GULLY EROSION OF CULTURAL SITES

Joel Pederson,
Paul Petersen, Wally McFarlane
and ***GCMRC survey group***

I. Erosion Control

How do we mitigate it?

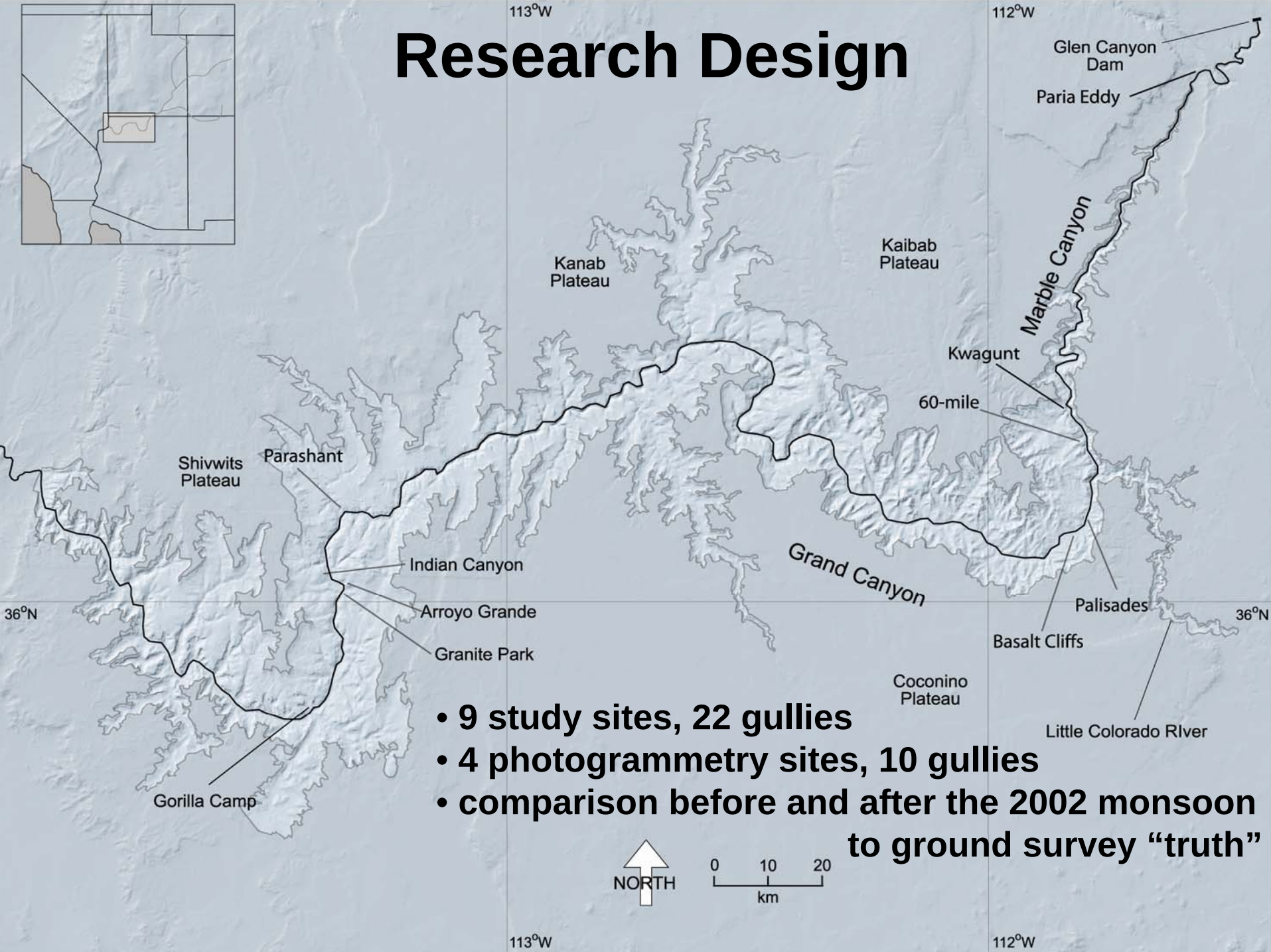
II. Photogrammetry

How do we monitor it?

needs = very l

III. Geomorphology

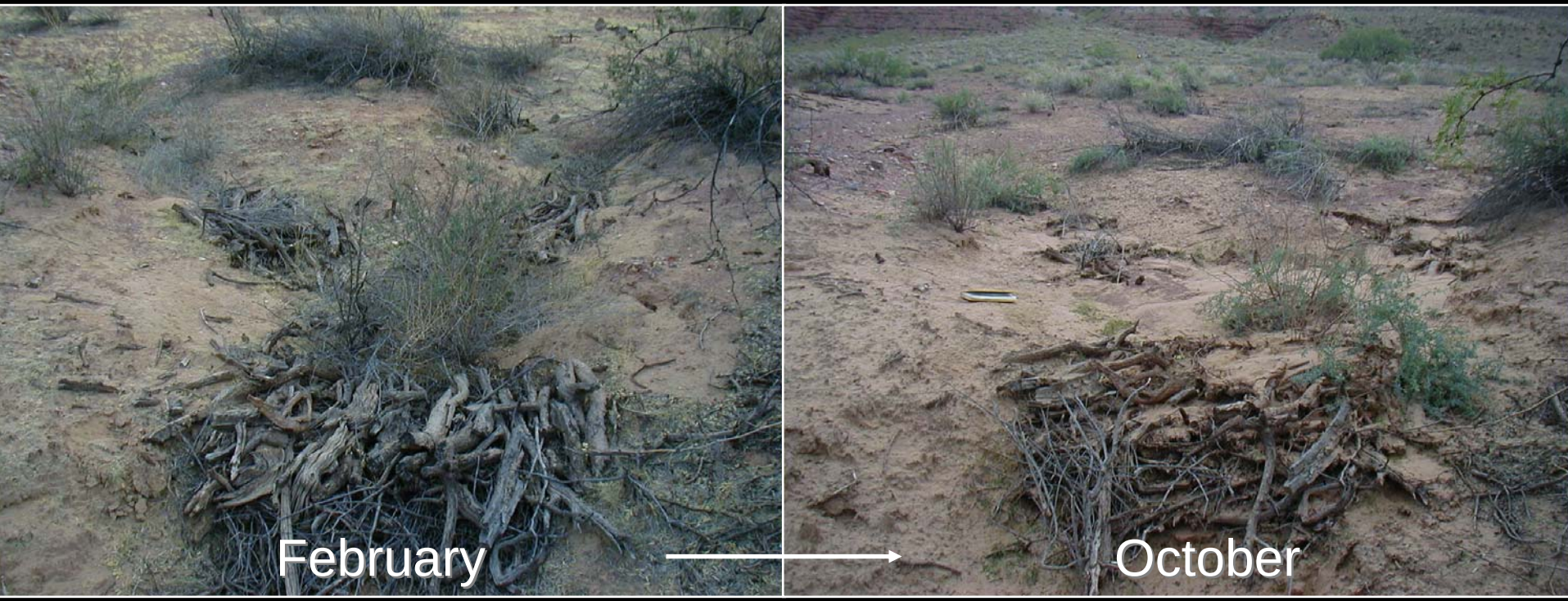
Why is it happening?


Research Design
113°W
112°W
Glen Canyon Dam
Paria Eddy
Kanab Plateau
Kaibab Plateau
Marble Canyon
Kwagunt
60-mile
Shivwits Plateau
Parashant
Indian Canyon
Grand Canyon
Arroyo Grande
Granite Park
Palisades
Basalt Cliffs
36°N
Coconino Plateau
Little Colorado RIver
Gorilla Camp
• 9 study sites, 22 gullies
• 4 photogrammetry sites, 10 gullies
• comparison before and after the 2002 monsoon to ground survey "truth"
NORTH
0 10 20
km

