# Flood and Paleoflood Science

## Flood frequency in transition regions of mixed-population flooding with the presence of a high outlier: Sweetwater Creek

for Eagle County Engineering Department, Colorado

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5th Annual Sustaining Colorado Watersheds Conference:
"Learning From the Past to Protect the Future"

October 7, 2010

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# Problem/Issue

**Q100 values using different regional flood-frequency relations for Colorado**

**for**

**Sweetwater Creek at mouth & Colorado River**

| | |
|---|---|
| **McCain and Jarrett (1976)** | **- Q100 = 2,800 cfs (SEE = 53%)** |
| **Kircher and others (1985)** | **- Q100 = 1,520 cfs (SEE = 63%)** |
| **Vaill (2000)** | **- Q100 = 1,910 cfs (SEE = 59%)** |
| **Capesius and Stephens (2009)** | **- Q100 = 1,540 cfs (SEE = 75%)** |

**Range in Q100 = 1,520 cfs to 2,800 cfs**

**SEE = Standard Error of Estimate "… is a measure of the accuracy of predictions."**

**What is the 100-yr flood, Q100, (AEP=0.01) four miles upstream from gage?**

# Objectives

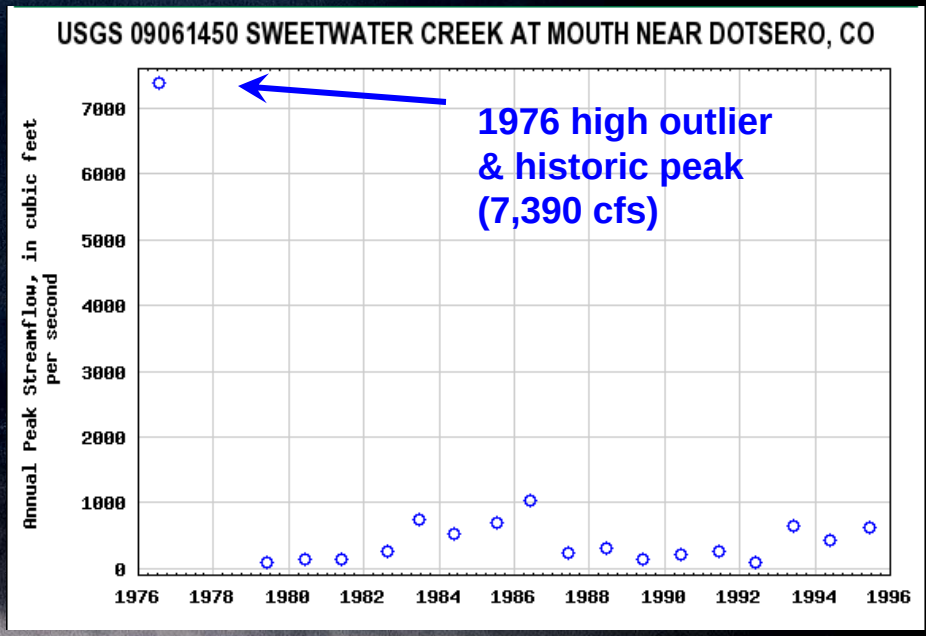
## Problems estimating flood frequency

- Insufficient data for extreme floods
- Mixed-population flood processes
- Rapid change in flooding over short distances
- High-outlier and historical floods
- Uncertainty/differences in FF estimates

## Overview of paleoflood hydrology

- Methods
- Application to Sweetwater Creek
- Results

## Concluding Remarks

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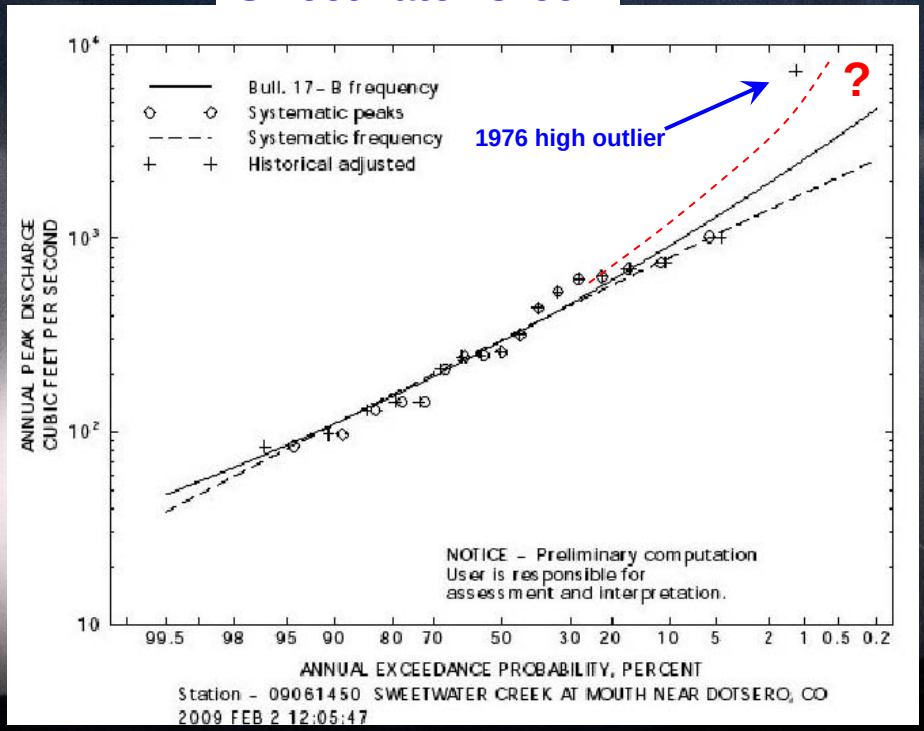
(mixed-population flooding = snowmelt, rainfall, and a combination of rain-on-snow runoff)

# Methods

- Multidisciplinary regional paleoflood study
- Help define maximum floods & ages, particularly the largest floods
- Incorporate paleoflood data in robust, flood-frequency analysis

