Archeological Sites and the Small Catchment Geomorphic System, Grand Canyon: a Model

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“Everything should be made as simple as possible, but not simpler”

-Albert Einstein, physicist, 1977

oh…and special thanks to:

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Problem

Ancient archeological sites are eroding for various reasons. How do we monitor, predict, and mitigate this problem?

Answer

Developa geomorphic model that predicts erosion of Colorado River terraces that contain the archaeological resources.

Develop a model for the small catchment geomorphic system

1. Determine geomorphic context.

   Where are archeological sites and what is their geomorphic context?

2. Fill knowledge gap.

   What causes erosion and deposition of sandy terraces containing archeologic sites?

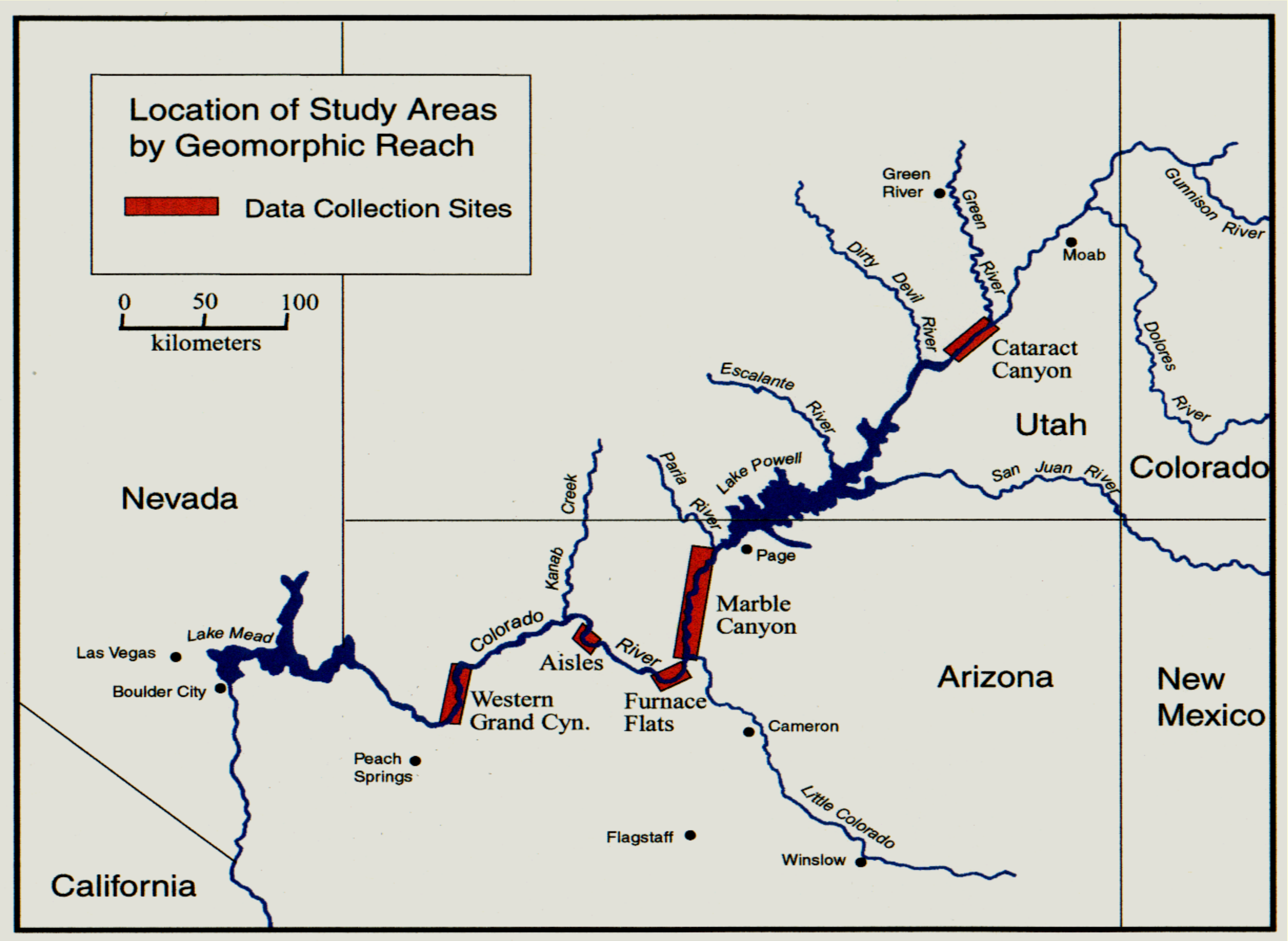
3. Assess relative vulnerability of sites.

   How to design monitoring and mitigation work?