I. Erosion-Control Structures

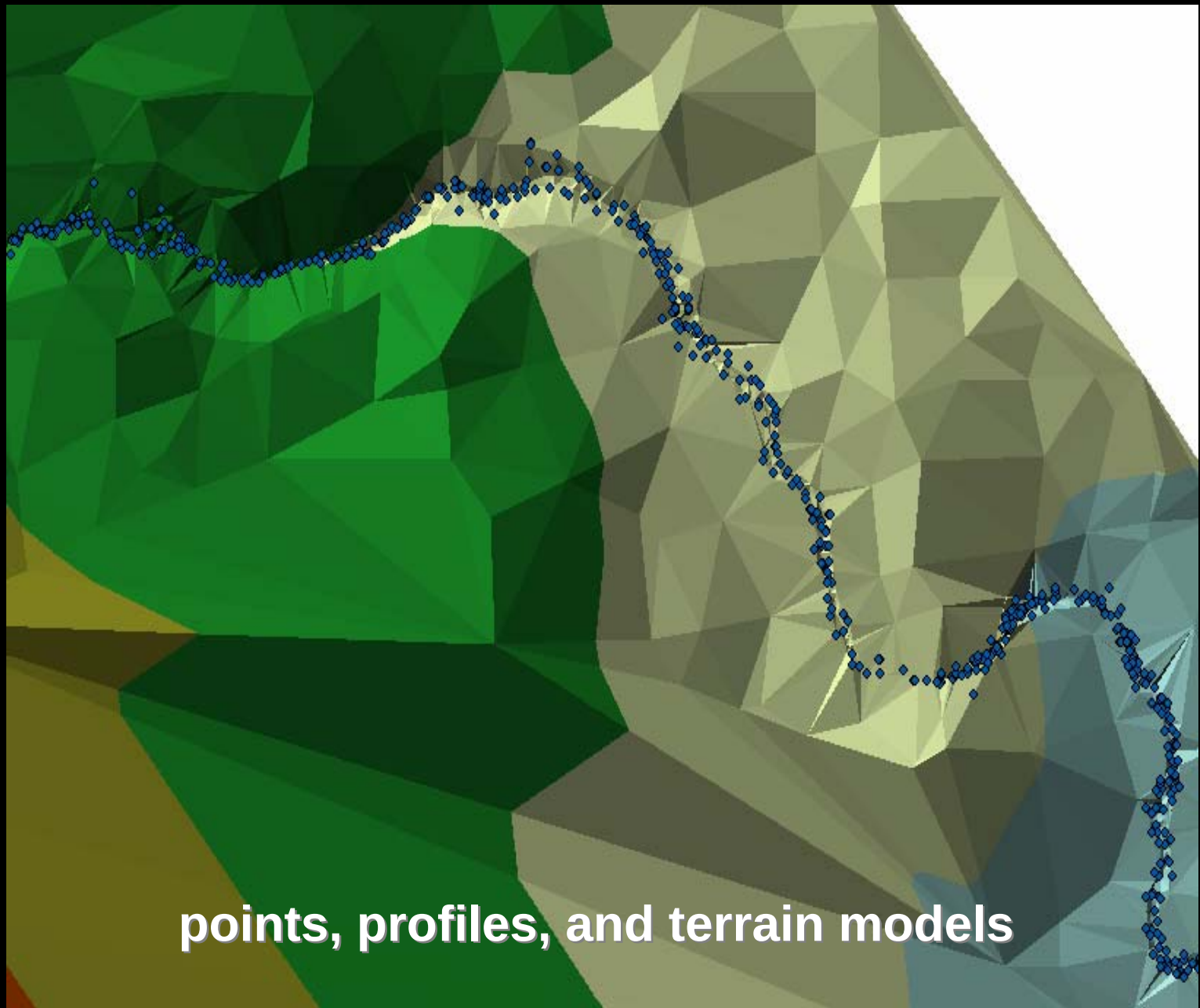
Are they effective?

after 1-year study = YES



- If maintained = damaged structures exacerbate erosion
- Wooden structures probably better than stone

II. Testing Photogrammetry for Monitoring



Results—Photogrammetric Vertical Accuracy

Interpolation (- to +)

Summary of February photogrammetry accuracy assessment for combined sites (m)

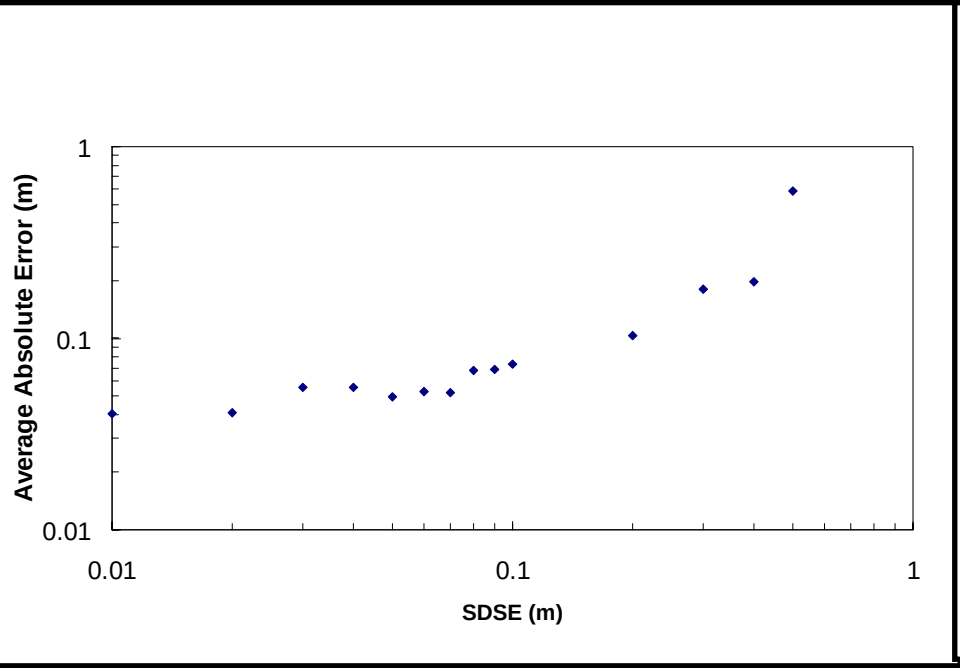
Site	n	mean	stdev	min (q_0)	q_1	median (q_2)	q_3	max (q_4)
Points	84	**0.07**	**0.07**	0.00	0.03	0.04	0.08	0.48
Profiles	983	**0.06**	**0.06**	0.00	0.02	0.04	0.09	0.45
Cross sections	207	**0.09**	**0.09**	0.00	0.04	0.07	0.13	0.44
Semi-auto TINs	4936	**0.08**	**0.11**	0.00	0.02	0.05	0.10	1.22
Manual TINs	5444	**0.09**	**0.10**	0.00	0.03	0.06	0.11	0.97
DEMs	20230	**0.10**	**0.10**	0.00	0.03	0.07	0.13	2.49

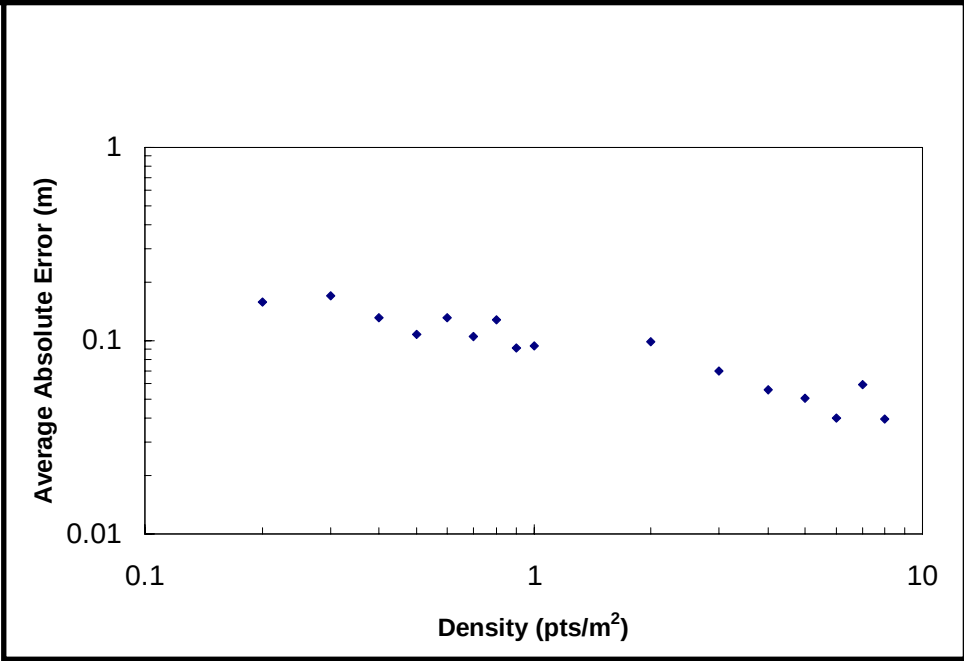
Summary of October photogrammetry accuracy assessment for combined sites (m)