**Sweetwater Creek**

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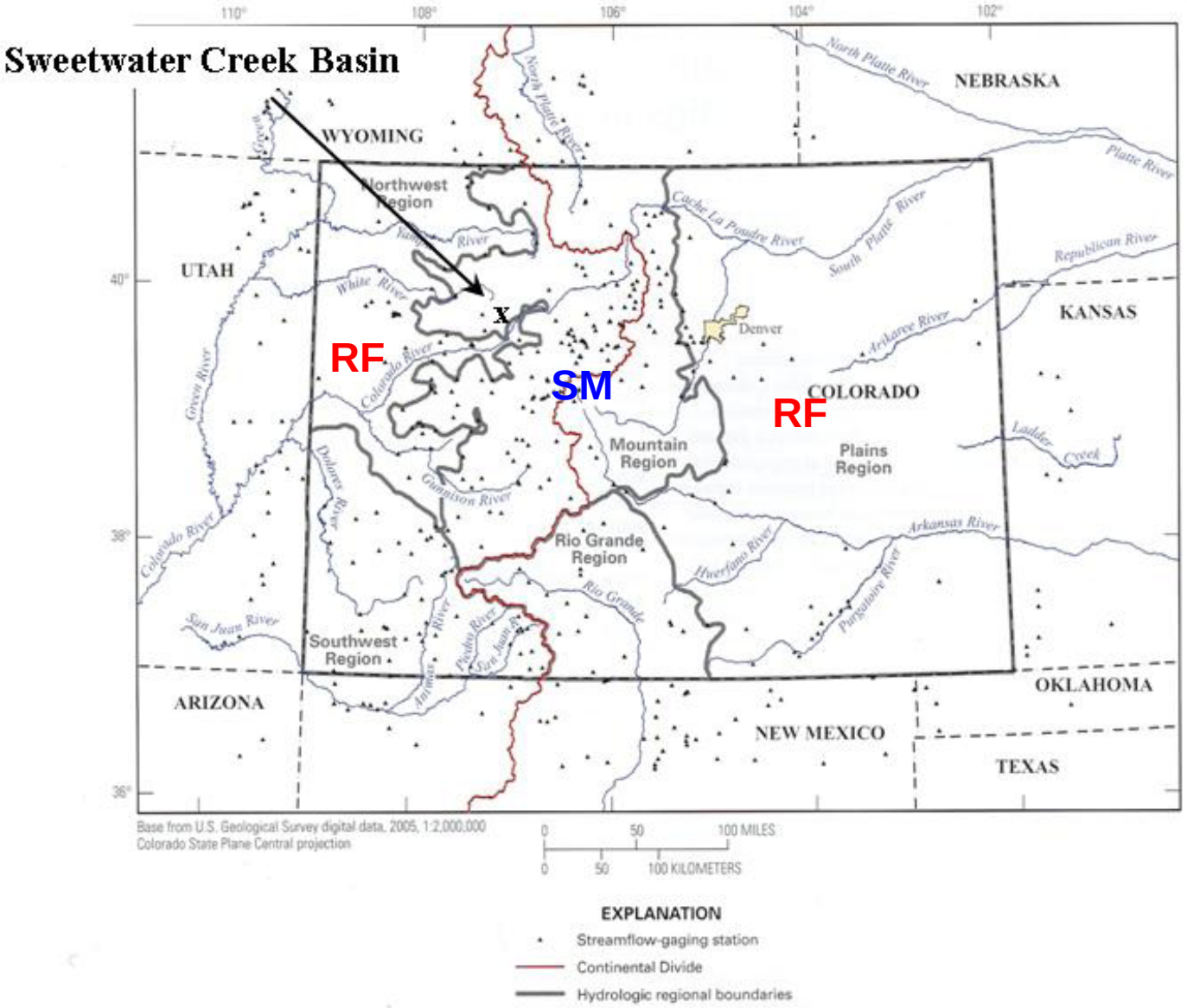
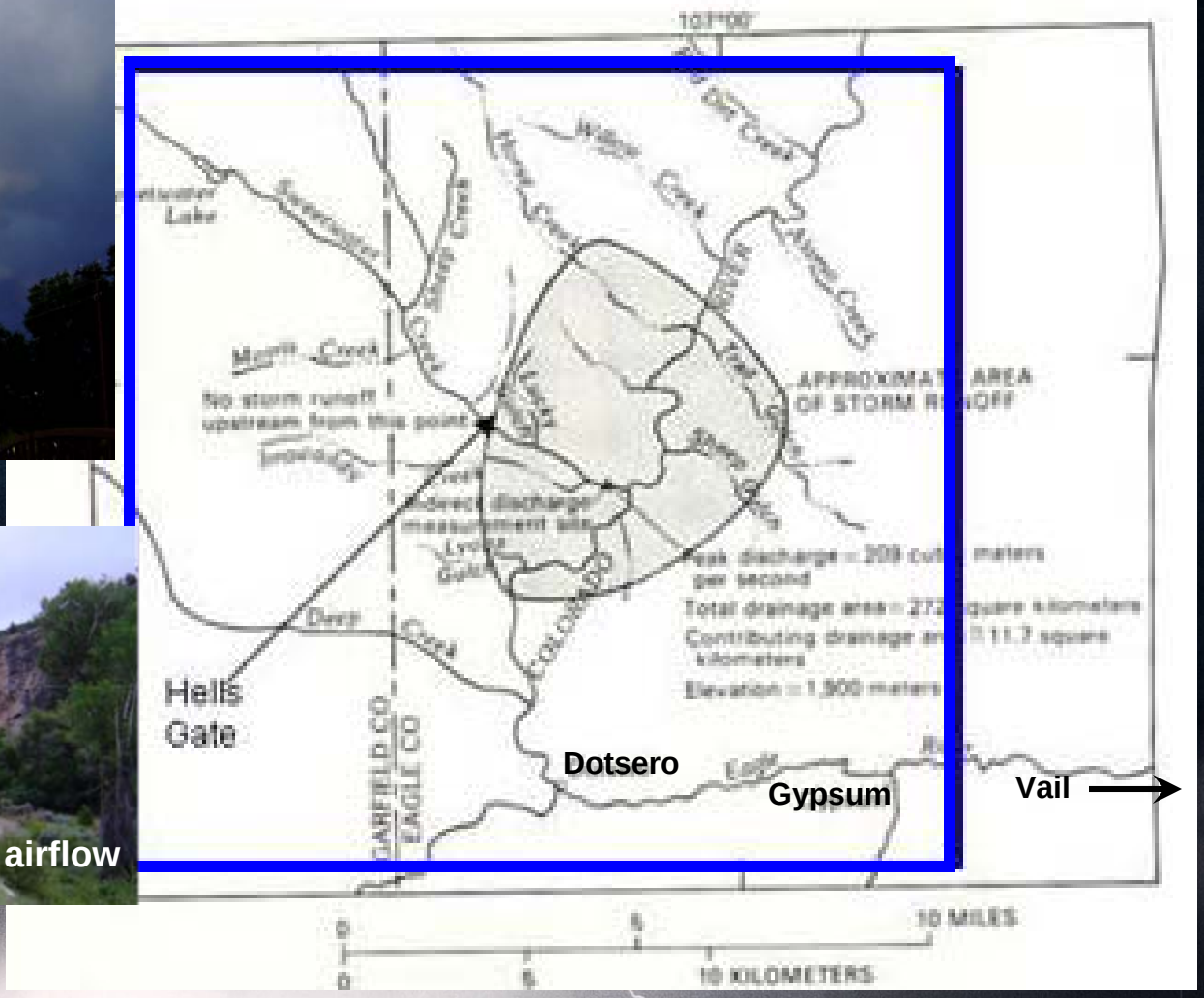



**Figure 1.** Boundaries of hydrologic regions and locations of streamflow gaging stations in Colorado and adjacent States.

**(Modified from Capesius and Stephens, 2009)**

Eagle 2009 storm clouds

Hells Gate – barrier to moist airflow




- Approximate storm contributing July 12, 1976, flood (shaded area)
- Sweetwater Creek regional study (blue square)
- July 12, 1976, flood =7,390 cfs 6 inches of rain ~90 minutes

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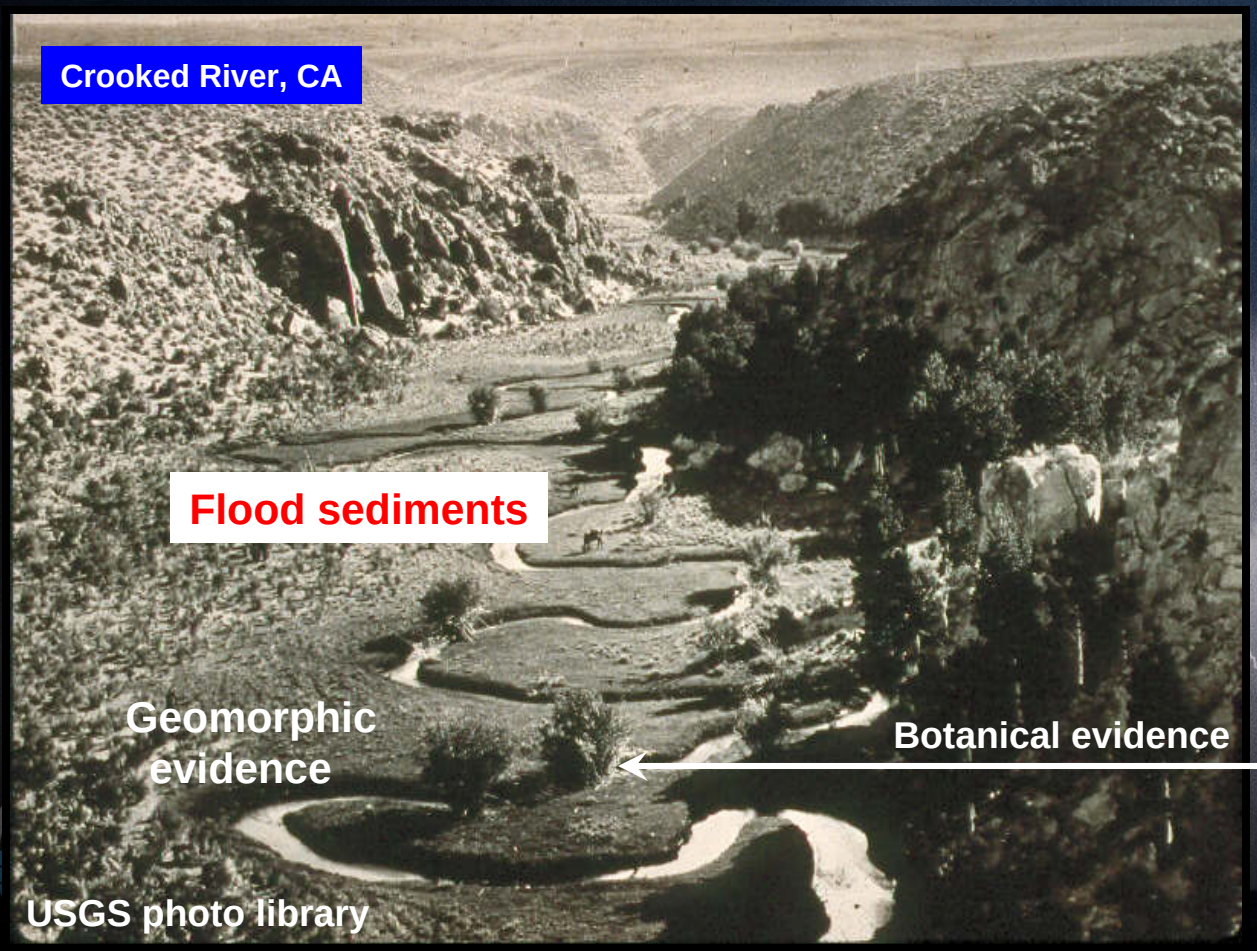
# Paleoflood Hydrology