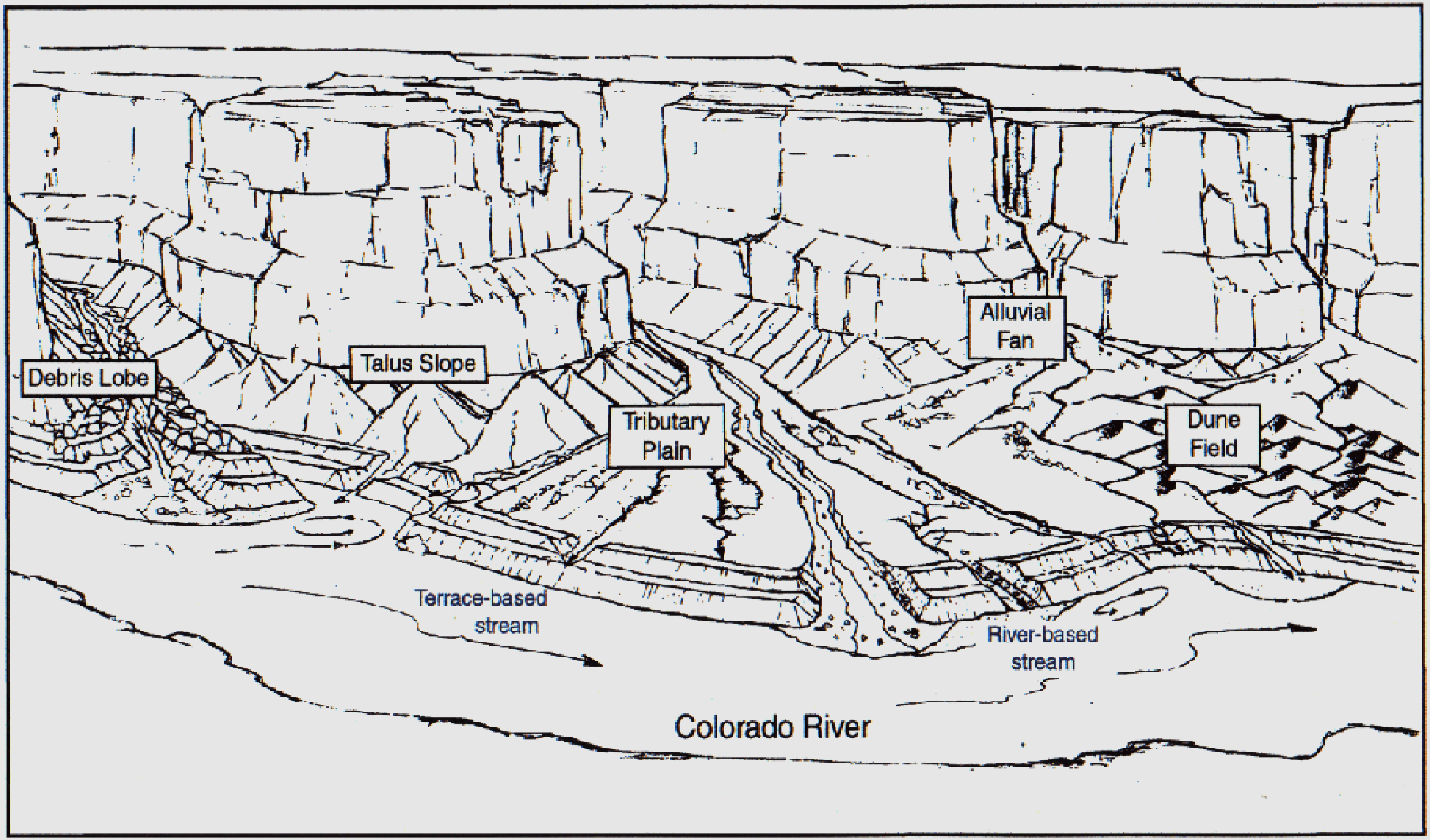
Steps to Build a Geomorphic Model of Archeological Sites

- Identify critical reaches.
- Classify catchments by geomorphic setting.
- Construct process-based conceptual model.
- Develop predictive mathematical model.
- Use model to predict vulnerability of individual sites.

Identify Critical Reaches



Classify catchments by geomorphic setting



Tributary Plain Setting

Type Locality: Palisades Canyon delta

Talus Slope Setting

Type Locality: Upper Unkar “forbidden zone”

