Frequency of Debris Flows in Grand Canyon

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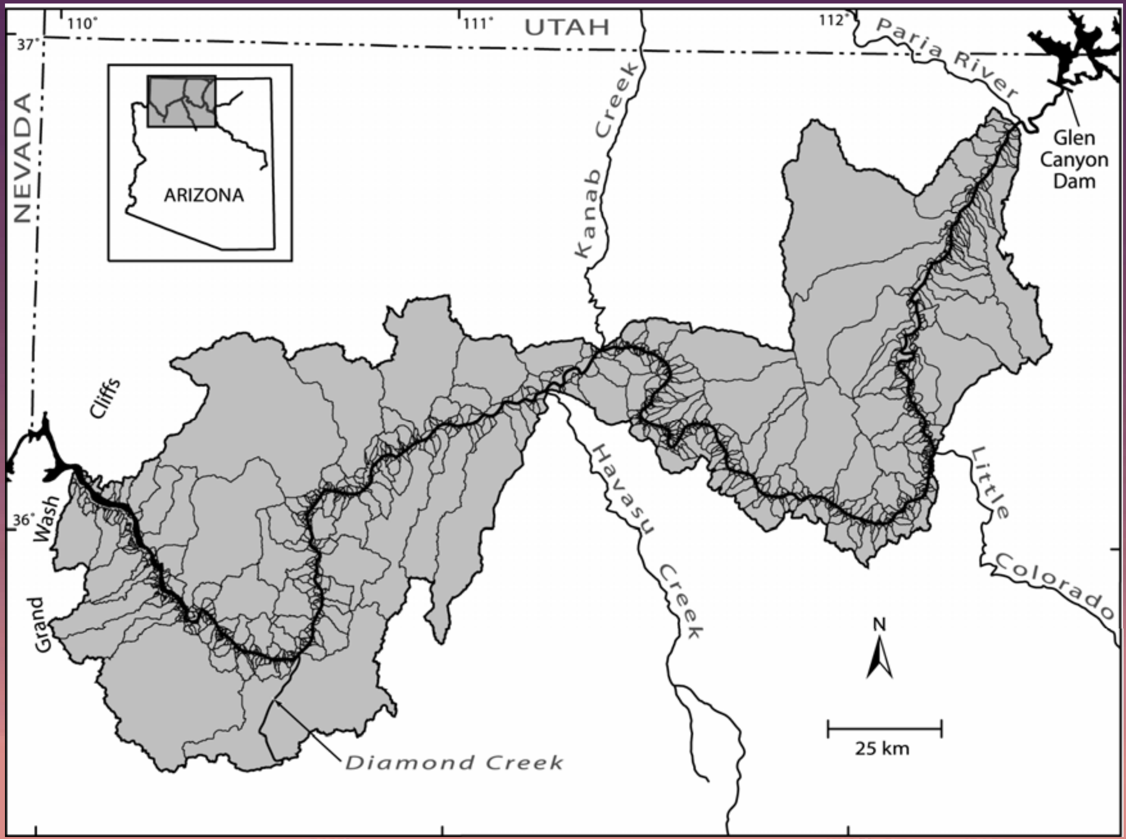

What is a Debris Flow?

- Debris flows are slurries of poorly sorted sediment and water
- > 80% sediment by weight
- Particles range from clay to boulders 1-6 m in diameter (b-axis)
- Typical moisture contents range from 5-20% (n=49)