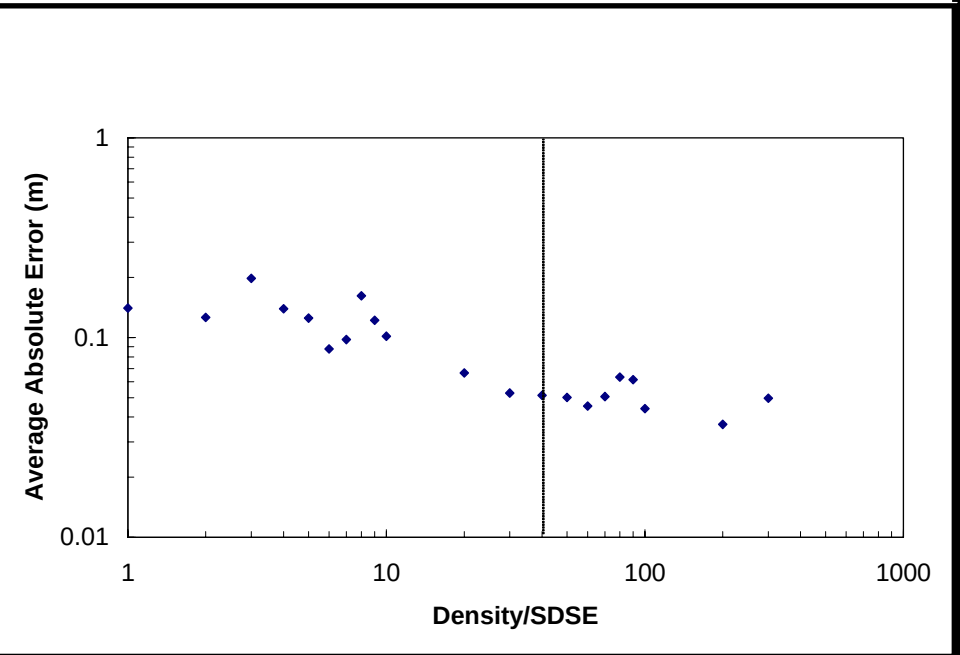
Site	n	mean	stdev	min (q_0)	q_1	median (q_2)	q_3	max (q_4)
Points	77	**0.08**	**0.08**	0.00	0.02	0.05	0.11	0.45
Profiles	983	**0.09**	**0.07**	0.00	0.04	0.07	0.12	0.59
Cross sections	207	**0.09**	**0.07**	0.00	0.03	0.06	0.14	0.35
Semi-auto TINs	3636	**0.10**	**0.10**	0.00	0.03	0.08	0.13	1.33
Manual TINs	207	**0.10**	**0.10**	0.00	0.03	0.07	0.12	0.77
DEMs	19424	**0.10**	**0.11**	0.00	0.03	0.07	0.13	2.16

Interpolation (- to +)

Results—GIS Error Analysis



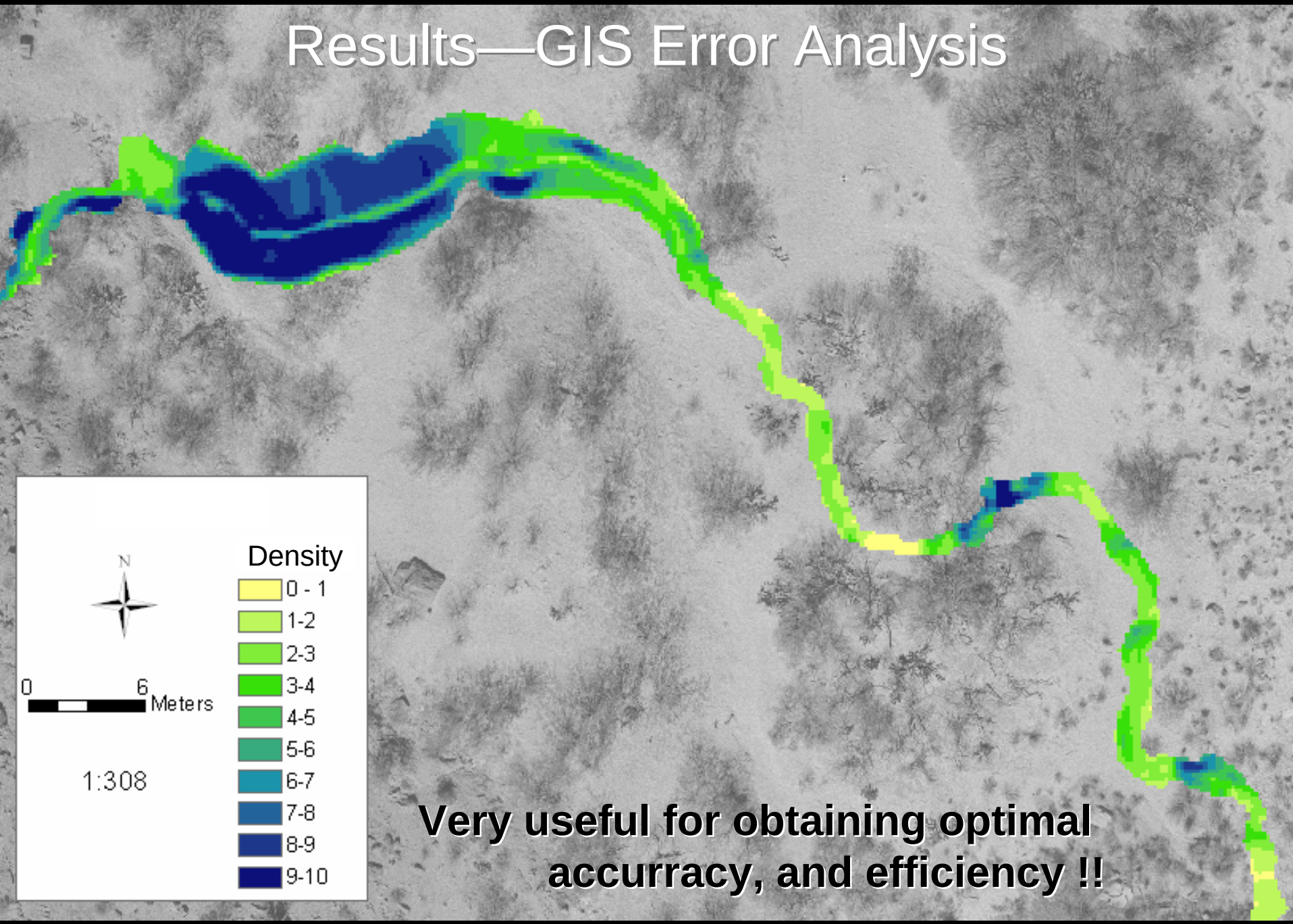




Accuracy of photogrammetry varies with:
1) Photogrammetric point density
2) Topographic ruggedness (SDSE)

when density/SDSE = ~40,
average error = ~5-7 cm

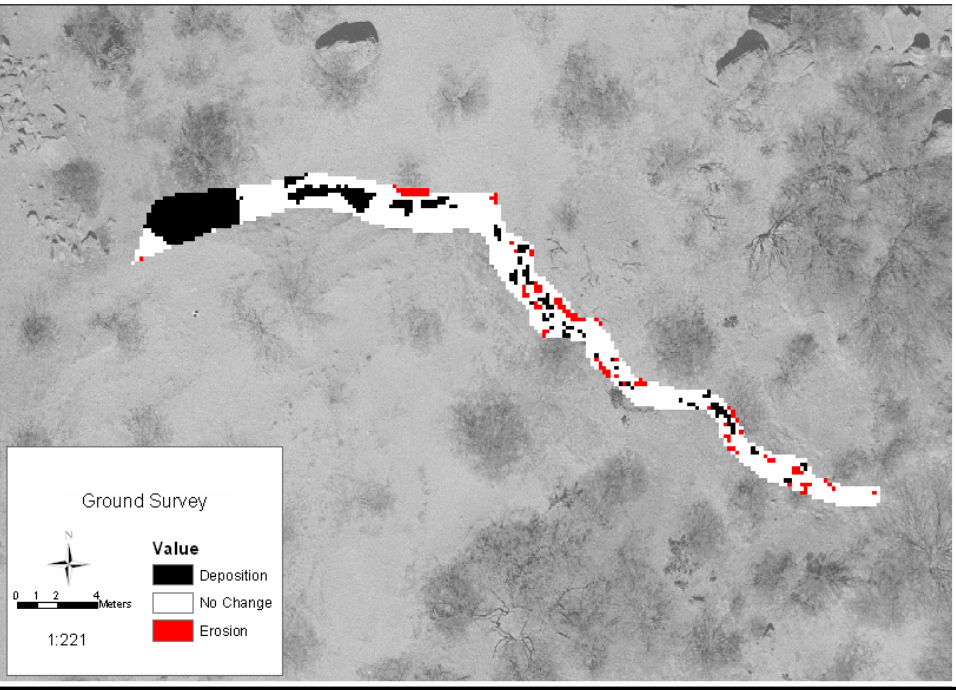
Results—GIS Error Analysis

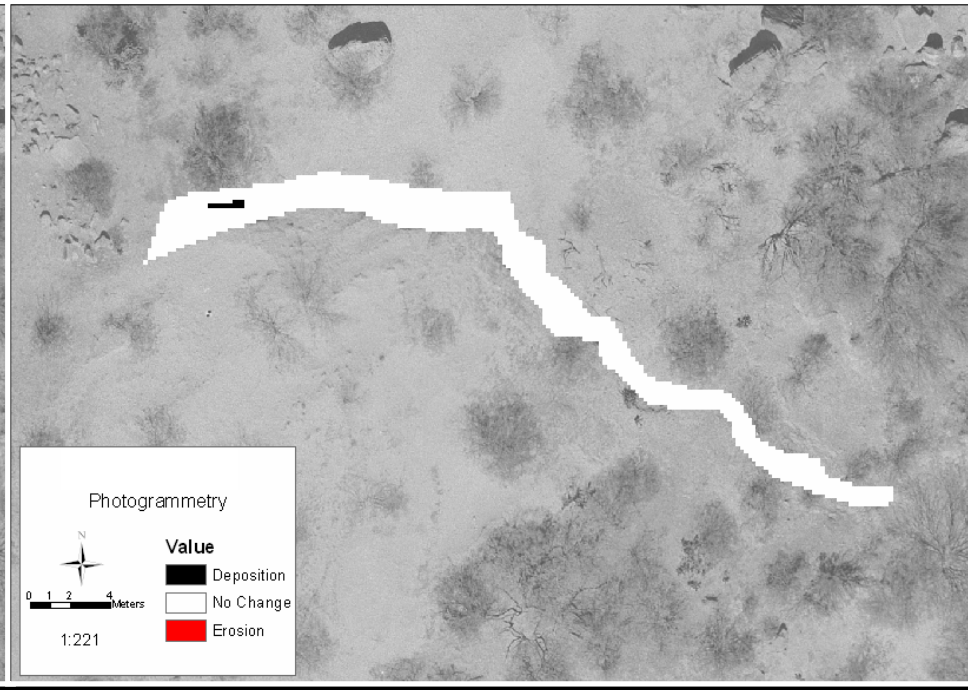


Very useful for obtaining optimal accurracy, and efficiency !!