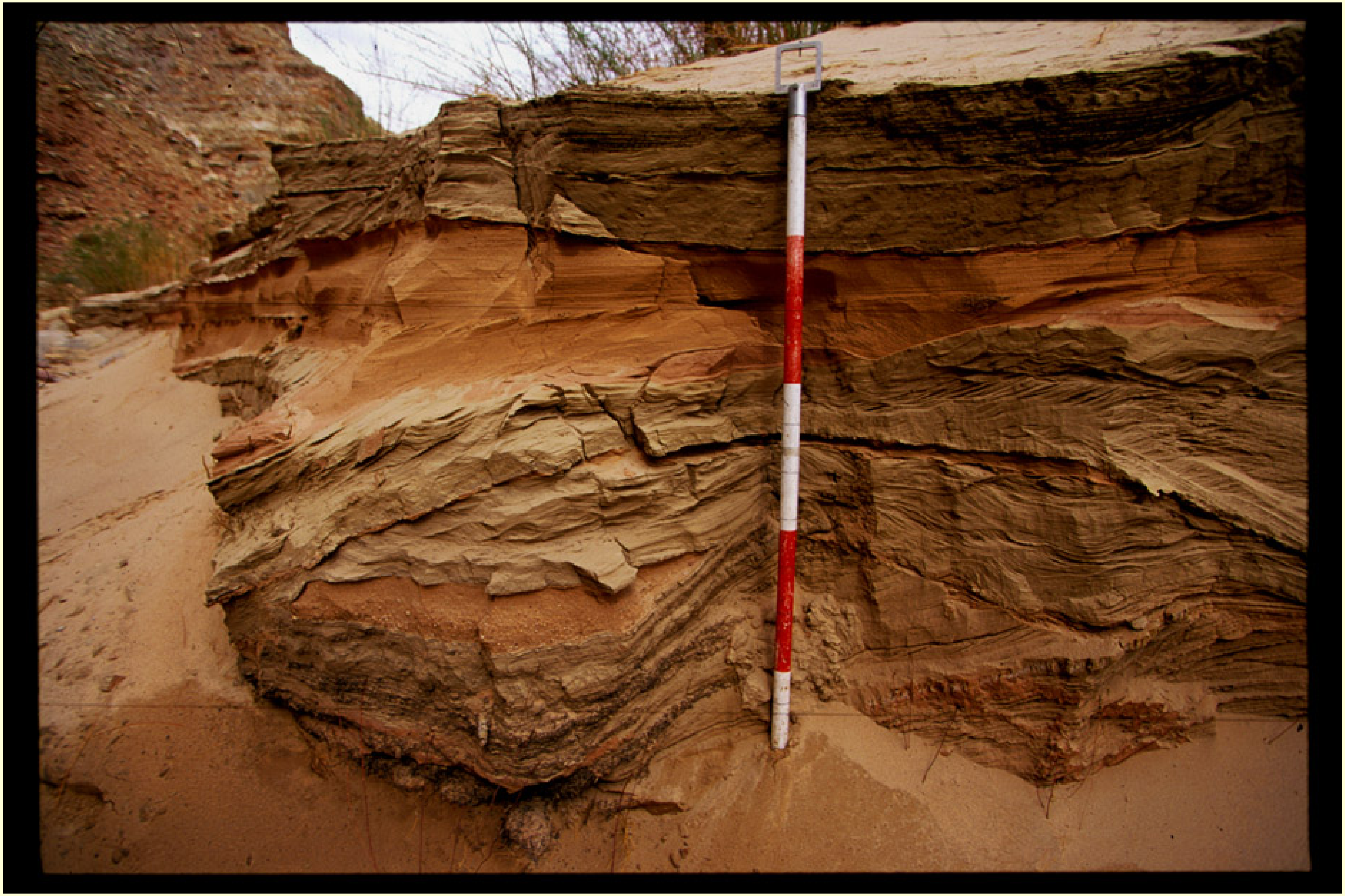
Debris Lobe Setting

Type Locality: 122 Mile Canyon

Alluvial Fan Setting

Type Locality: Nankoweap Cyn.“main camp”

Cut and Fill (Cataract Canyon)



Construct process-based conceptual model

•Small catchment runoff onto sandy terraces
(Stream power of catchment “funnel

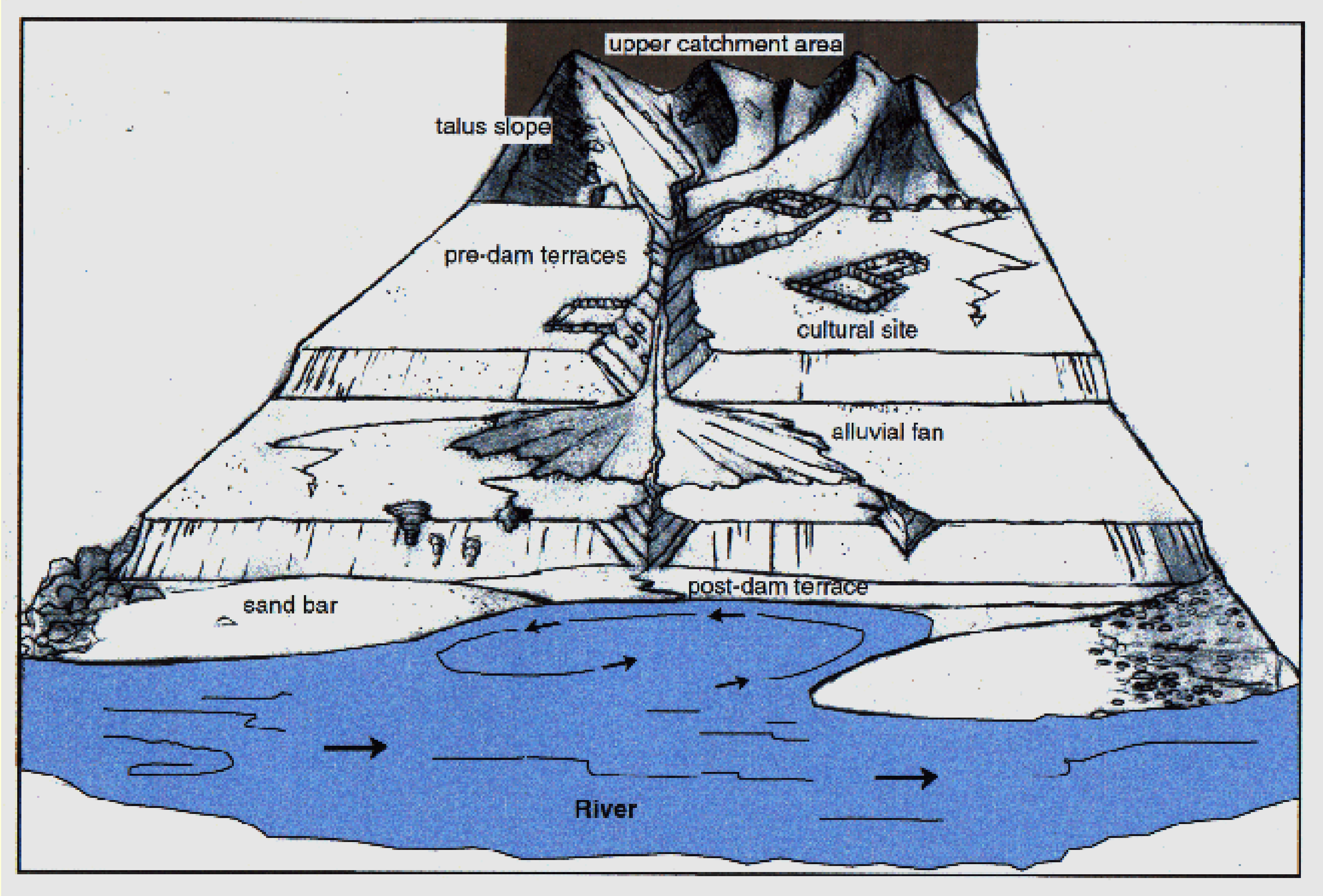
vs.

