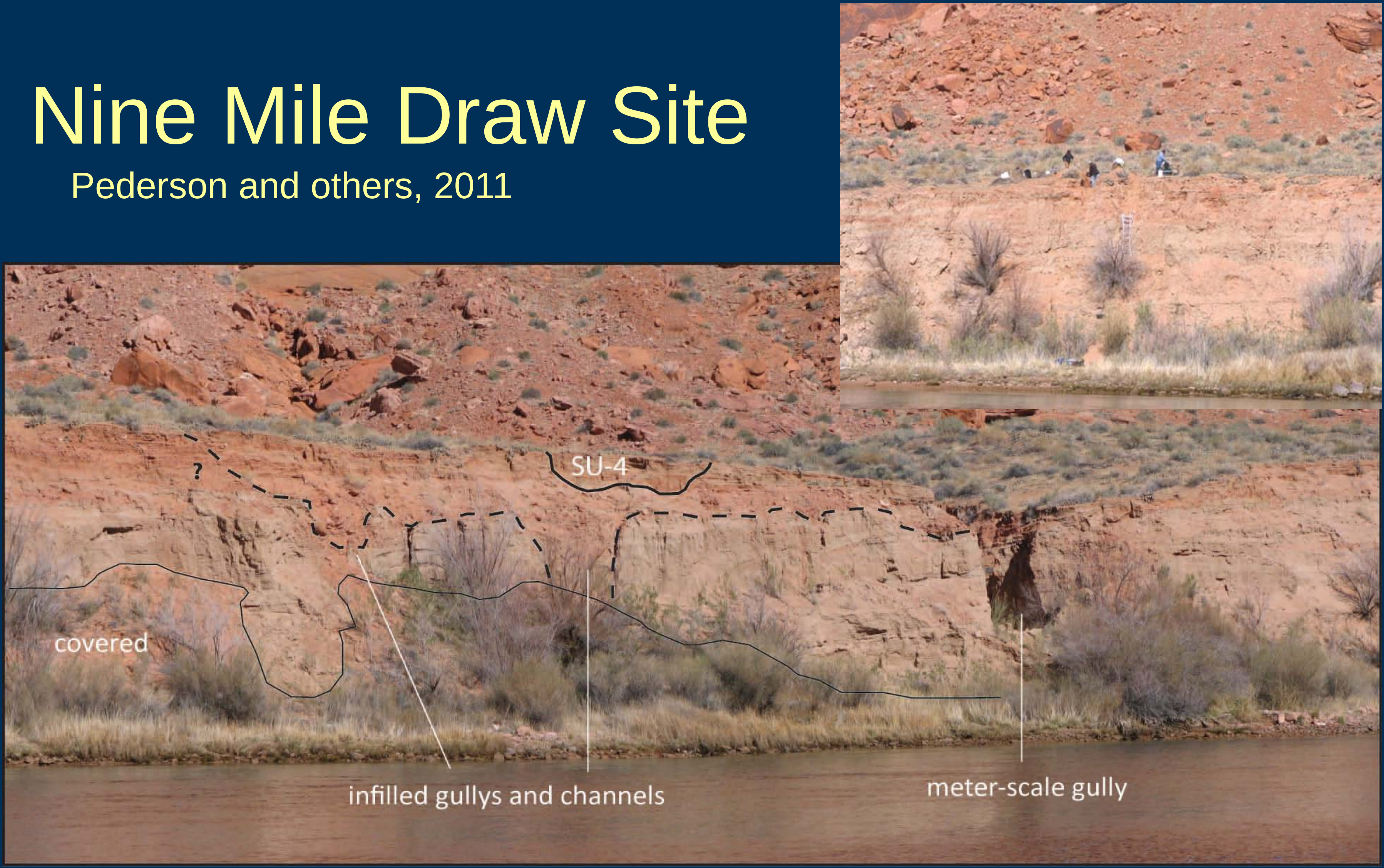
- **September 17-22, 2012**
  - Collected topographic surveys from 4 sites, plus surrounding terrain
  - Initiated mapping of geomorphic setting

- **November 2012**
  - Stationary cameras collected repeat photographs of -9 Mile cut bank during HFE
  - Documented 42,300 cfs shoreline (photos, survey)