Results—Change Detection

propagated error between two datasets = ~20 cm
best likely at this photographic scale = ~15 cm



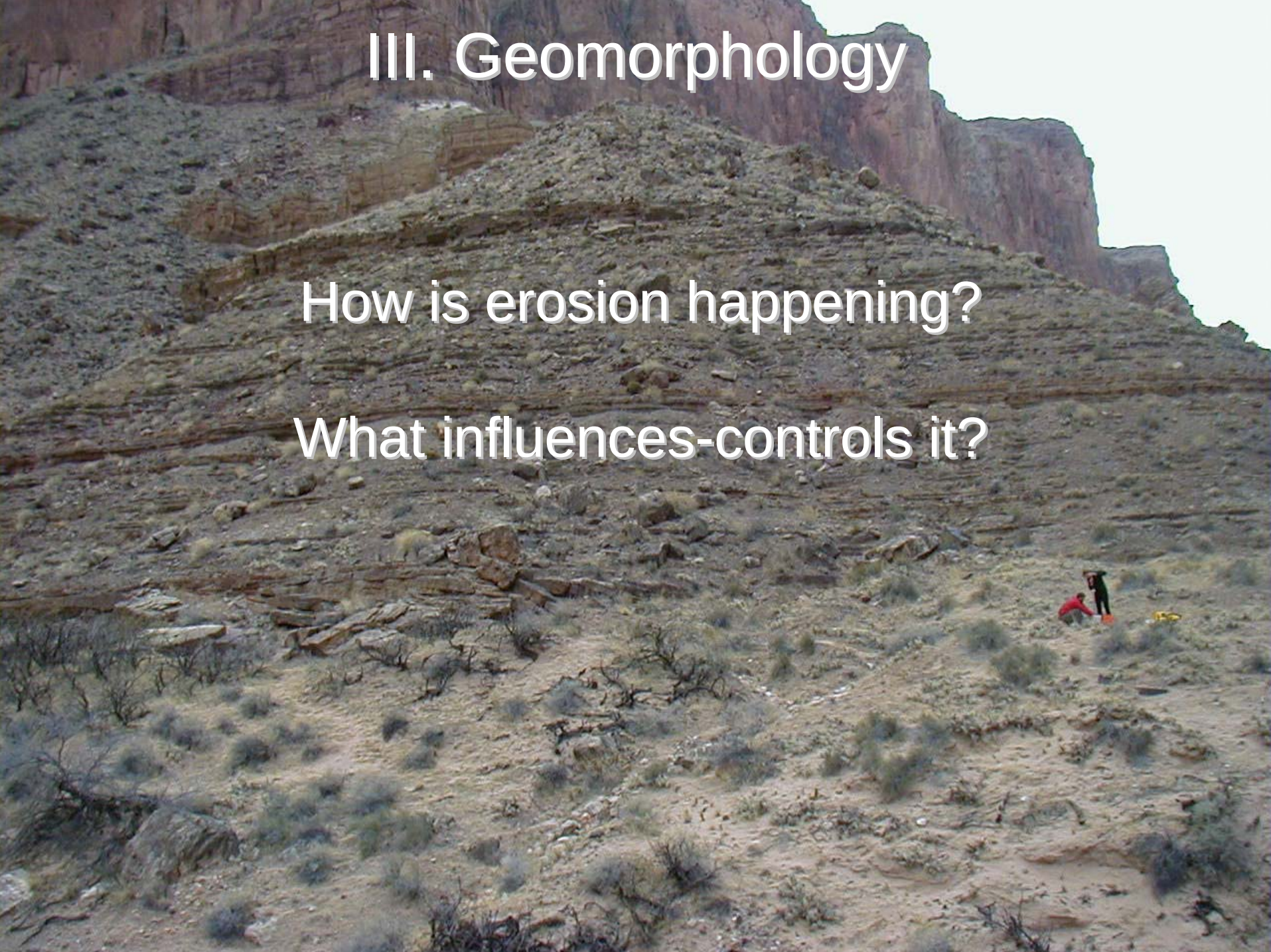


Conclusion: Photogrammetry not yet good enough

~10 cm of observed change over study period

THE EOLIAN QUESTION:

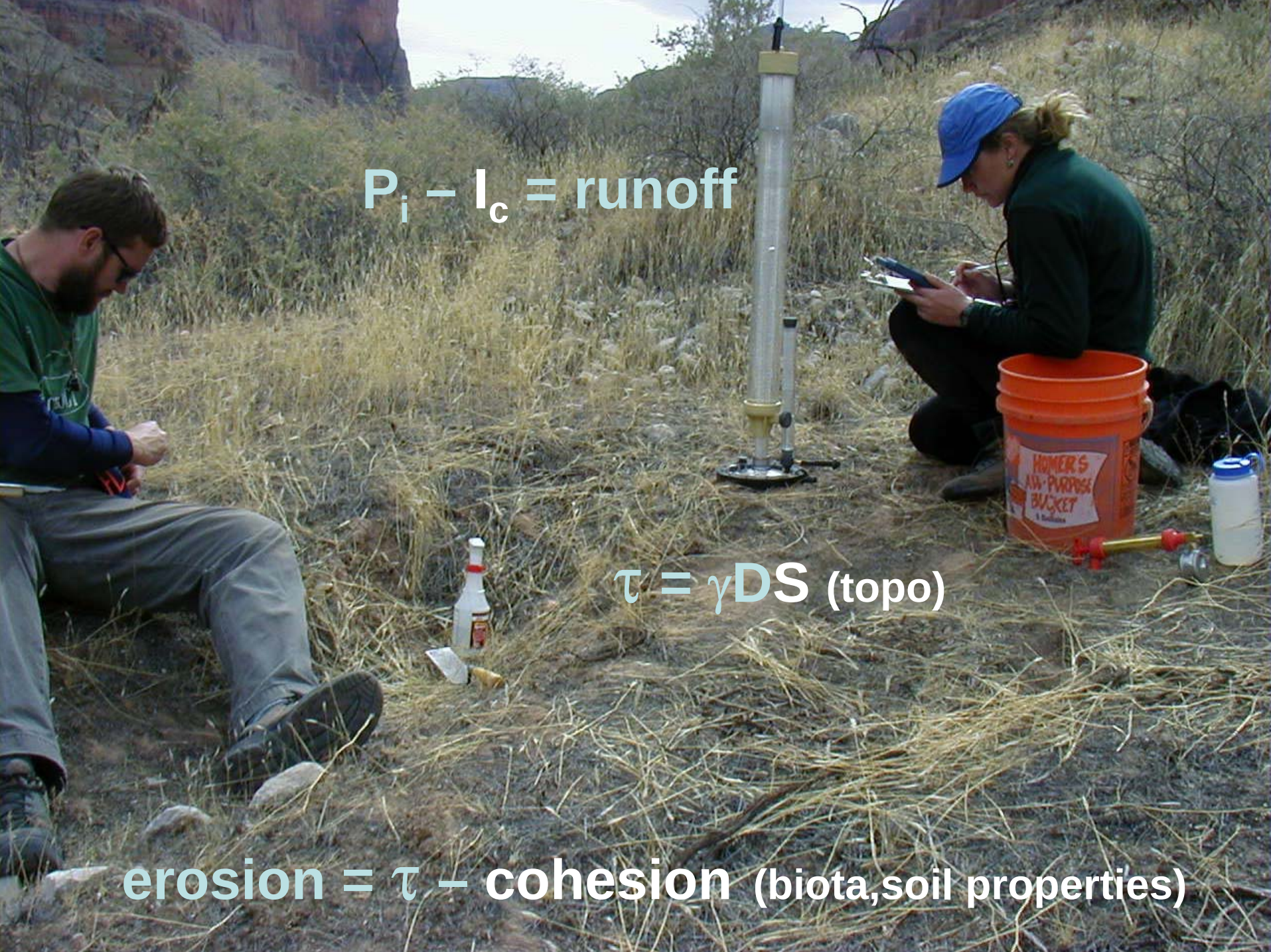
Are we seriously suggesting that the pre-dam state was a dynamic equillibrium between gullying and eolian infilling?