Diffusion capacity of terrace “sponge”)

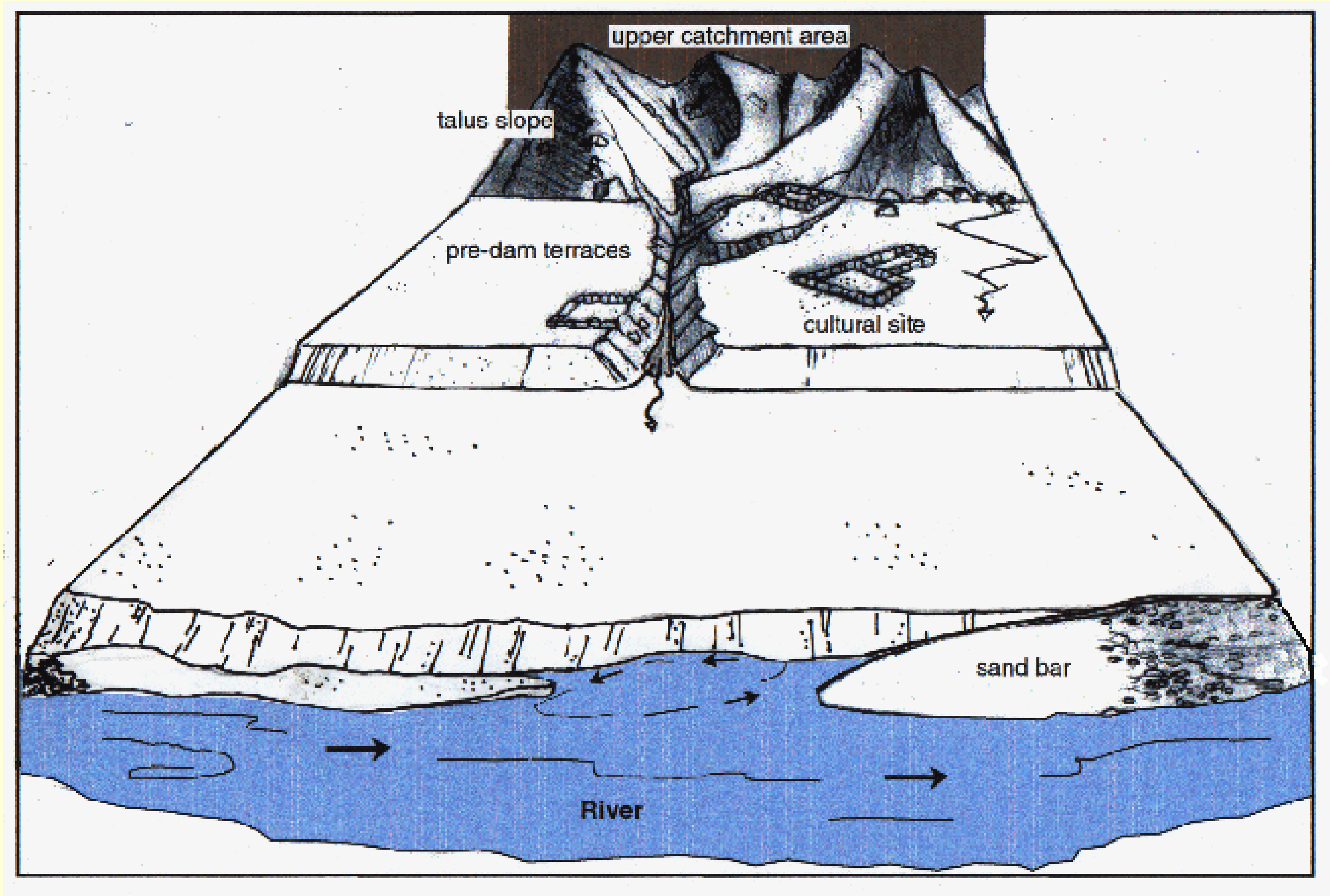
•Mechanisms causing headward erosion of
gullies in sandy terraces.

•Mechanisms slowing drainage
integration across sandy terraces.