**Study of environmental signatures of past floods to help better understand past, present, and future flood hazards, and the effects of future climate variability**




1976 flood scar
Big Thompson River
at Drake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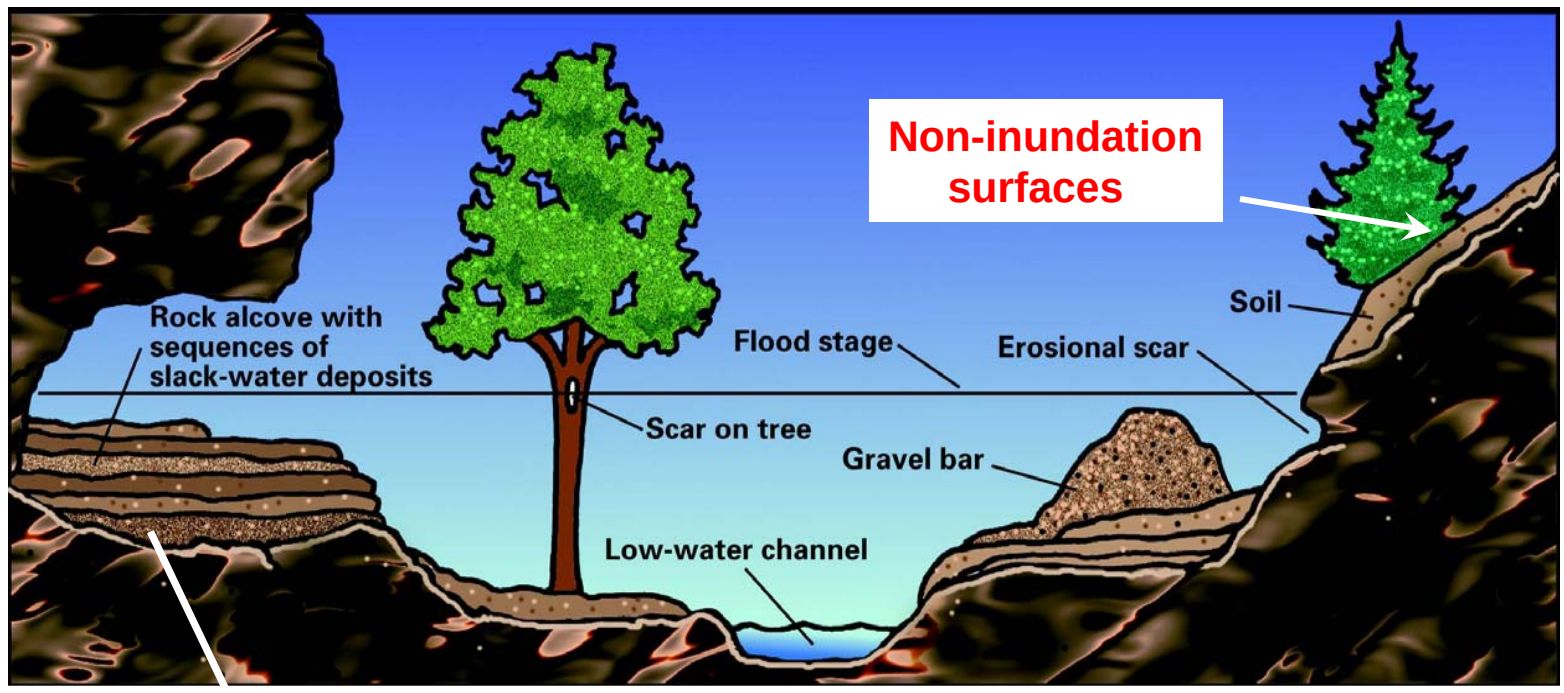
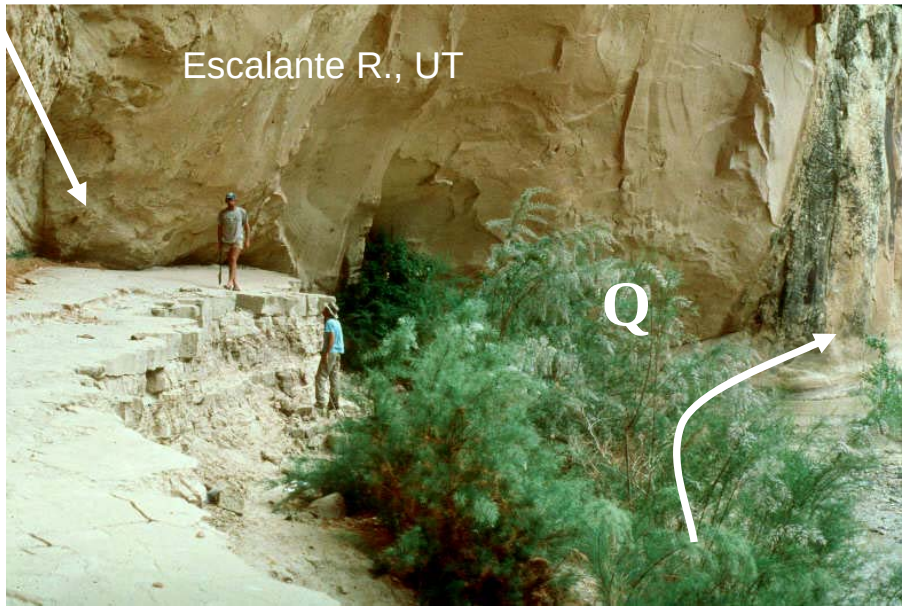
# Types and locations of PaleoStage indicators (PSIs)




**PSIs are old high-water marks (~ Qgage data w/ larger uncertainty)**

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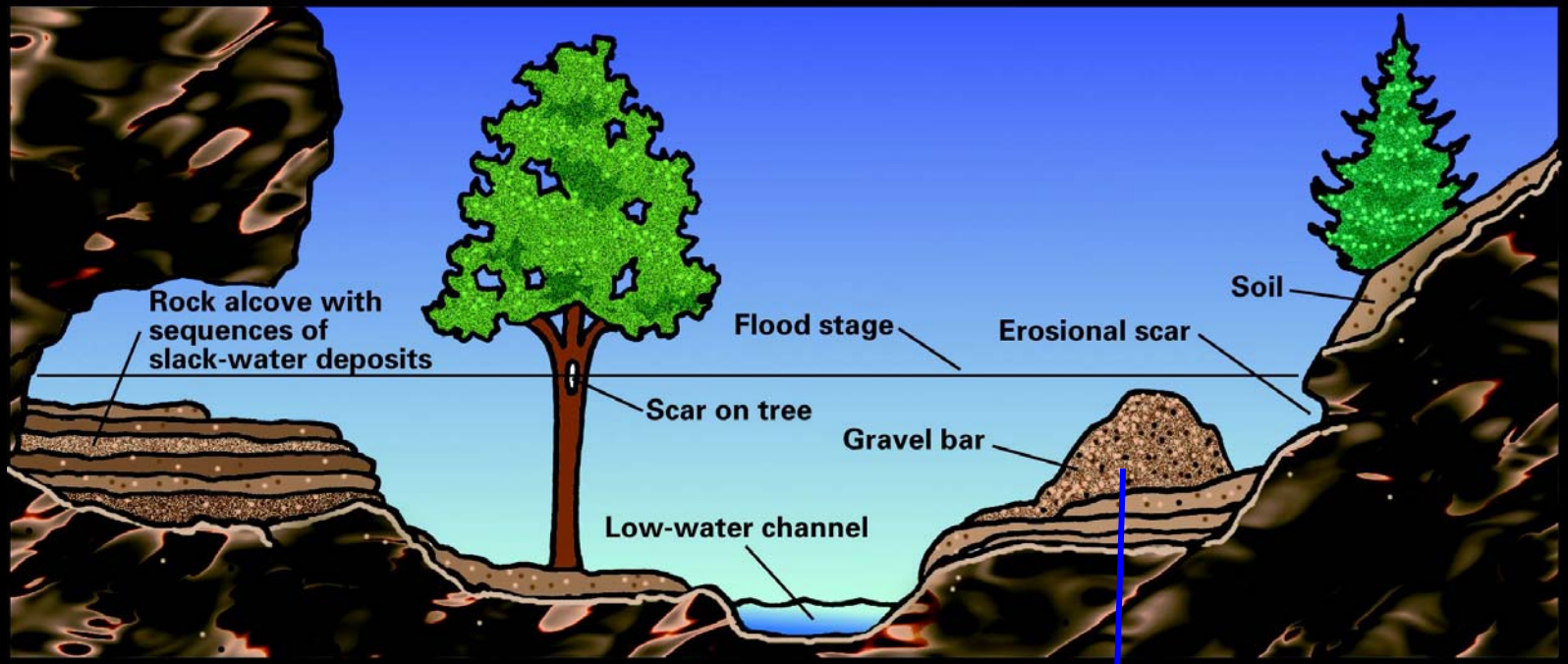
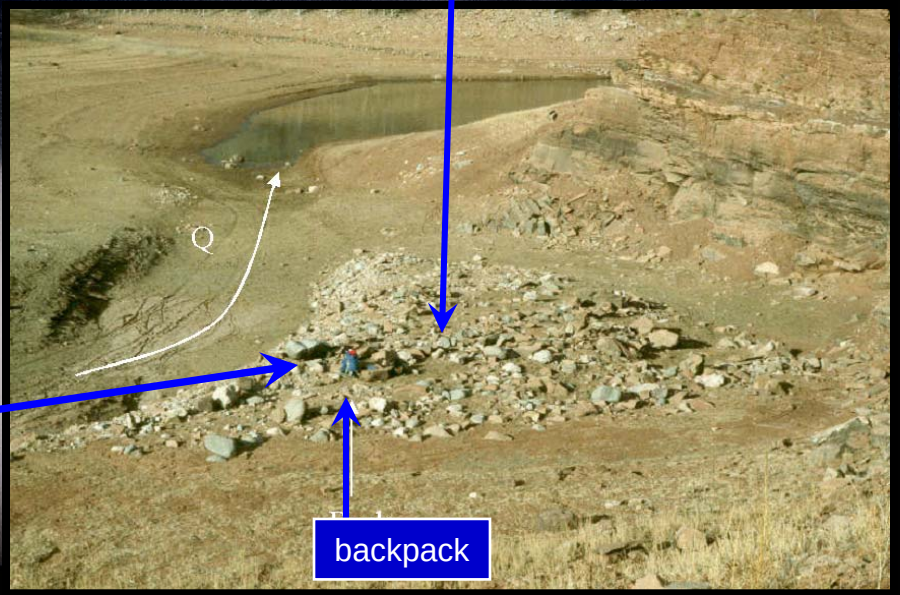
# Types and locations of PaleoStage Indicators (PSIs)