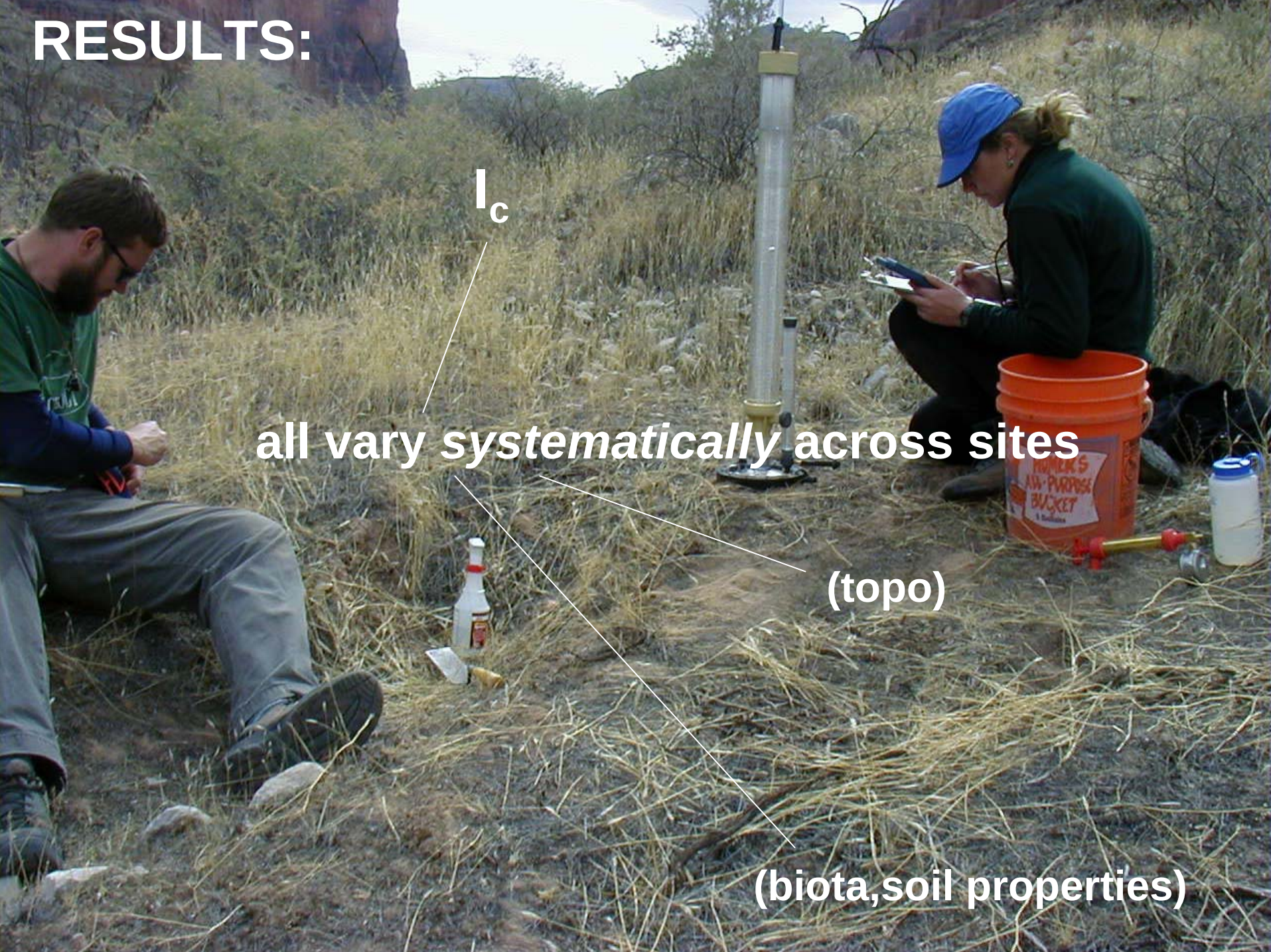
III. Geomorphology

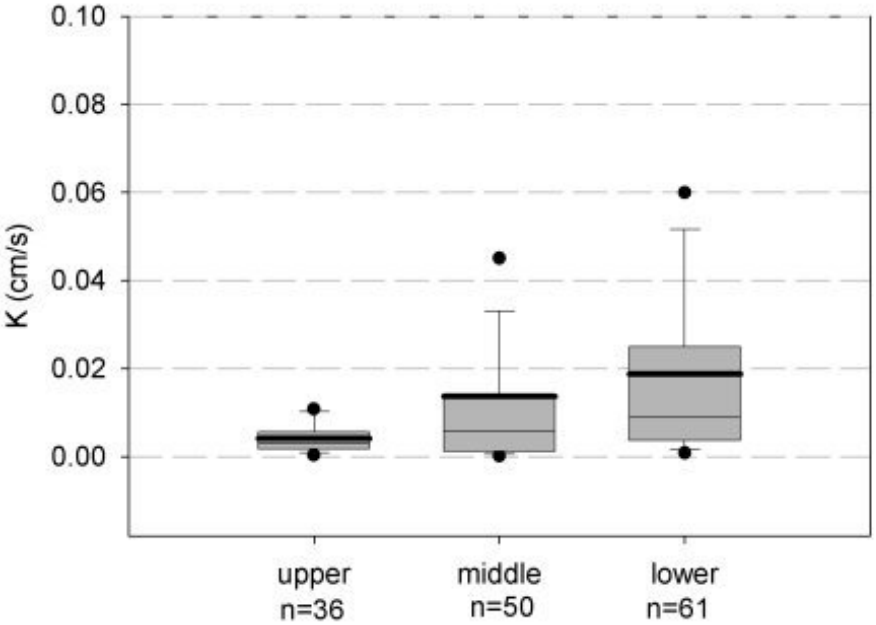
How is erosion happening?

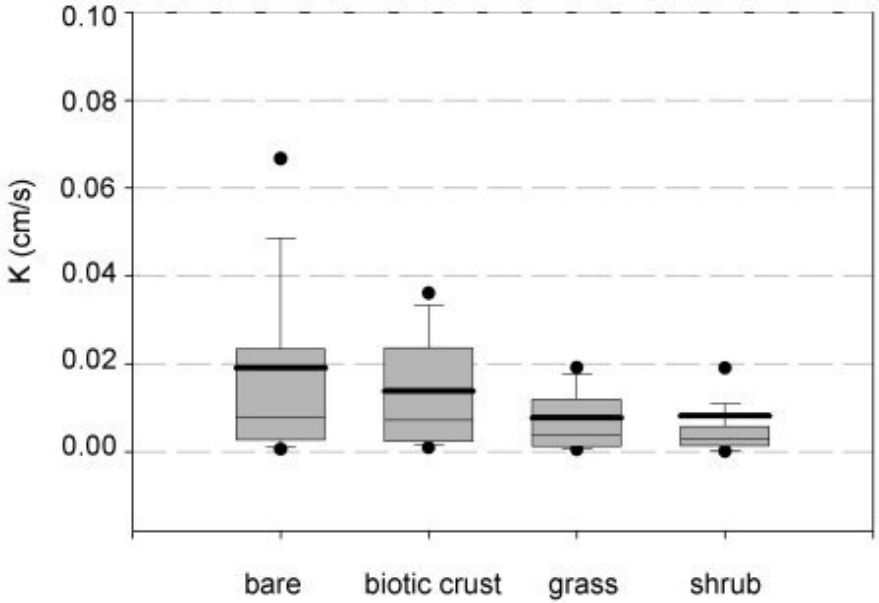
What influences-controls it?

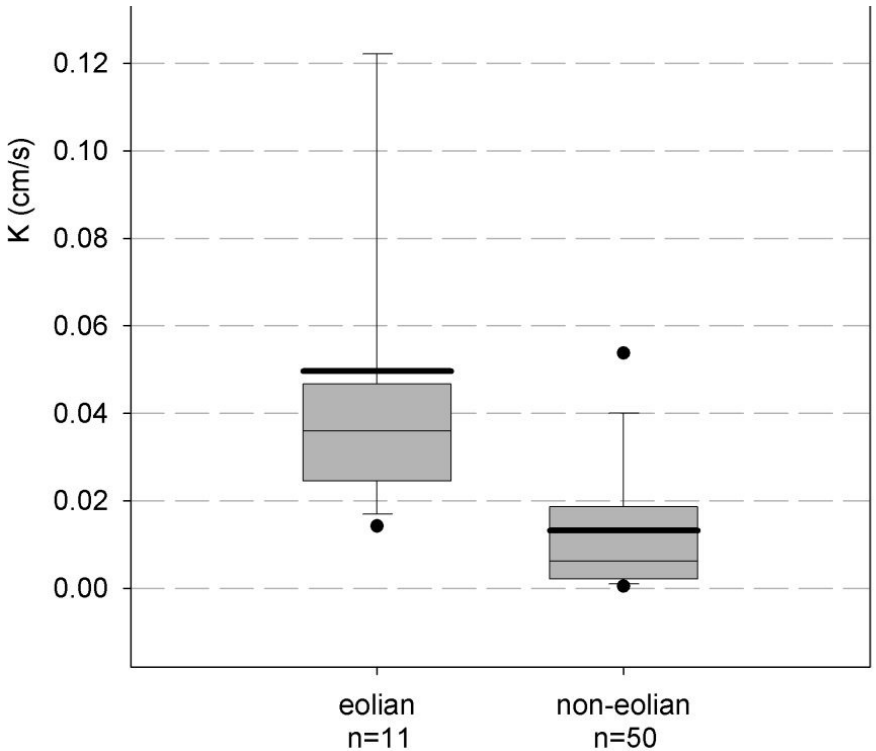

$P_i - I_c$ = runoff
$\tau = \gamma DS$ (topo)
erosion = τ – cohesion (biota,soil properties)