Ref: Webb et al., 1989, USGS Prof. Paper 1492

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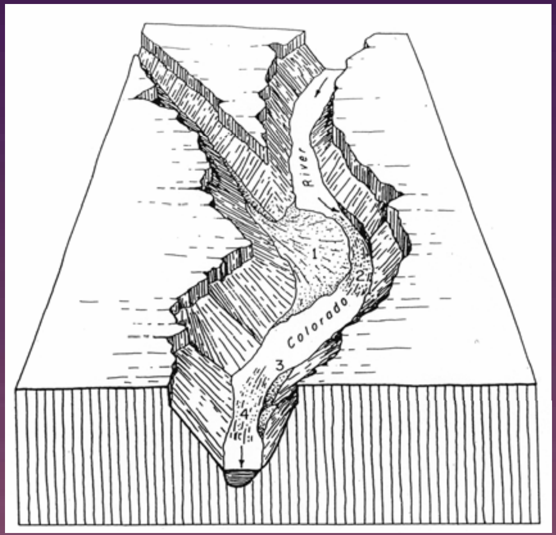
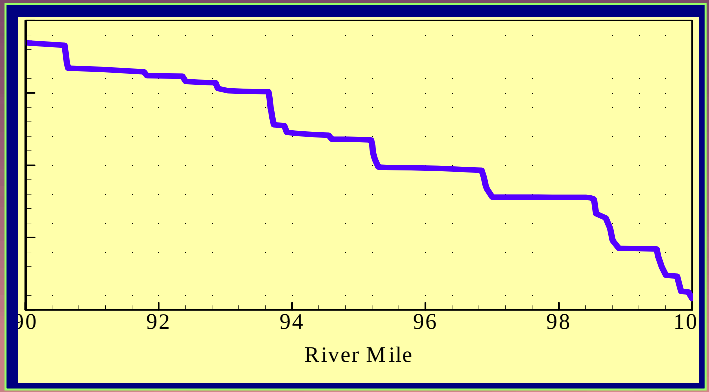
SIGNIFICANCE OF DEBRIS FLOWS

- Debris flows threaten humans and structures
- Debris flows create rapids and eddies that are efficient sand traps and create beaches
- Debris flows add boulders and cobbles to the river that form substrate for aquatic plants
- The occurrence of debris flows influences the types of native fishes present in the river





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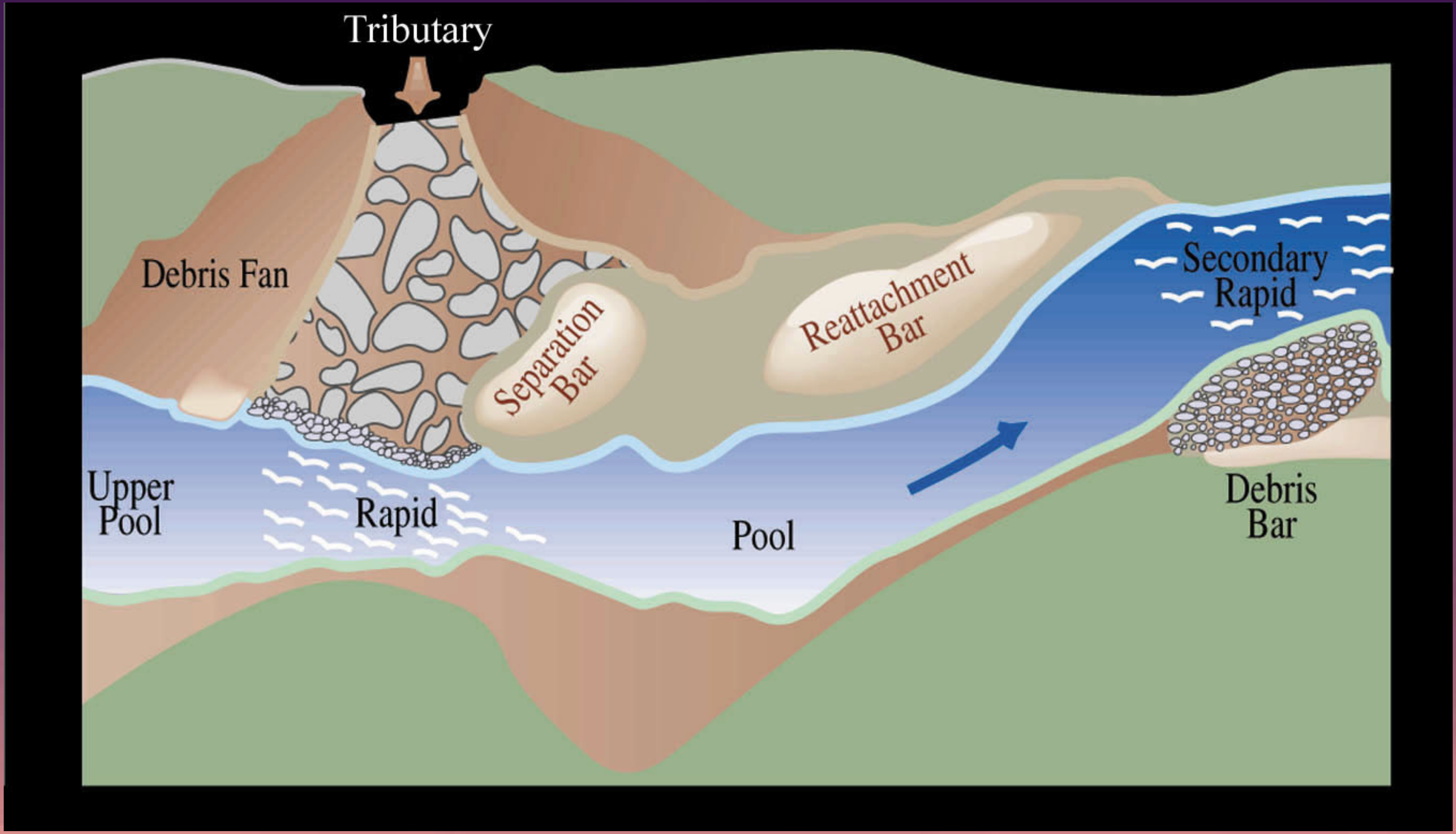
Significance of Debris Flows