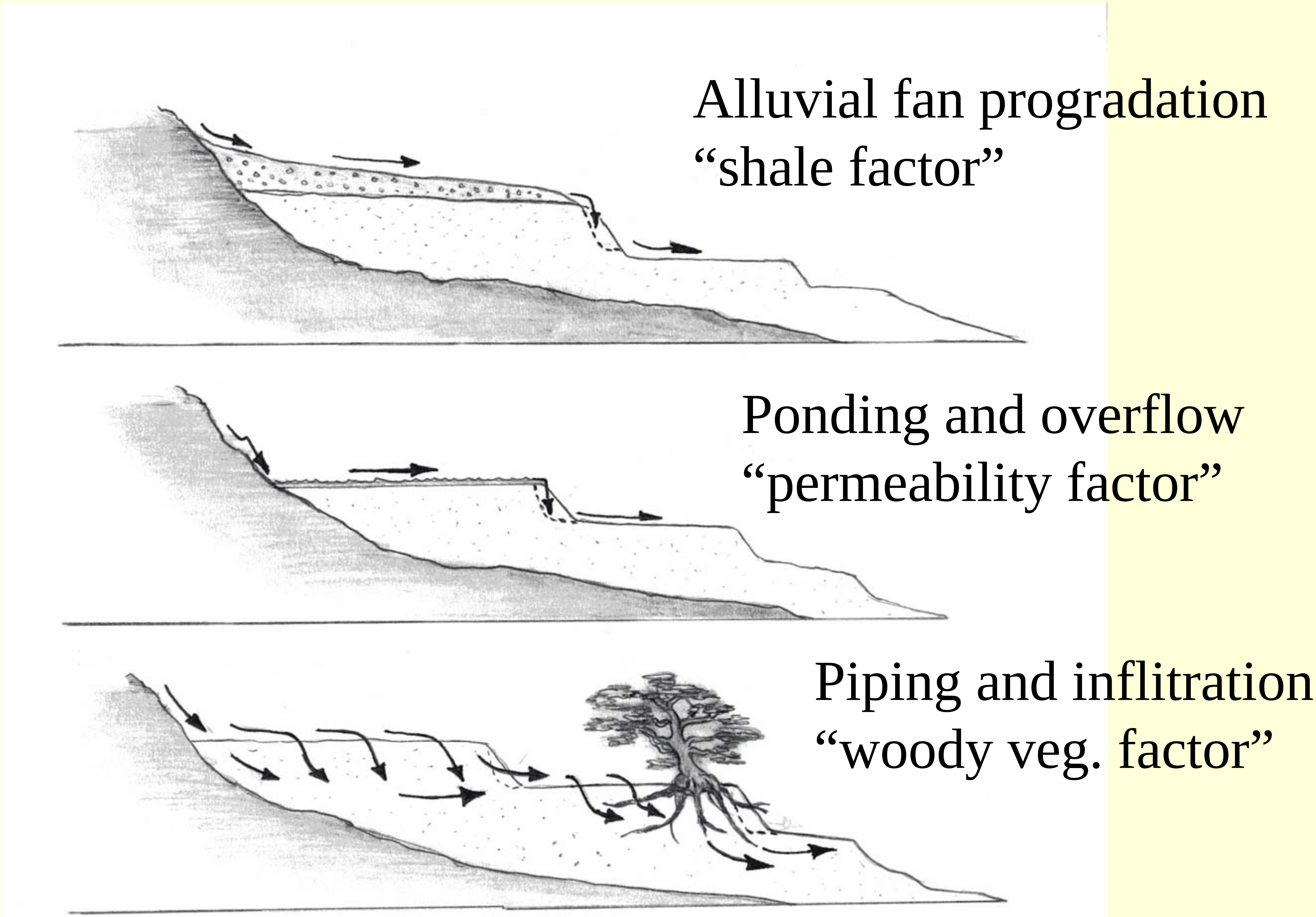
Processes Driving and Resisting Erosion



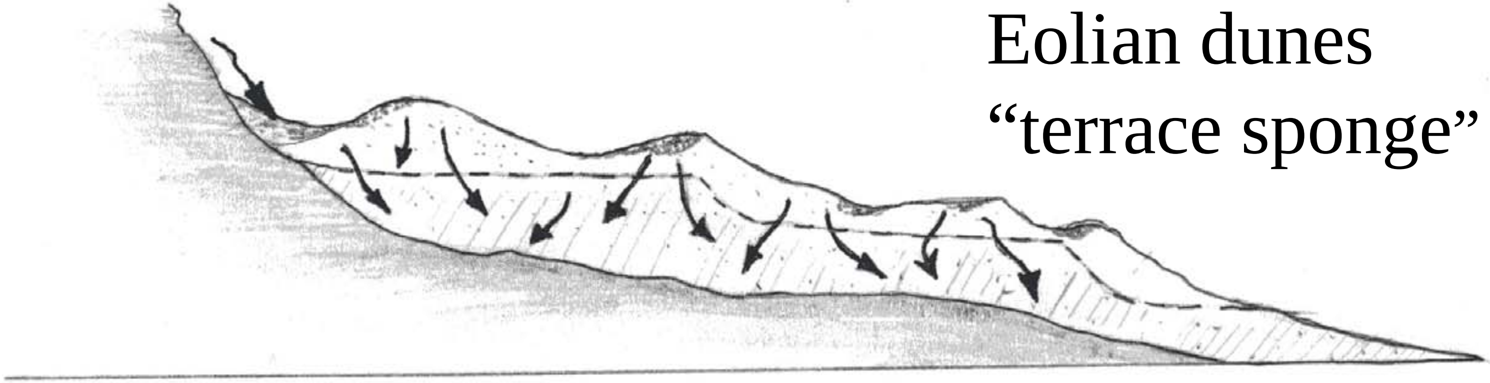
Fluvial Process Restoring Erosion



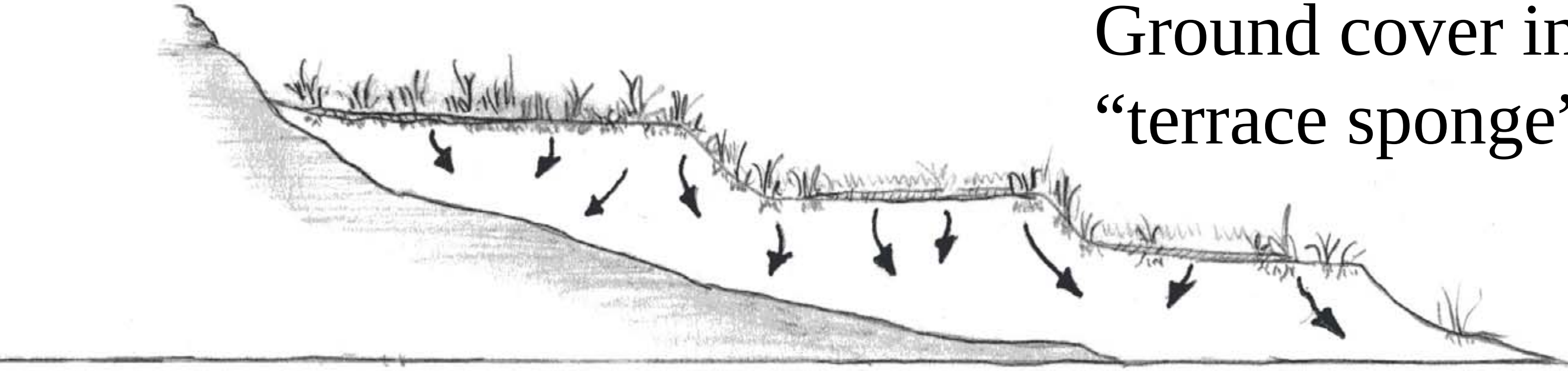
Mechanisms Advancing Headward Erosion of Gullies in Sandy Terraces