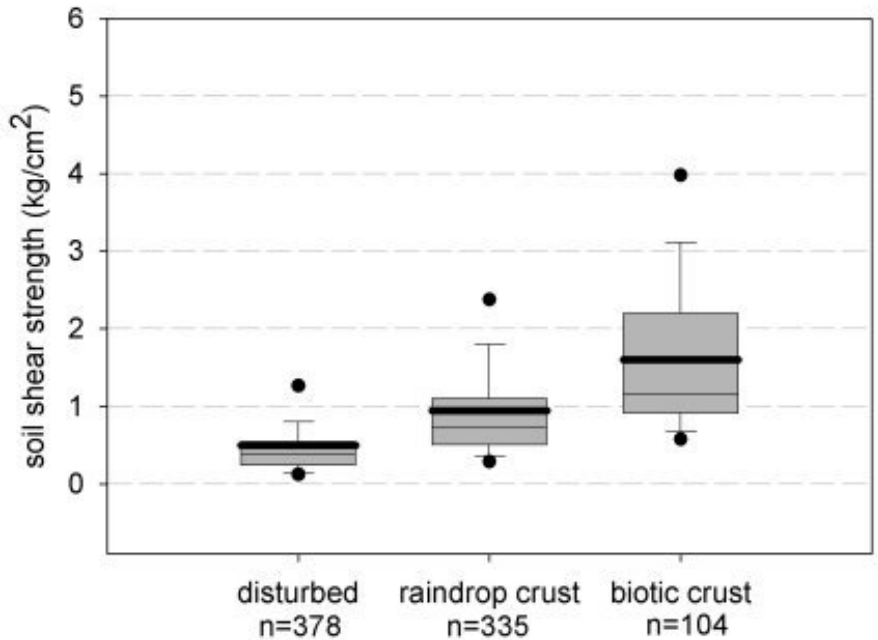
RESULTS:


I_c
all vary *systematically* across sites
(topo)
(biota,soil properties)