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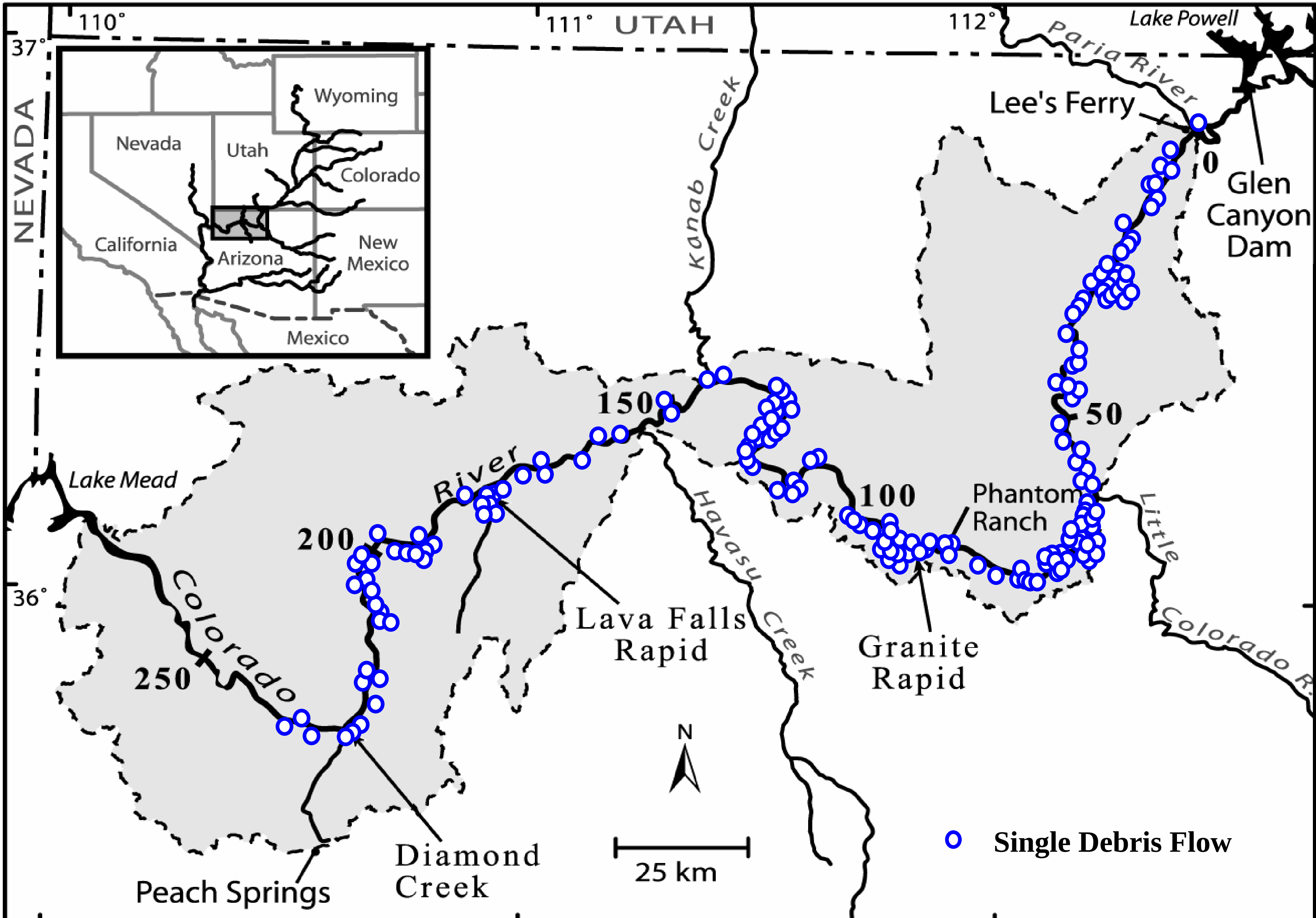
Distribution of Historical Debris Flows (1872-2002)