USGS

Nine Mile Draw Site

Pederson and others, 2011



USGS

USU 288: ~2500 yr
USU 289: ~300 yr
SU-5
14C
F8
cal B.P. 2780-2400
ashy lens
USU 458: ~1500 yr
USU 355: ~3000 yr
USU 284: ~5000 yr
USU 283: ~800 yr
L
1 m

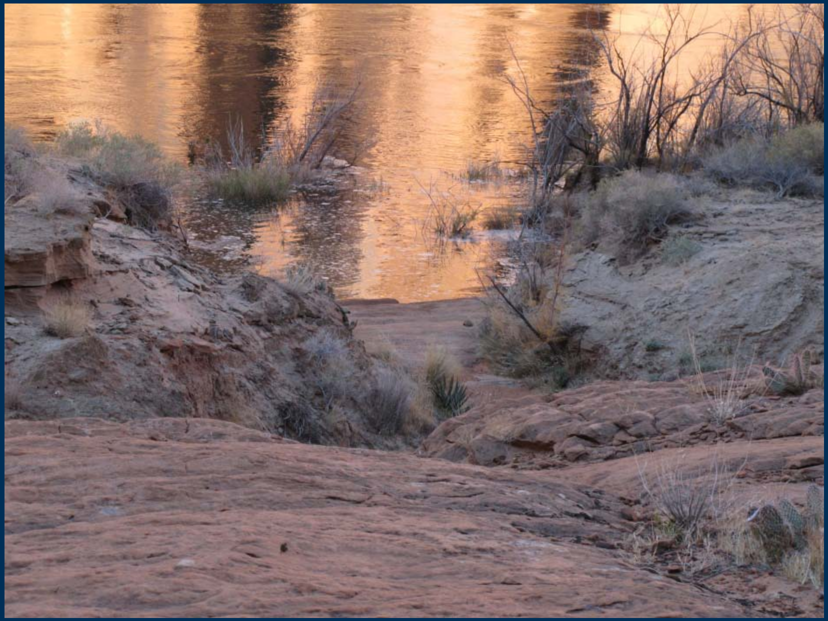
Sept 17-21, 2012

Baseline Topographic Data Collected for 4 Glen Canyon Sites & Surrounding Area