Mechanisms Slowing Drainage Integration across Sandy Terraces



Eolian dunes
“terrace sponge”



Ground cover interception
“terrace sponge”

Intrinsic Factors of Small Catchments

Erosion Driving	**Erosion Resisting**
Drainage Area	Ground Cover
Stream Length	Grain Size
Runoff Efficiency	Permeability
Catchment Length	Terrace Width
Catchment Relief	Terrace Height
Slope and Aspect	Sand Depth
Shale Factor	# Terraces

Extrinsic Factors of Small Catchments

- Human Mitigation
- Eolian Infilling
- Flood Flow Infilling
- Human Impact
- Side Canyon Overflow

Develop mathematical model to predict vulnerability of individual catchments

Mathematical Model - Step 1

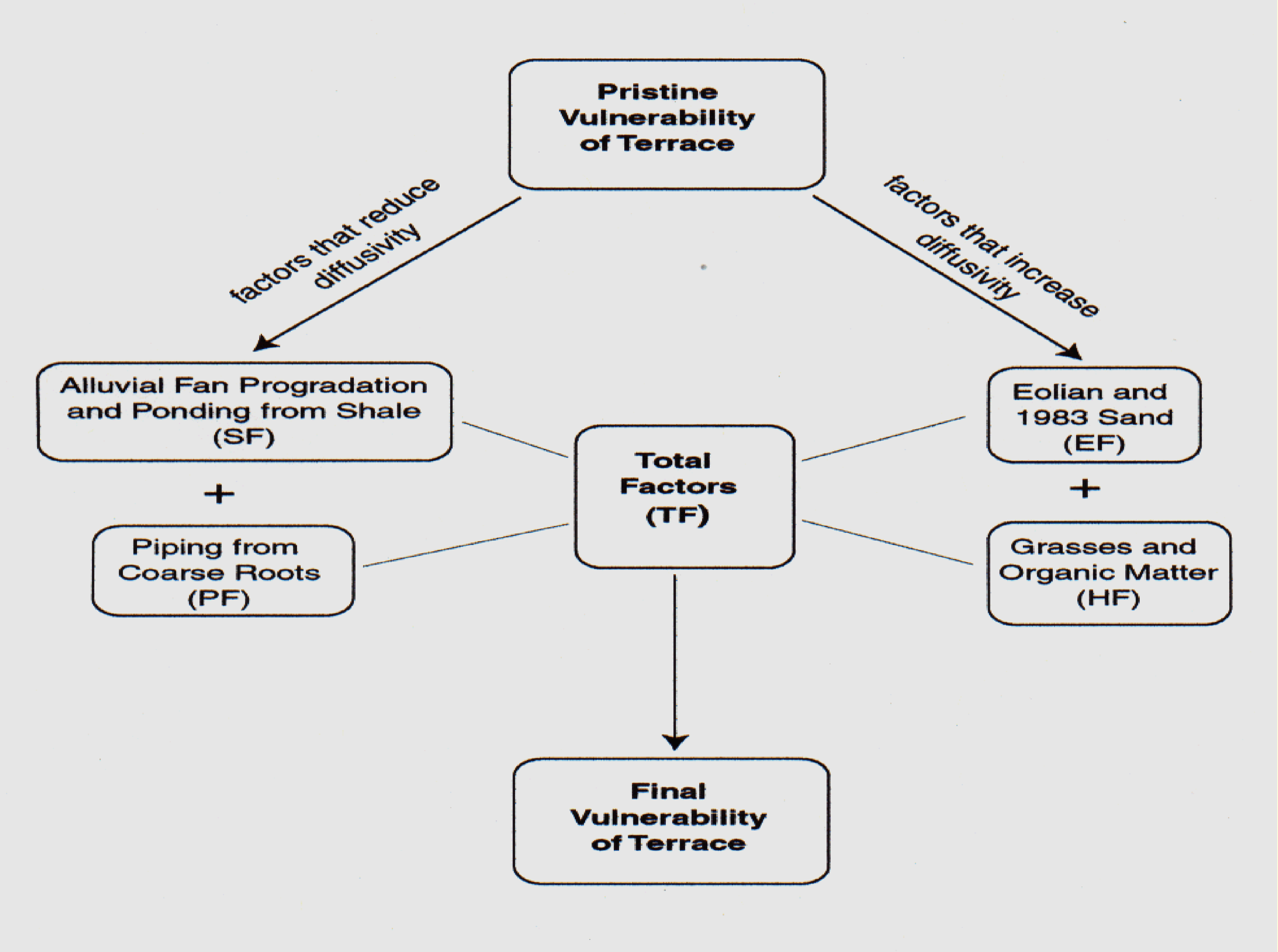
- **Quantify driving and resisting parameters**
- **Q = C*I*A (Am. Soc. Civil Engineers)**

  Total runoff (m^3) upper catchment
- **Axt = Wt * Dt**

  Cross-sectional area of terrace segment

Q=runoff volume (m3)
I=total rainfall (m)
A=catchment area
C=runoff coefficient (bedrock/gravel/sand)