Frequency of Debris Flows

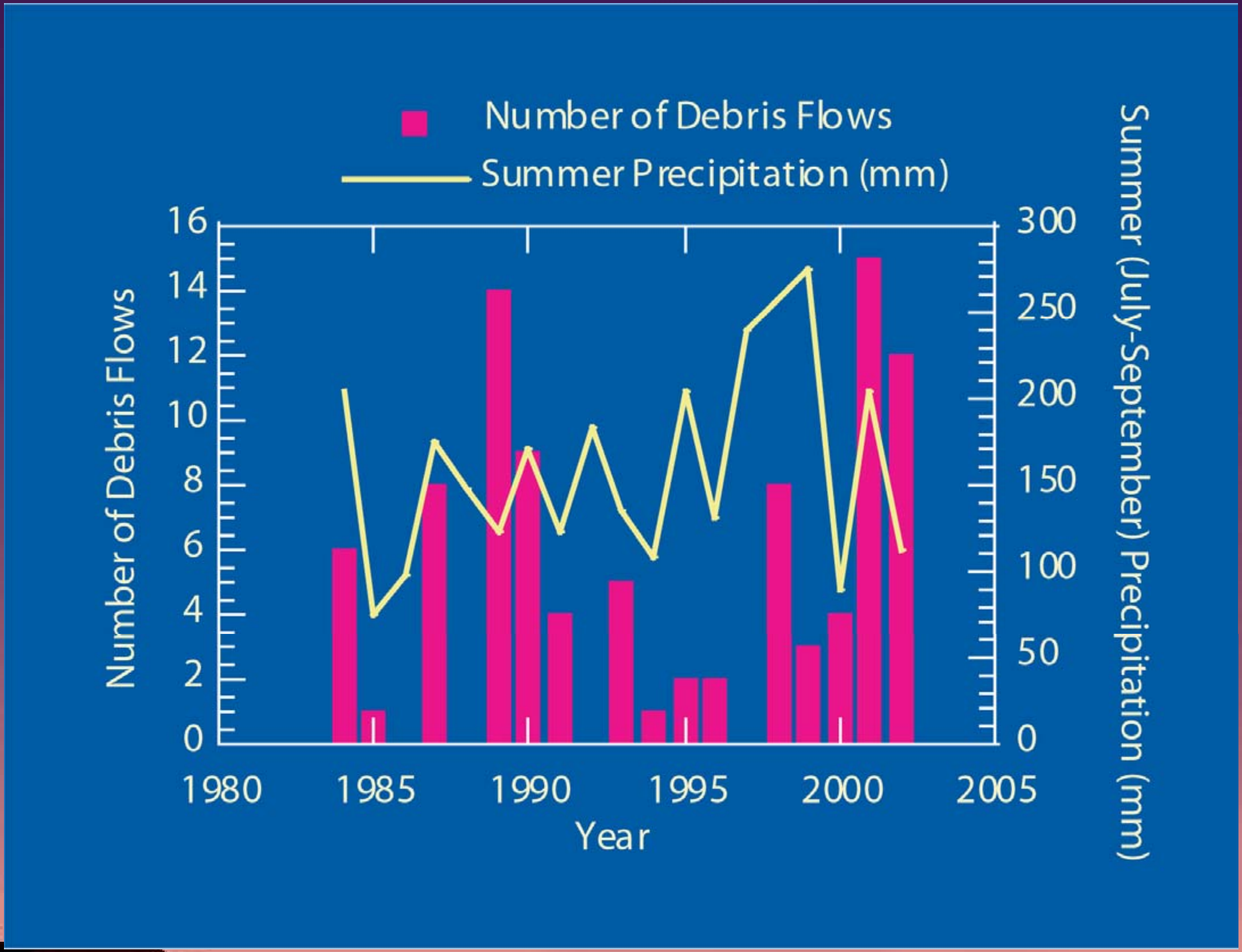
How do you study rare events when few have been watching or measuring?