**Arthurs Rock Gulch**
**Horsetooth Reservoir**
**Fort Collins, Colo.**

**Largest paleoflood ~5,000 yrs old ($^{14}C$)**

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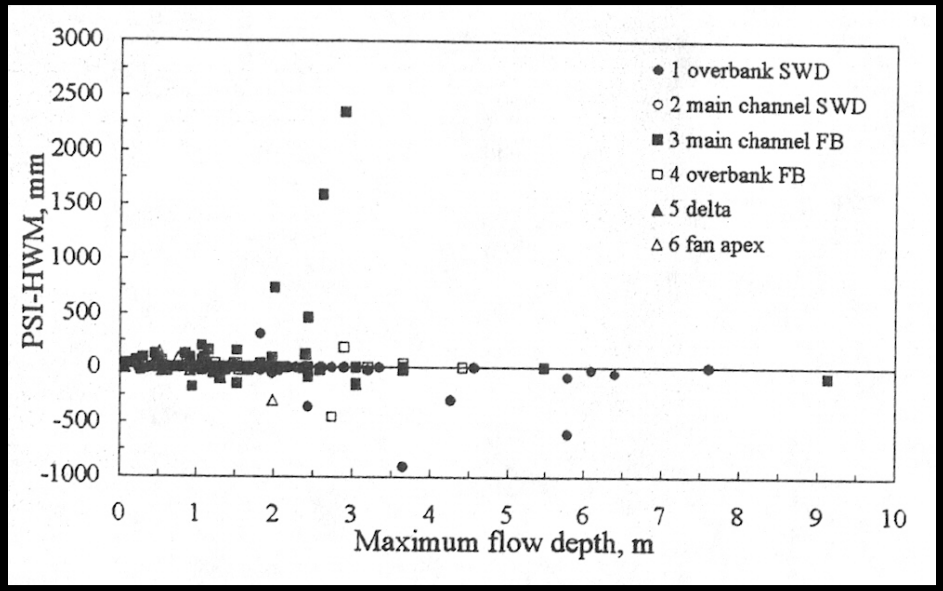
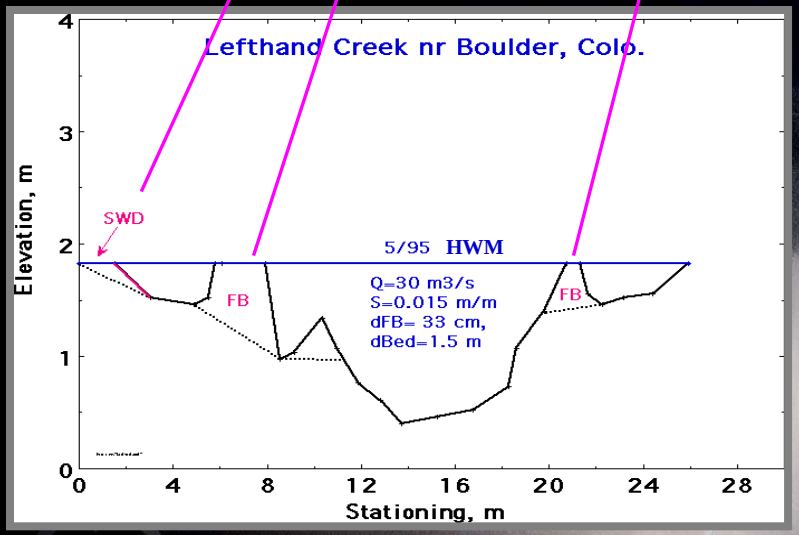
## “Flood chasing 101”

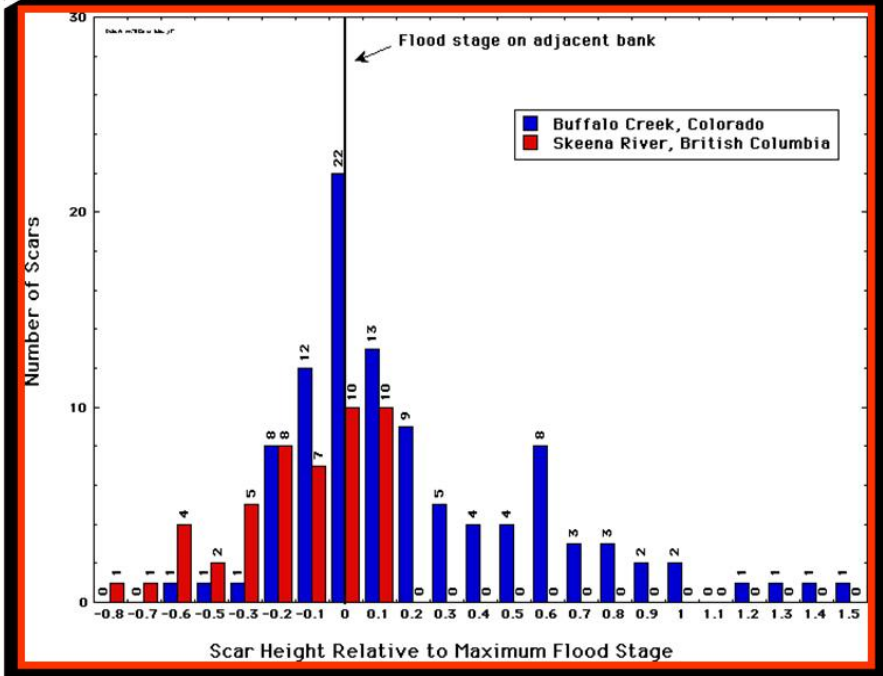




Cross section of Left Hand Creek near Boulder, CO.