0.10
0.08
0.06
0.04
0.02
0.00
K (cm/s)
upper
n=36
middle
n=50
lower
n=61

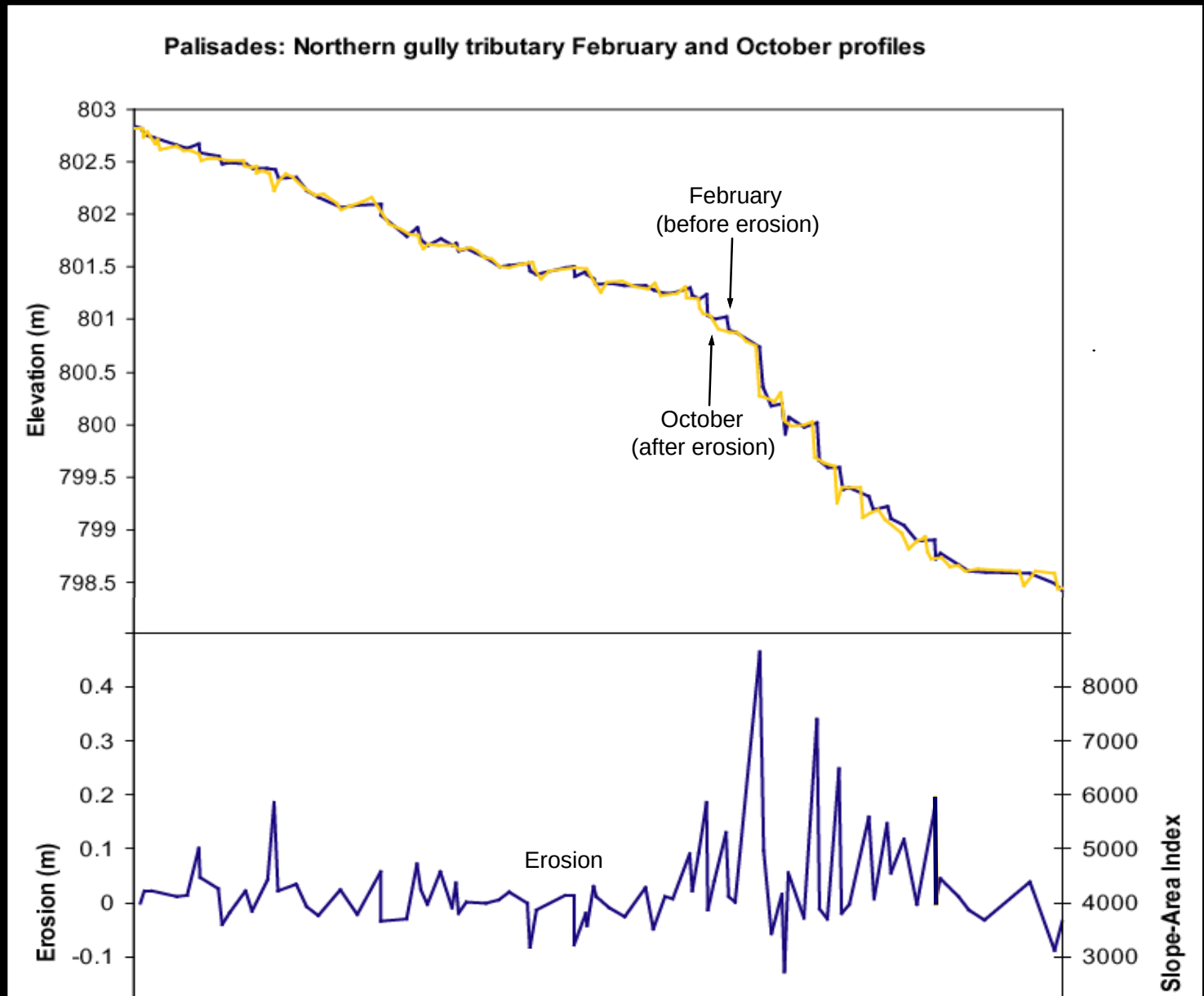

0.10
0.08
0.06
0.04
0.02
0.00
K (cm/s)
bare
biotic crust
grass
shrub

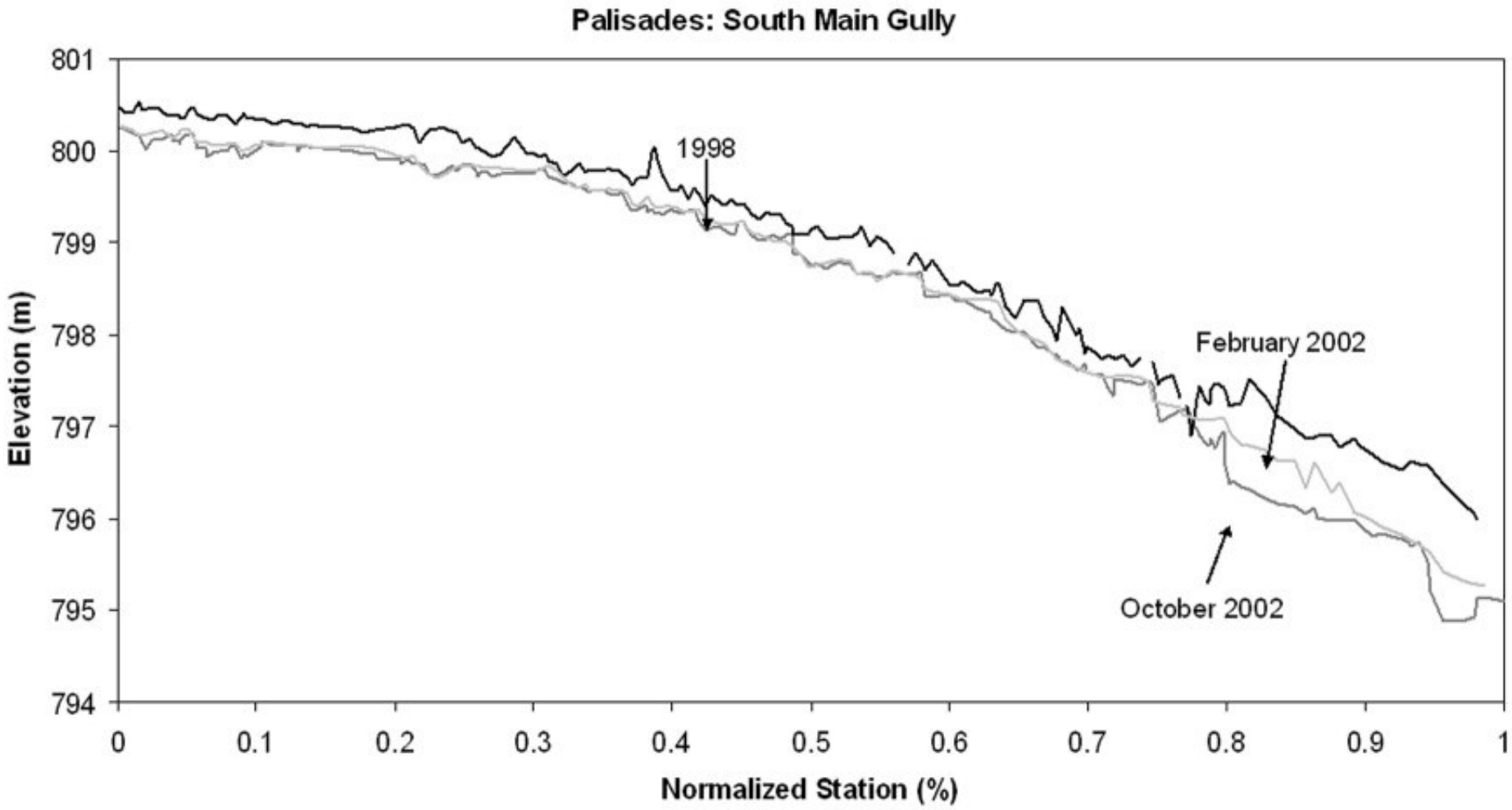

0.12
0.10
0.08
0.06
0.04
0.02
0.00
K (cm/s)
eolian
n=11
non-eolian
n=50

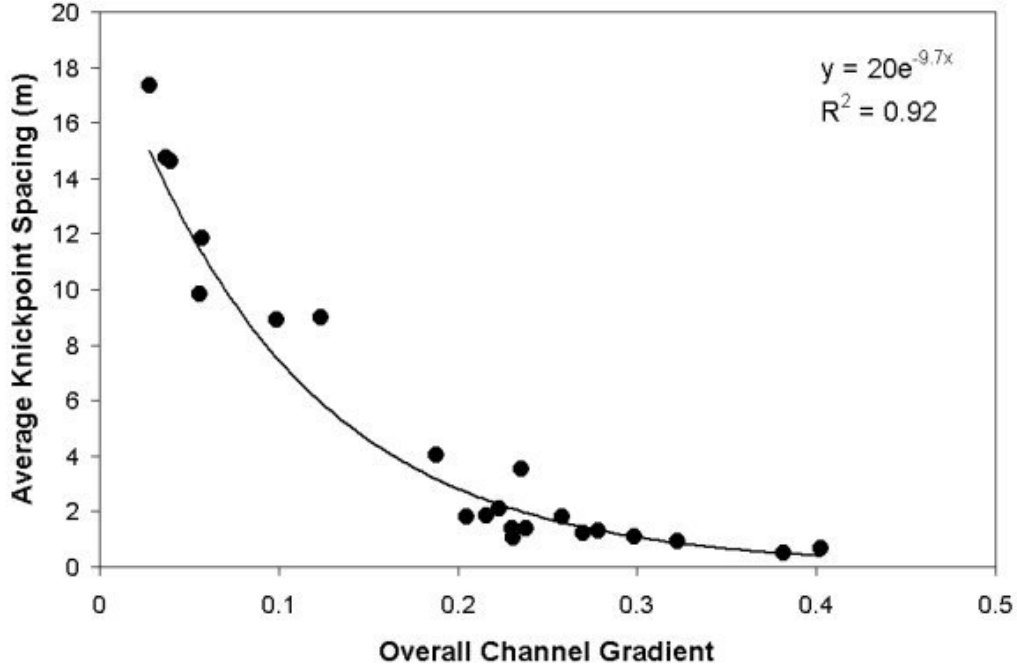

6
5
4
3
2
1
0
soil shear strength (kg/cm2)
disturbed
n=378
raindrop crust
n=335
biotic crust
n=104

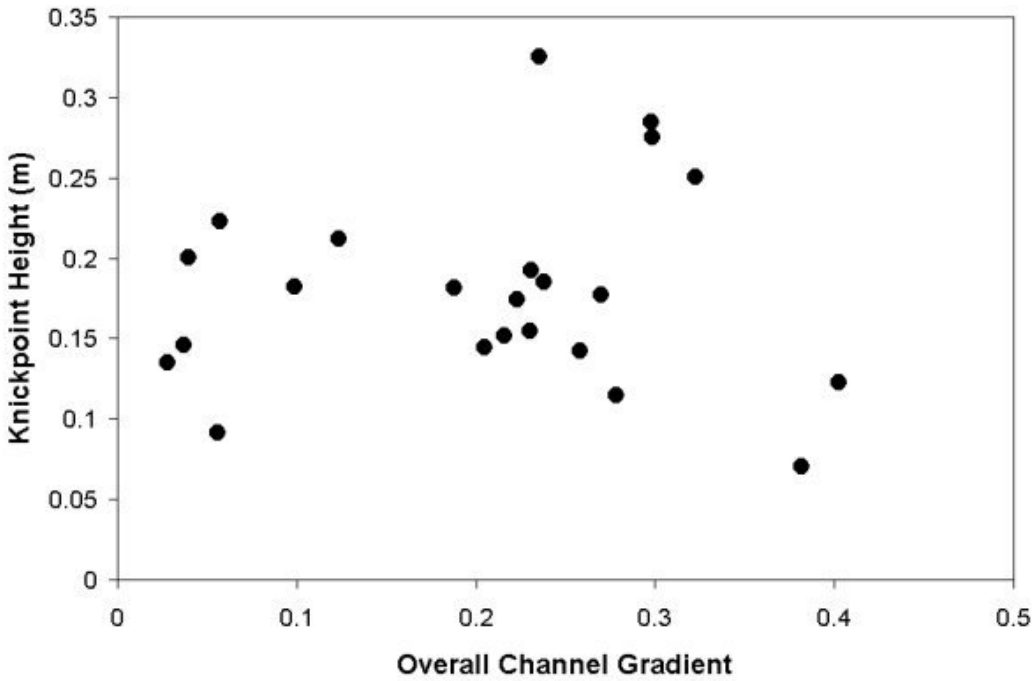

Palisades = not normal

erosion, knickpoint formation, and checkdam failure correlate with high gradient

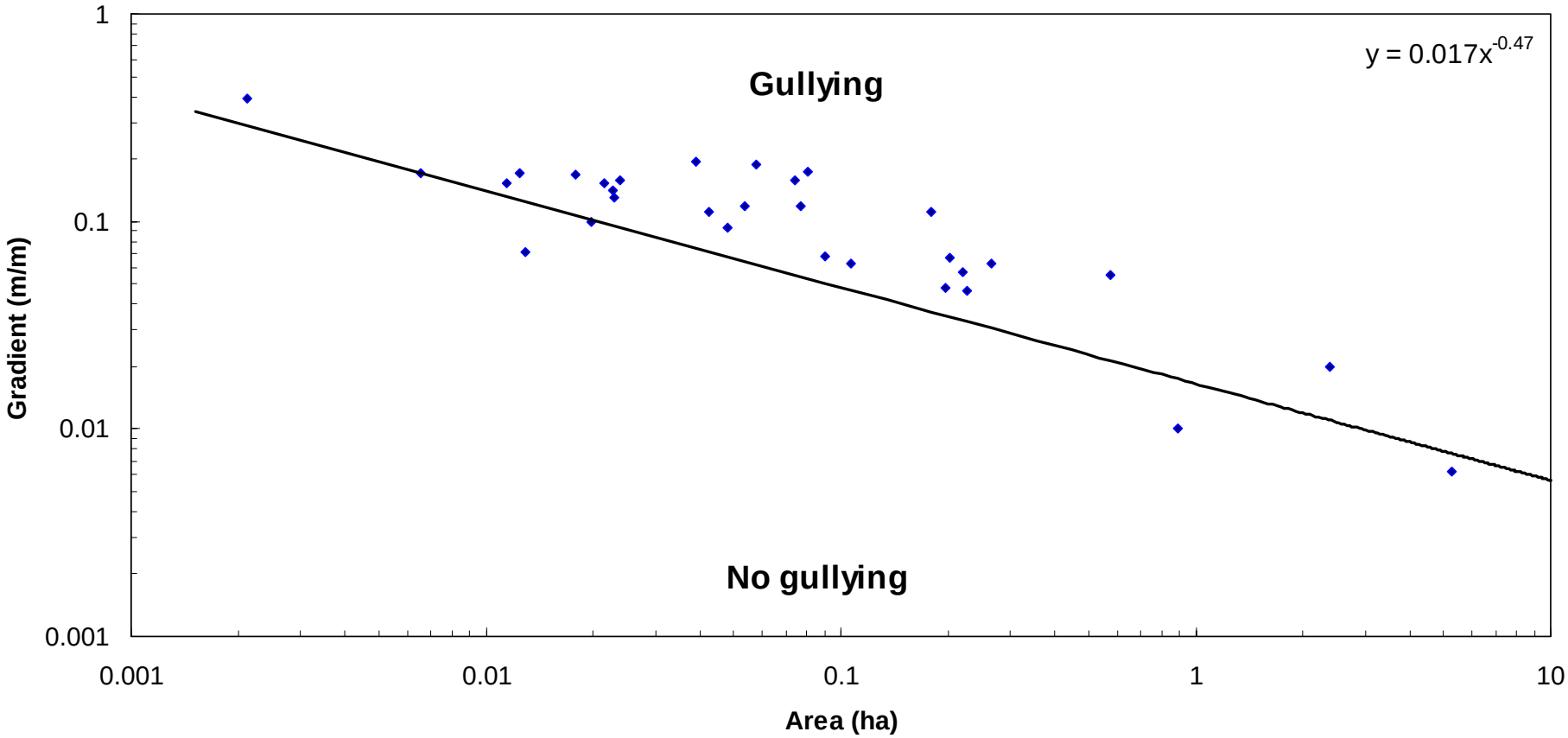



Palisades: South Main Gully
801
800
799
798
797
796
795
794
Elevation (m)
1998
February 2002
October 2002
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Normalized Station (%)