1. Stratigraphy (^{14}C, ^{3}He, other dating methods)
2. Historical diaries (1869-1964)
3. Repeat photography (1871-2002)
4. Direct observation (1984-2002)
5. Remote sensing: LIDAR, ISTARs (2000)

Observed Debris Flows, 1984-2002

- From 1984-2002, a total of 93 debris flows were observed in Grand Canyon = **4.9/yr**.
- 9 increased the severity of existing rapids
- 7 changed existing riffles into rapids
- 3 created new riffles

Observed Debris Flows, 1984-2002



26 debris flows occurred in 2001-2002

Repeat Photography and Debris Flows

- Matched 1,365 photos showing debris-flow evidence
- Earliest photo:1871; Most useful group: 1890 (Stanton)
- 147 tributaries: 93 debris flows at 84 tributaries (1890-1983)
- Extrapolating = **5.0** debris flows per year (1890-1983)

Crystal Rapid 1890 and 1990 (Webb 1996)

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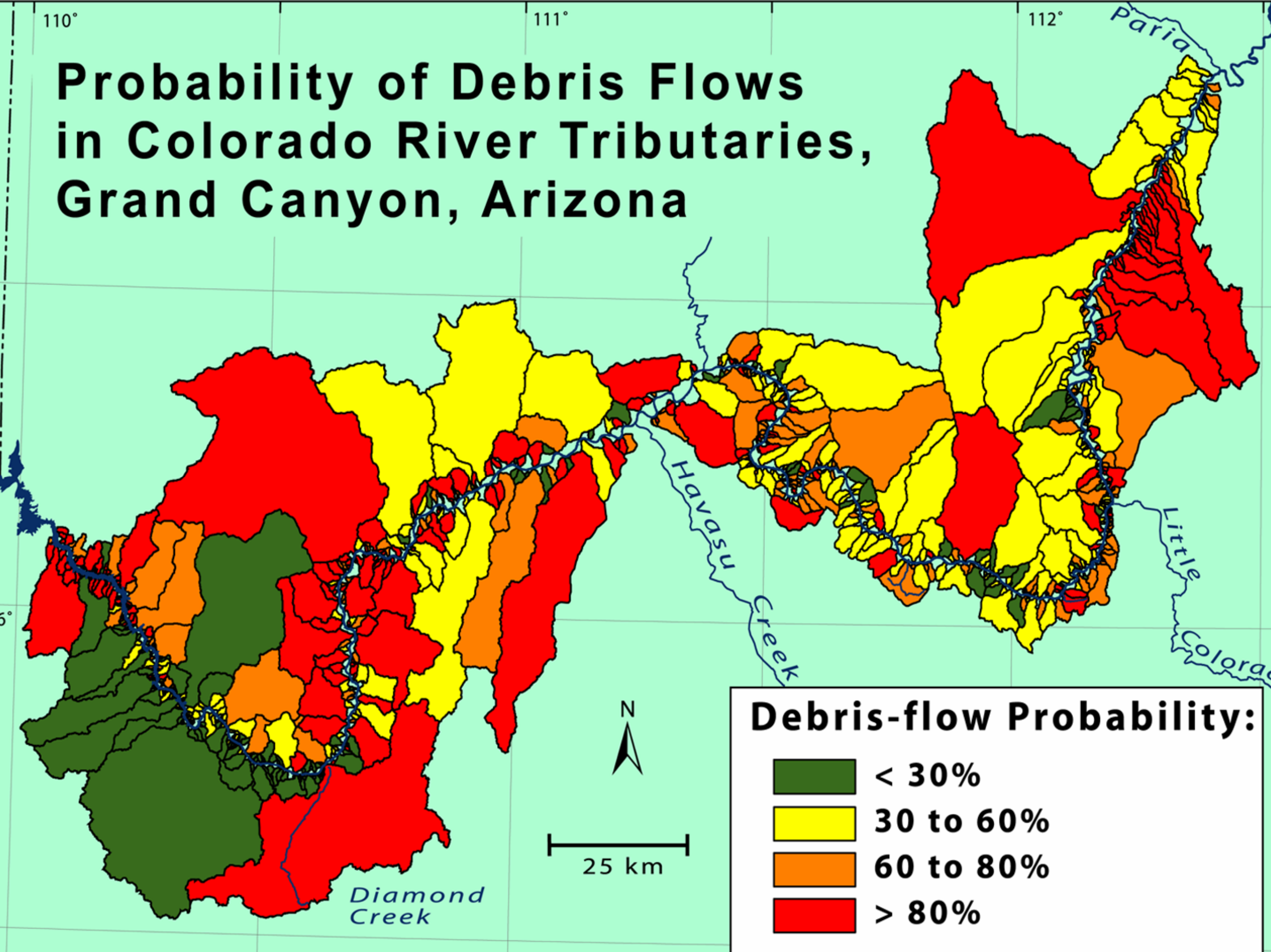
Modeling Debris-flow Frequency with Logistic Regression