Add Geomorphic Factors to Model



Mathematical Model - Step 2

- $Vr = \ln(Q)/\ln[Axt * (1+TF)]$

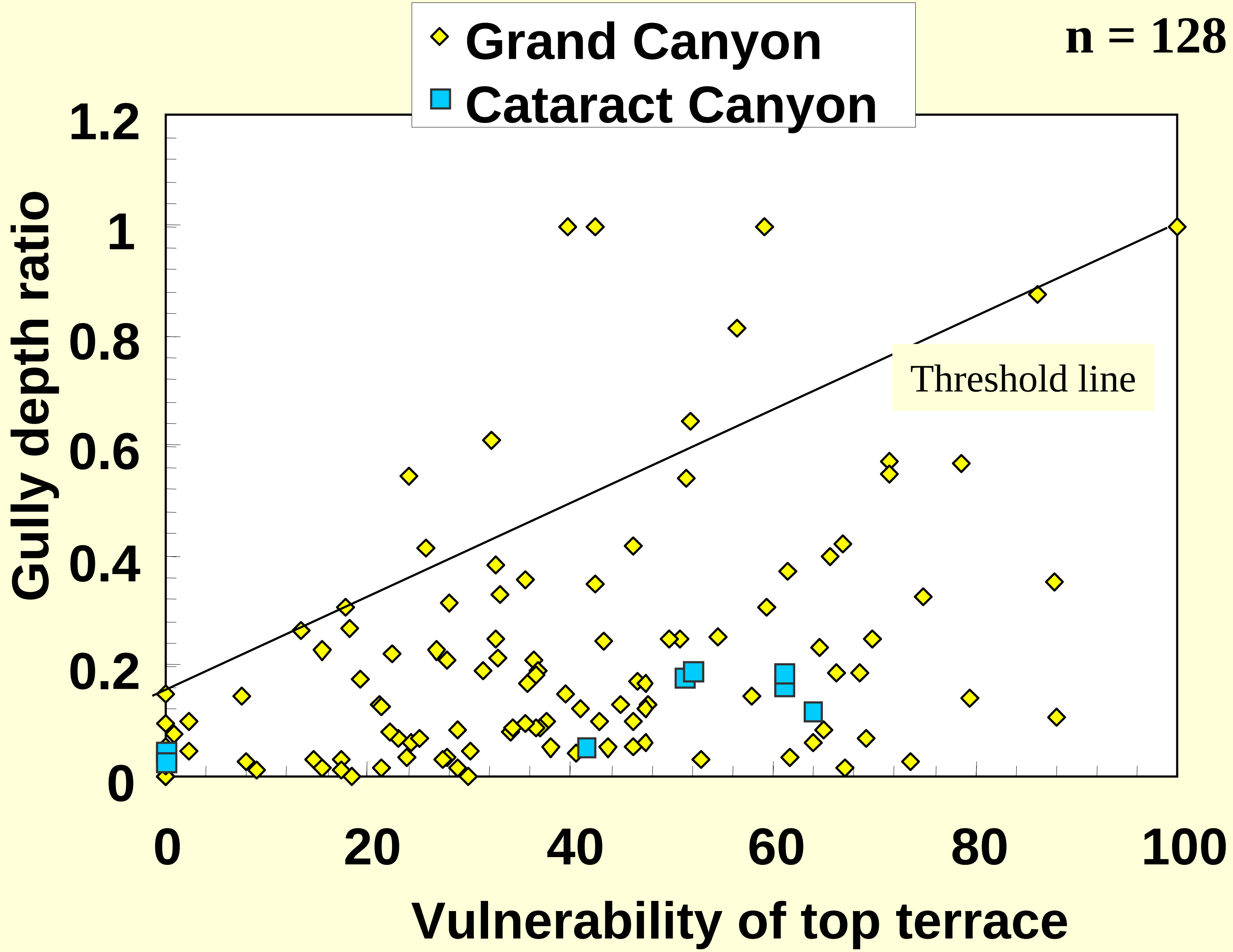
  Vr is raw vulnerability
- $FVC_i = (Vr * FVC_{i-1})/100$