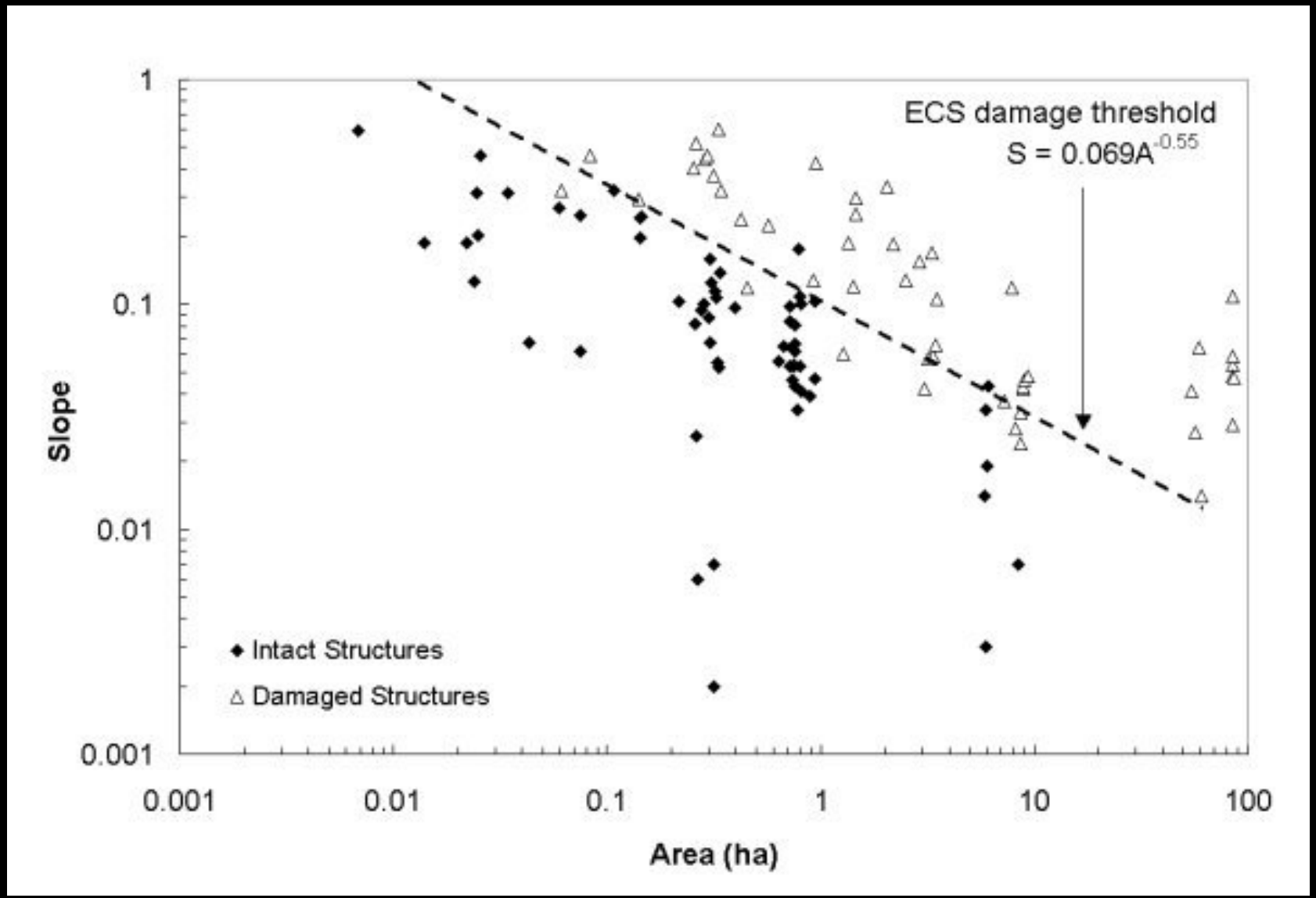

y = 20e-9.7x
R2 = 0.92
Average Knickpoint Spacing (m)
Overall Channel Gradient
0
2
4
6
8
10
12
14
16
18
20
0
0.1
0.2
0.3
0.4
0.5


Knickpoint Height (m)
Overall Channel Gradient
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0
0.1
0.2
0.3
0.4
0.5

slope-area erosion threshold

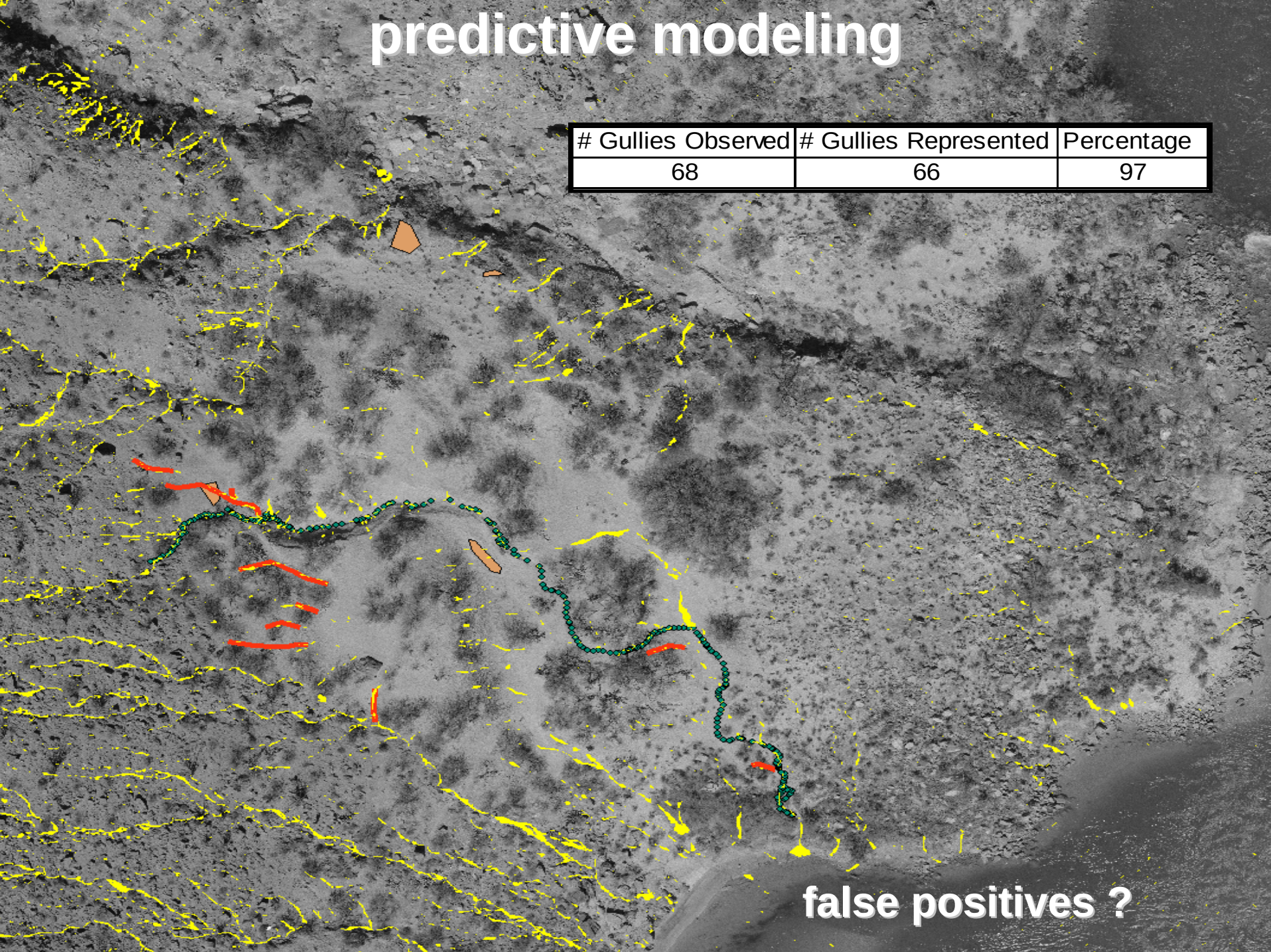


slope-area erosion threshold



predictive modeling

# Gullies Observed	# Gullies Represented	Percentage
68	66	97



false positives ?

Recommendations

- **Complete empirical dataset to understand geomorphic processes**

- **Take the next step in numerical modeling for management and to understand controls on erosion**