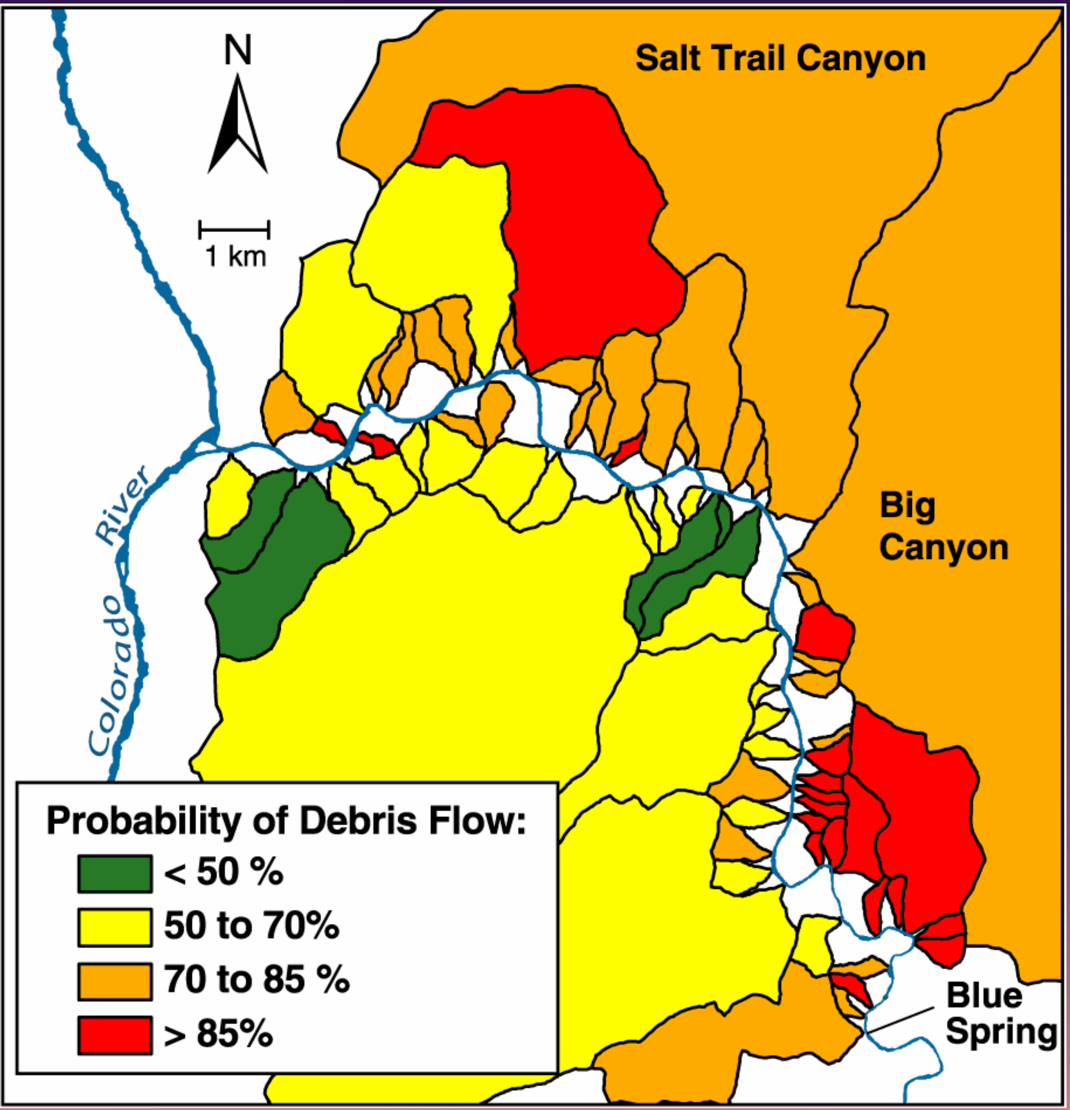
- 160 tributaries with a photographic record of debris-flow frequency (1890-1990)
- 11 geomorphic variables linked to the process of debris flow initiation
- Identify those geomorphic factors that are statistically significant to debris-flow frequency
- Model the probability of debris flow occurrence based on significant geomorphic factors and frequency data
- Apply model to all 740 tributaries