- 212 flood sites in a wide range of settings
- Flood recurrence intervals from 2-yr to 10,000 years
- Top of flood sediments ~ high-water marks

Jarrett and England (2002)


**Merced River, Yosemite National Park, CA**




Yanosky and Jarrett, 2002

**Photo of tree scar, and a histogram of maximum height of scars on riparian trees relative to peak HWMs for low gradient rivers (Red - Skeena River, British Columbia, N = 48 trees) and for higher gradient streams (Blue - Buffalo Creek basin, CO, N = 102 trees).**

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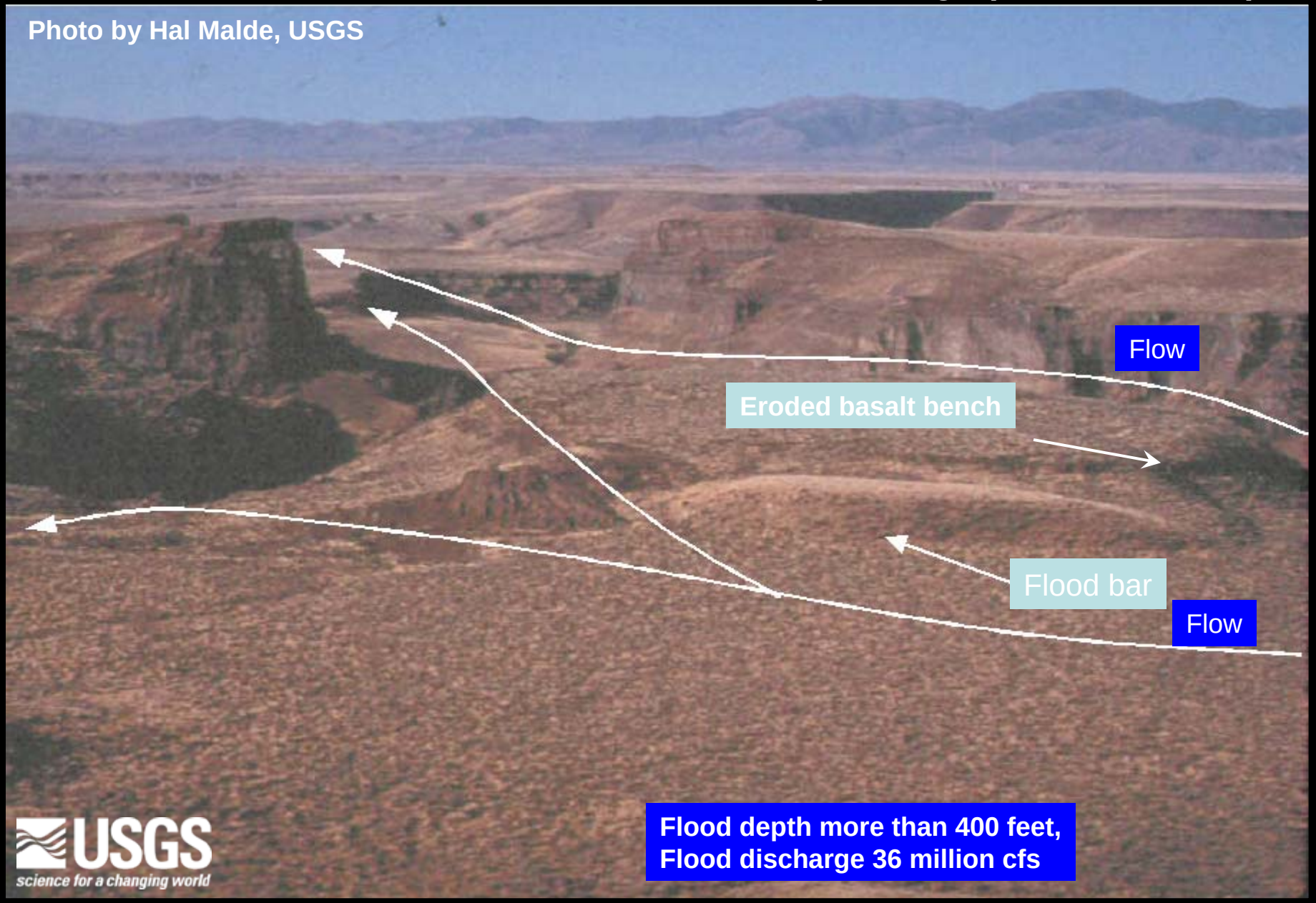
# Bonneville Glacial Lake Outburst Flood ~15,000 years ago (Snake River, ID)




Note: preservation of paleostage indicators for 10's of thousands of years, particularly the largest flood.

# Types of Paleoflood Studies


1976 Big Thompson Flood damage

## When there is a lack of data for water-resources investigations

- Flood-plain management
- Design of infrastructure in flood plains
- Risk assessments of dam safety
- Erosion of bed and bank sediments
- Wildland fire hydrology
- Determine rainfall amounts and thresholds of flash flooding for National Weather Service
- River restoration and riparian ecosystem assessments
- Paleodebris-flow hazard assessment

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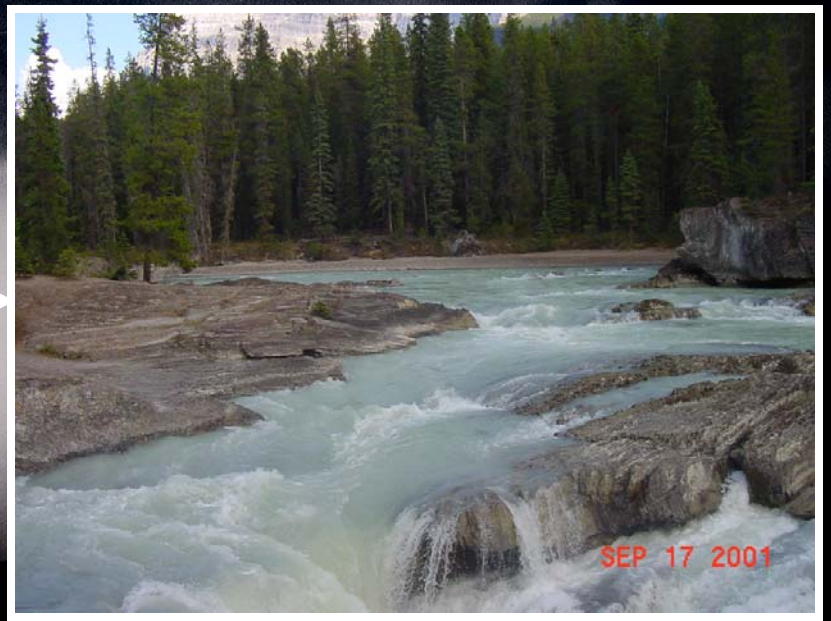
# Benefits of Paleoflood Research

- Can provide flood data for hundreds to thousands of years
- Complements existing streamflow-gage data
- More robust flood-frequency estimates
- Can evaluate effects of climate variability/change on maximum flooding
- Can be used in many water-resources studies
  e.g., reservoir water-storage reallocation (2009 Conference presentation)

Upper Columbia River, Canada -
"An ideal paleoflood site"
Bedrock channel with ~10,000 years of paleoflood deposits

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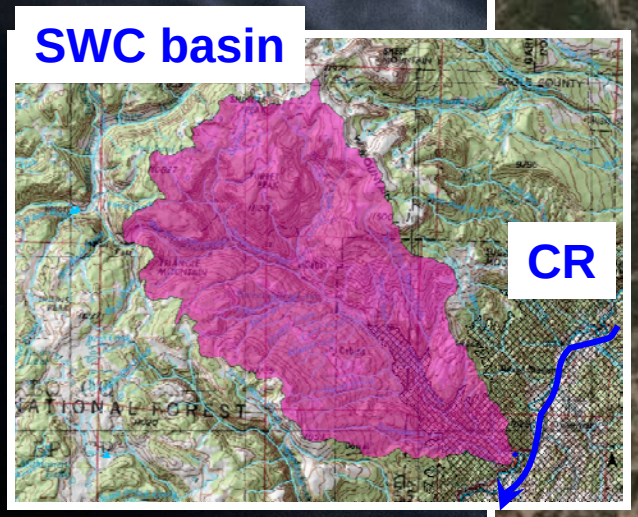
# Lower Sweetwater Creek basin




Turret Creek

Colorado River

SWC Lake

Sheep Creek

Sweetwater Creek

Lucky Gulch

Morris Creek

Eagle County's site of interest (80 mi²)

Area of less vegetation, increasing rainfall runoff, and debris flows in SWC basin

USGS gage (105 mi²)