USGS

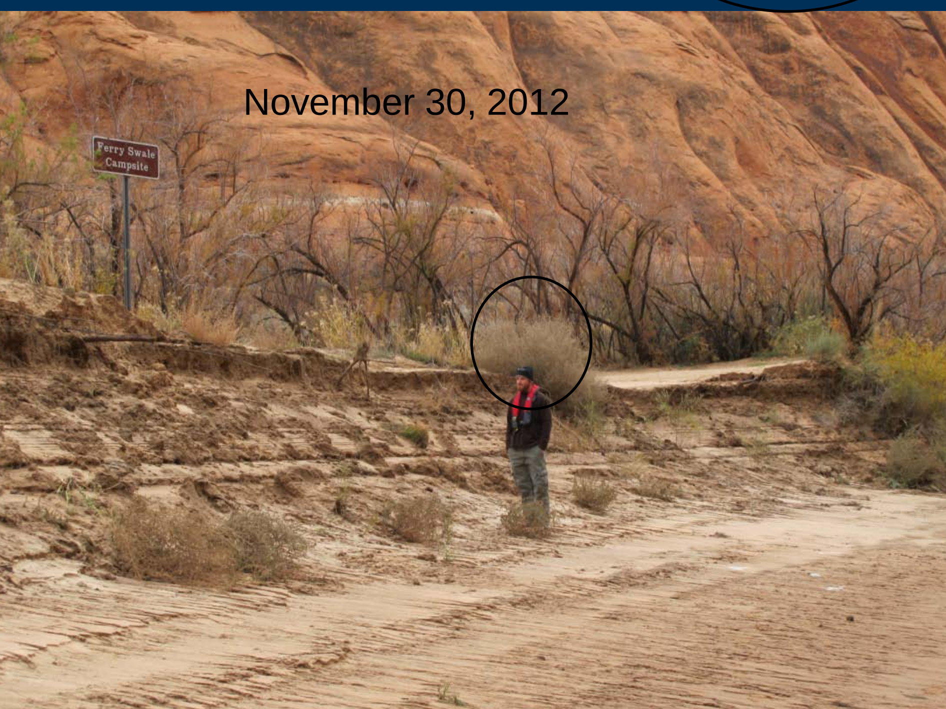
AZ C:2:75

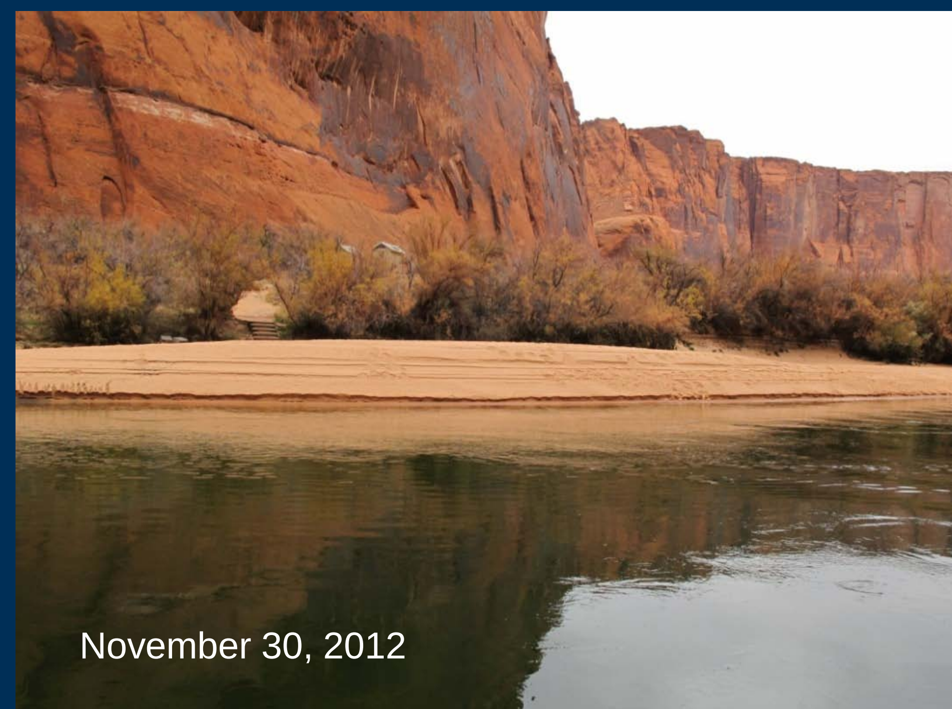
Level of inundation
by 2012 HFE




November 20, 2012


November 30, 2012

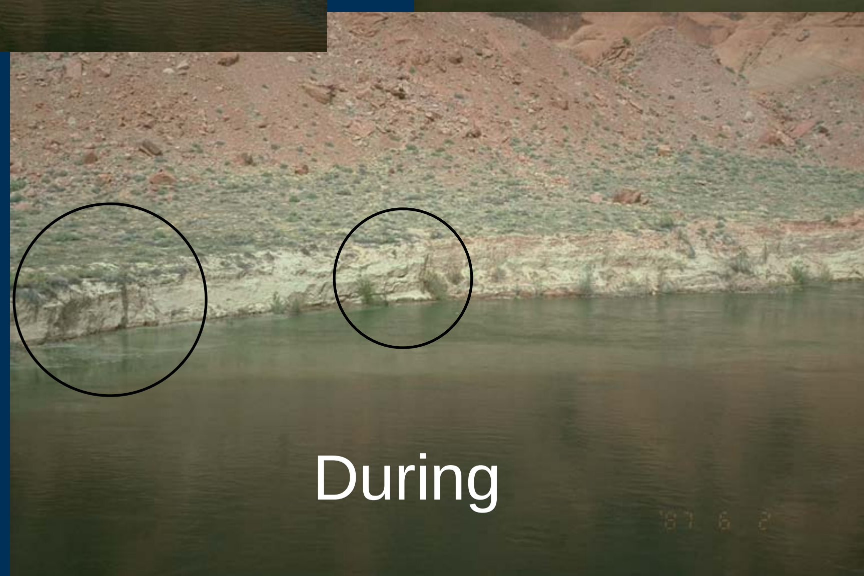

November 30, 2012
Ferry Swale
Campsite


November 30, 2012

Stationary Cameras (1996 HFE)

Before

After



During


Questions?