Probability of Debris Flows
in Colorado River Tributaries,
Grand Canyon, Arizona
110°
111°
112°
Paria
Havasu Creek
Little
Diamond Creek
N
25 km
Debris-flow Probability:
< 30%
30 to 60%
60 to 80%
> 80%

Debris Flows and Native Fishes

- Areas where humpback chub are most common are also areas with highest debris-flow frequency.
- In 1993, radio-tagged humpback chub were attracted to the newly aggraded debris fan at Tanner Rapid.
- Debris flows also occur in the Little Colorado River canyon, an important avenue of chub migration.

Debris Flow and the Little Colorado River



- LCR tributaries are comparable to those along the Colorado and should generate similar quantities of coarse sediment.
- LCR channel is narrower than that of the Colorado and more susceptible to the effects of debris flows.
- Debris flows could block channel in reach within 1-2 miles of the Confluence.
- 74 tributaries occur in reach up to Blue Spring. 50% have a debris-flow probability > 80%.

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Conclusions

- Debris flows are the only significant source of coarse sediment and have profound effects on the river corridor: fans, rapids, pools, eddies, substrate.
- Debris flows that reach the river occur five times a year on average.
- Debris flow frequency can not be altered by management practices and will continue to alter the river corridor.
- Once deposited, coarse sediment – cobbles, boulders, gravel – can only be managed by periodic flushing flows released from Glen Canyon Dam (e.g. 1996 flood).

Future Work

Modeling of sediment transport by episodic events such as debris flows is possible with a sustained research effort:

- Magnitude and frequency of debris flows is already well-documented and modeled
- Developing a state-of-the-art 1-D model of flow through rapids (C. Magirl).
- Develop a realistic model of debris-flow deposition and reworking by dam releases (C. Magirl).
- Shift to monitoring new debris-flow activity by remote sensing (ISTARS, DEMs, photogrammetry)