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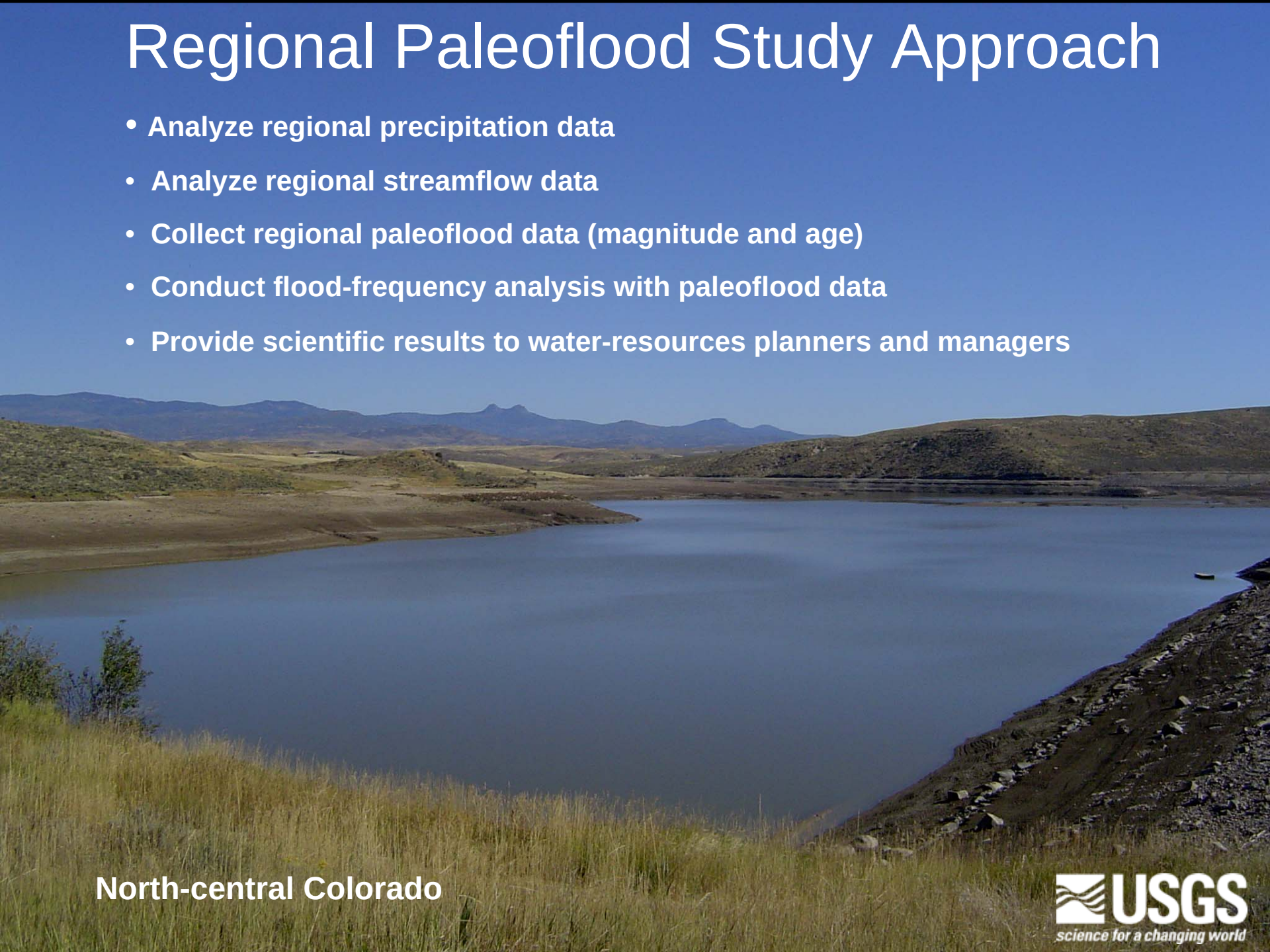
# Regional Paleoflood Study Approach

- Analyze regional precipitation data
- Analyze regional streamflow data
- Collect regional paleoflood data (magnitude and age)
- Conduct flood-frequency analysis with paleoflood data
- Provide scientific results to water-resources planners and managers



North-central Colorado

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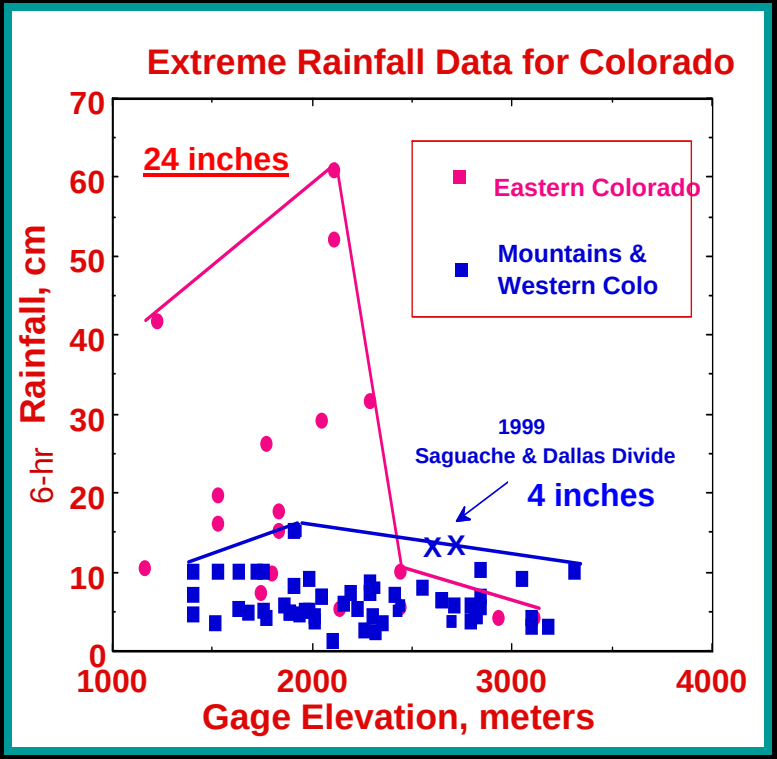
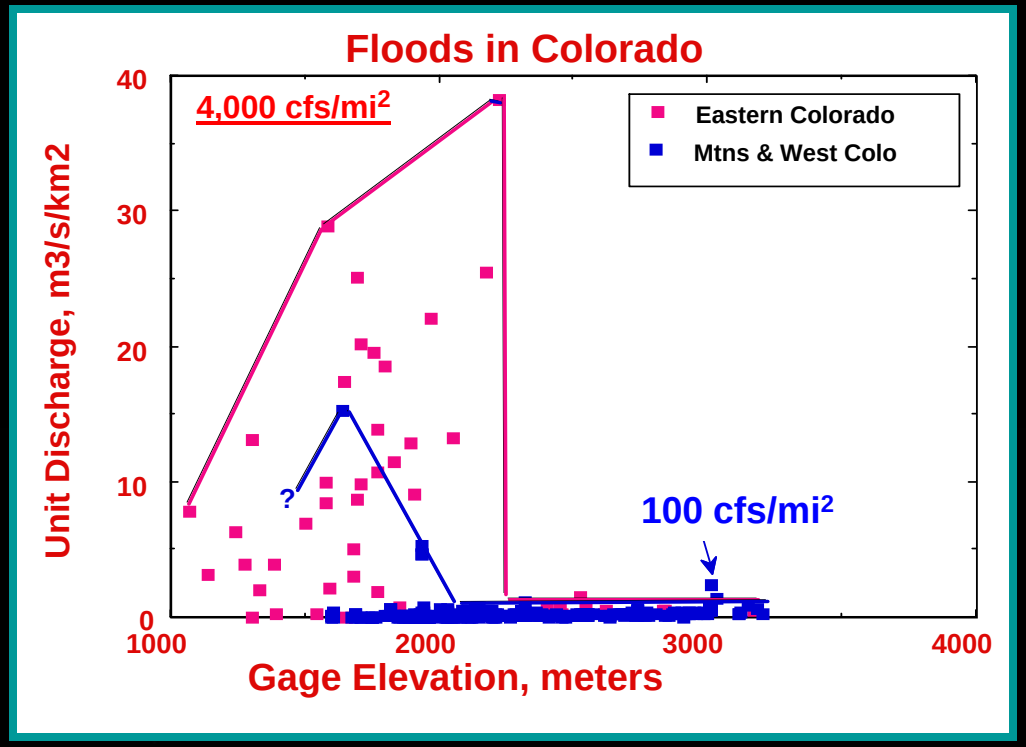



**2,300 meters ~ 7,500 feet elevation**

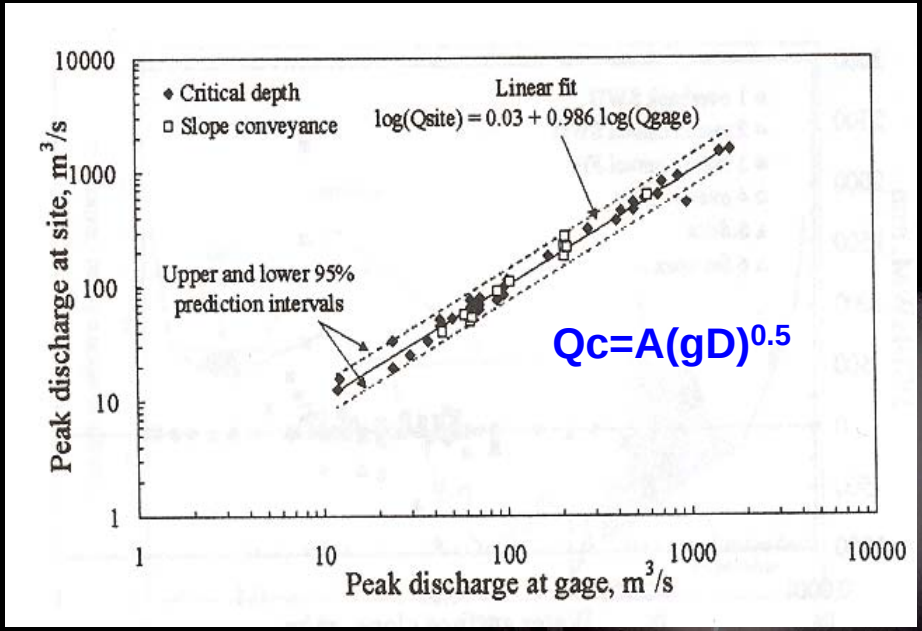
## Summary - Colorado Analyses of Storms and Floods