  FVC_i is cumulative vulnerability

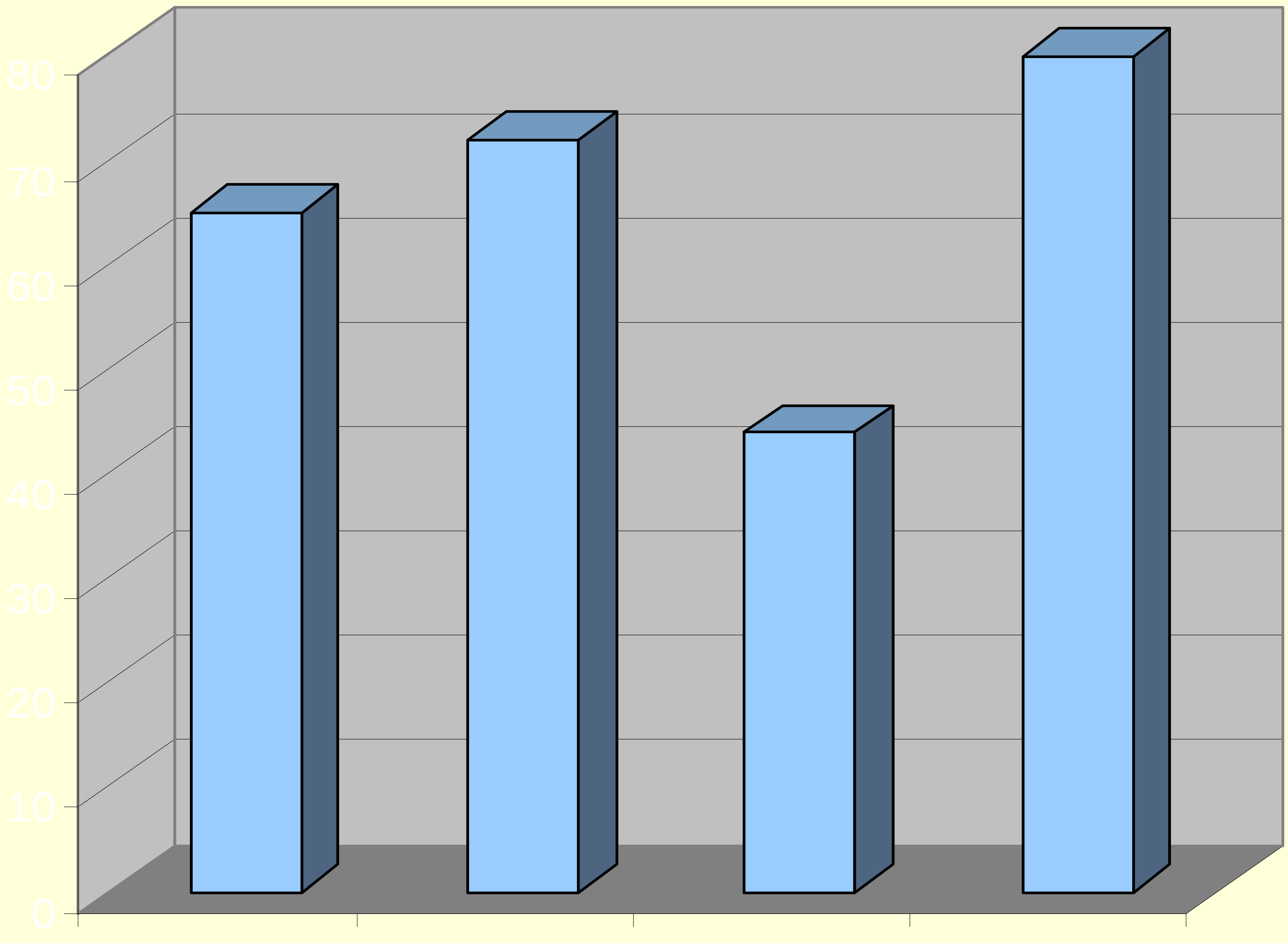
thus: vulnerability rating of archaeological terrace = Vr of highest terrace

and: vulnerability rating/catchment = mean FVC_i

Vulnerability Plot

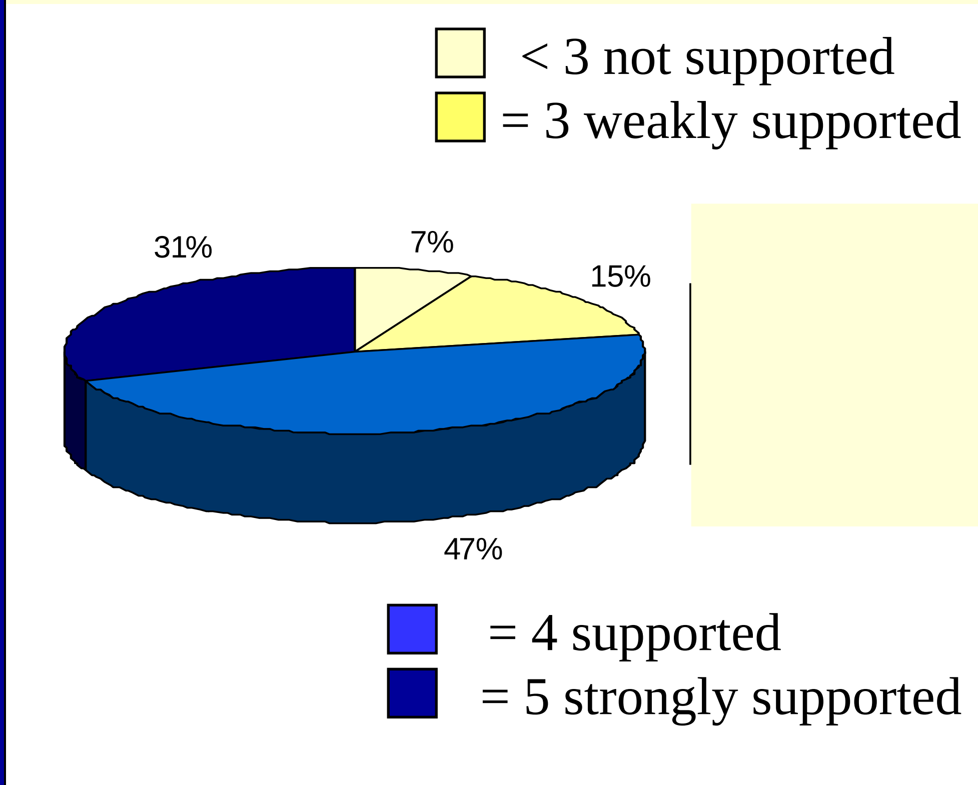


Percent of sites containing 1983 and pda deposits



Sites Supporting Base-Level Hypothesis

Geomorphic Process No Evidence Of:	Score
Pre-dam arroyo-cutting	1
Cutbank retreat by river	1
Side-canyon erosion	1
Sandy Deposit Present:	
Pda and 1983	1
Active eolian sand	1
Maximum Score Possible	**5**



Conclusions

- Process-based model works best for this small-catchment geomorphic system
  - it simplifies enormous variety and complexity of small catchments
- Statistically based model does not work well
  - poor correlation of gully depth/width to most measured parameters
- Highest vulnerabilities are function of large catchment area and narrow terrace width

222 mile - 1923 (E.C. LaRue photo)