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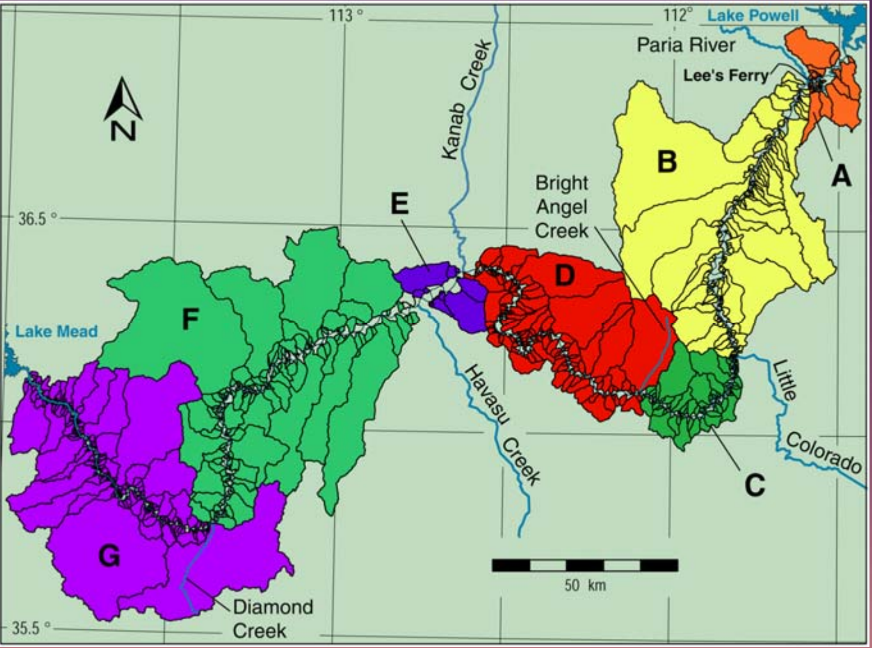
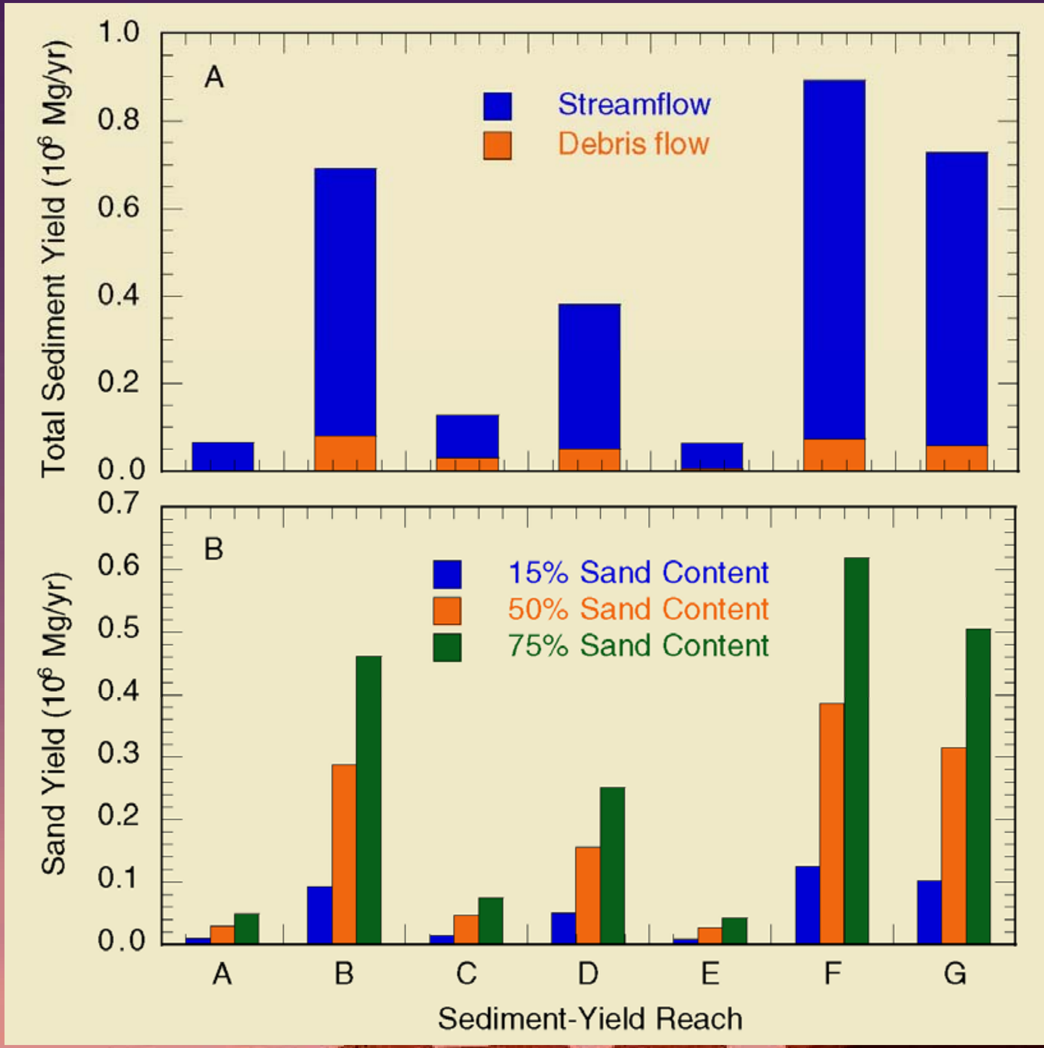
Sediment Yield of Grand Canyon Tributaries

Seven geomorphic reaches



Reach B: 25% of Paria inputs



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