- small rainstorms and flooding >7,500 ft
- storm footprint in mountains <25 $mi^2$
- rapid transition from snowmelt to rain floods below about 7,500 ft

# Paleoflood Methods

## Flood Discharge

**Validation of flood discharge using critical-depth method (Qc) for 36 higher gradient streams (±15 percent)**




Jarrett & England (2002)

**For streams with slopes of 0.01+ ft/ft**

## Age of Paleofloods

- **Absolute-dating methods**
  - **$^{14}$C of organic material in flood deposits**
  - **OLS**
  - **Dendrochronology of age of trees on flood deposits**
- **Relative-dating methods**

Jarrett & Tomlinson (2000)

# Types of paleoflood evidence in the Sweetwater Creek area to assess flood height

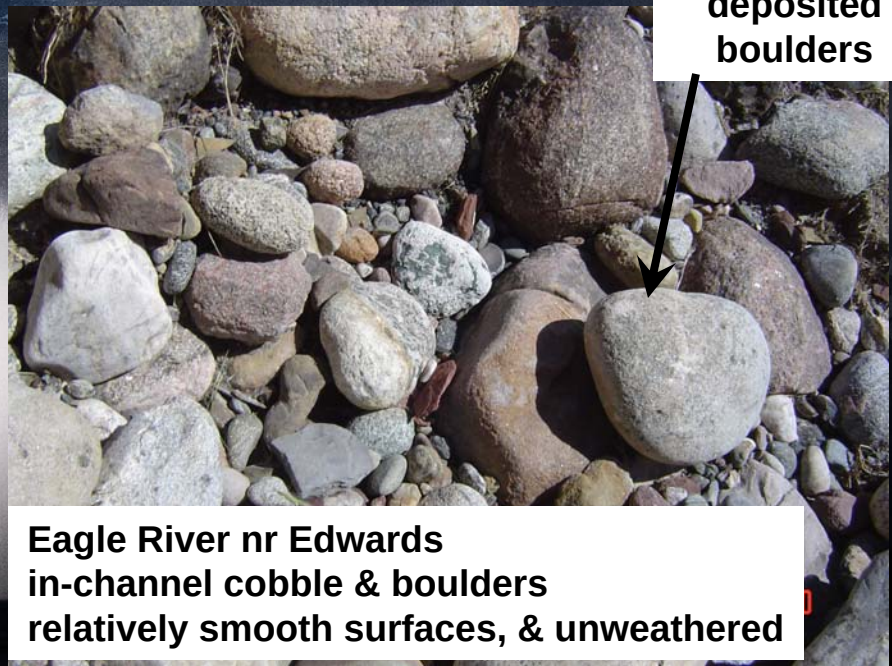

Old woody debris


Older tree scar

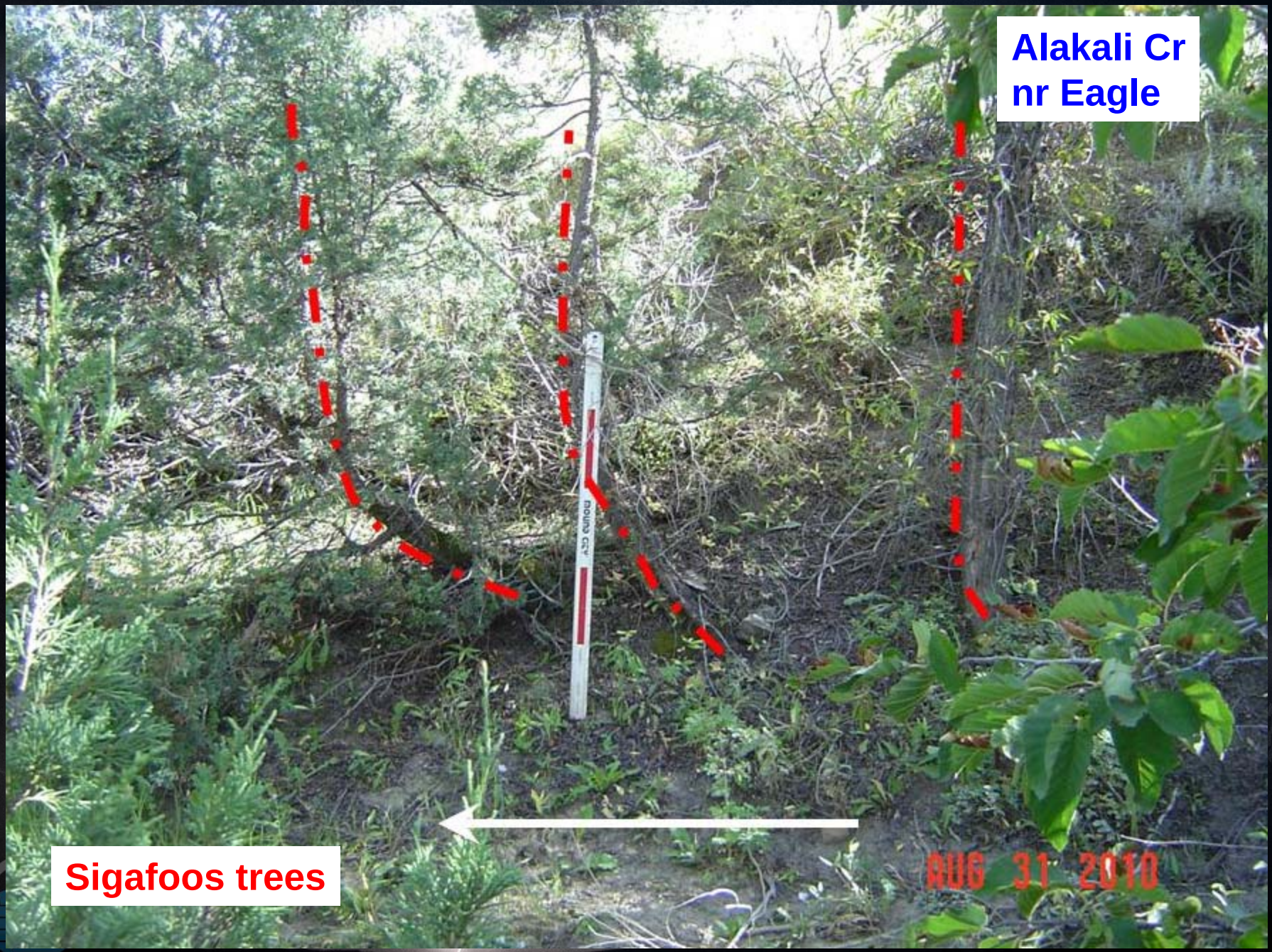
recent woody debris

Unweathered, recent flood-deposited boulders

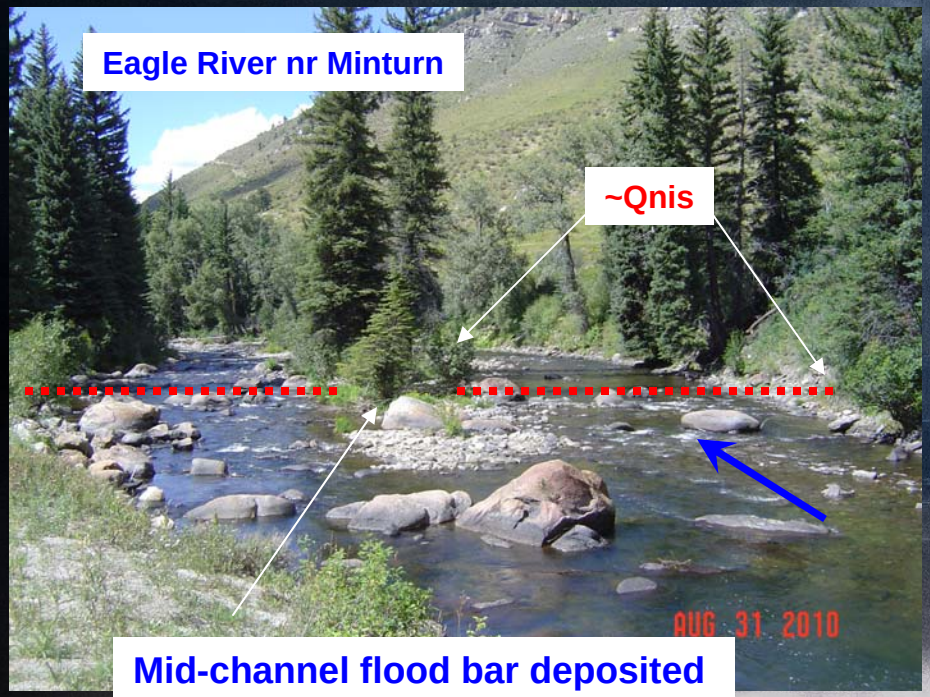

Extremely weathered, very old flood boulders (stream to left of deposit)



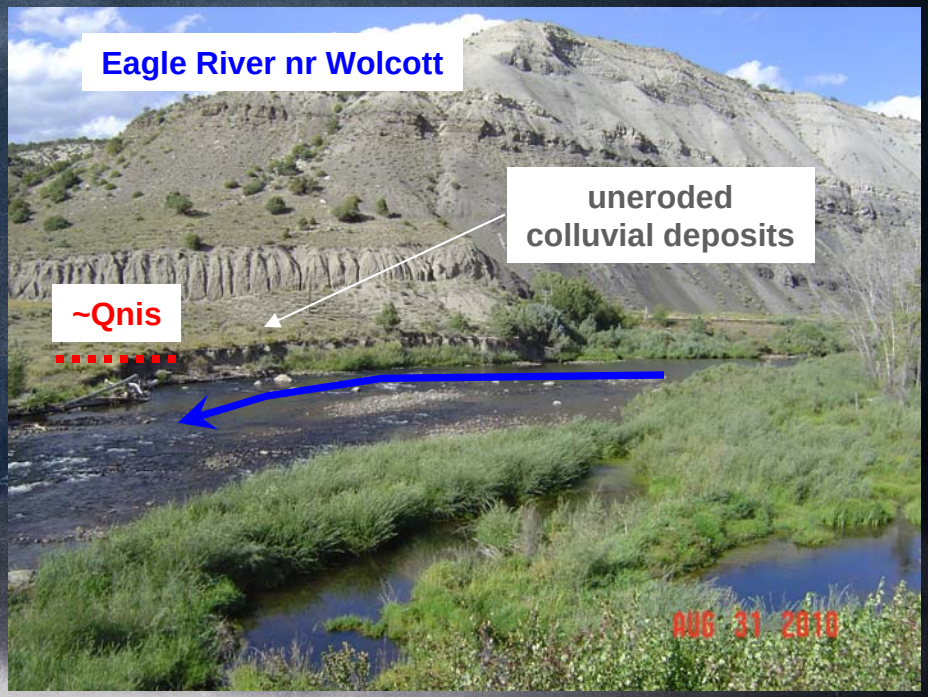
Eagle River nr Edwards
in-channel cobble & boulders
relatively smooth surfaces, & unweathered


Alakali Cr
nr Eagle
Sigafoos trees
AUG 31 2010

# Lack of flood evidence, non-inundation surfaces (upper bound of flooding in some length of time)




Mid-channel flood bar deposited d/s from glacial-outwash boulder w/ 100+ year old spruce trees

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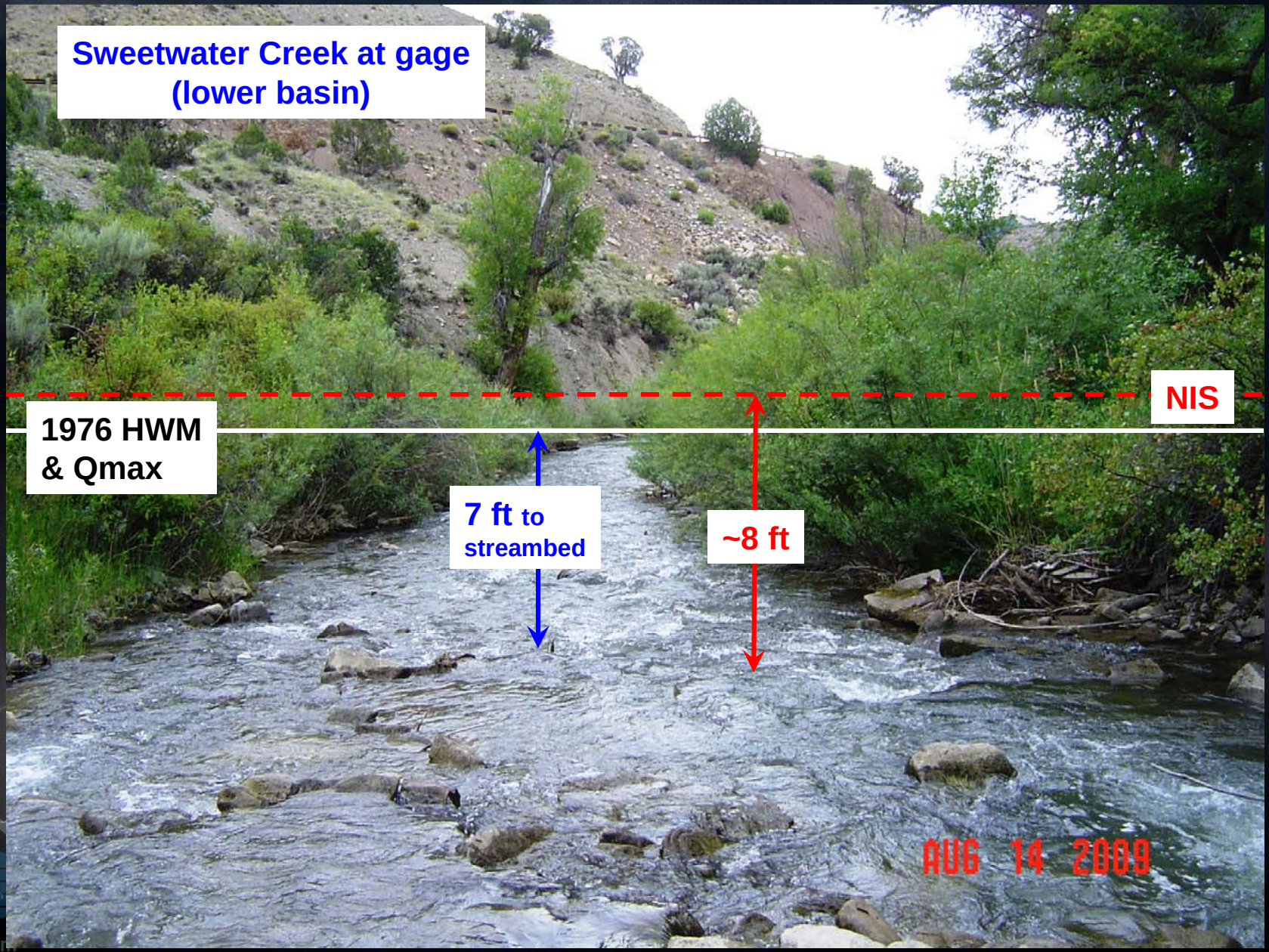
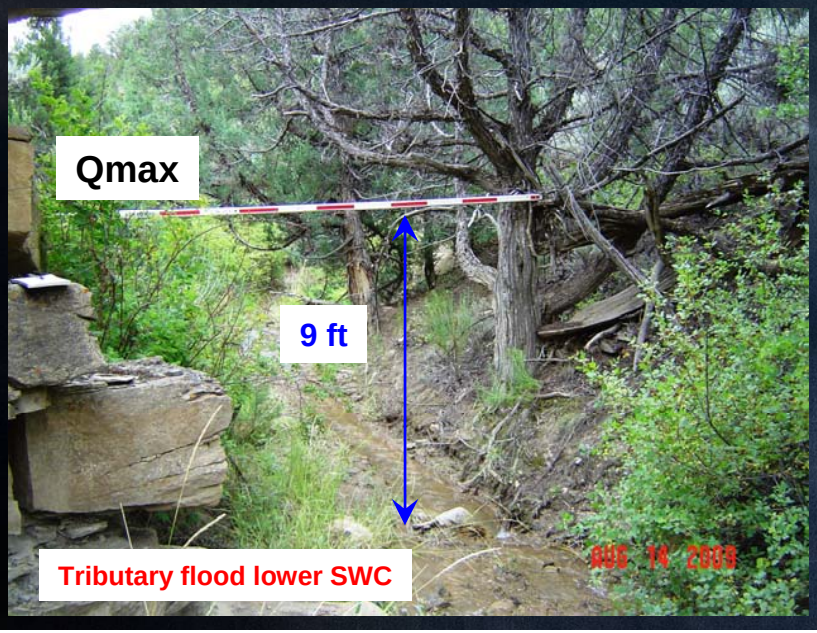
Photos for Paleoflood & Ecological Restoration Fieldtrip

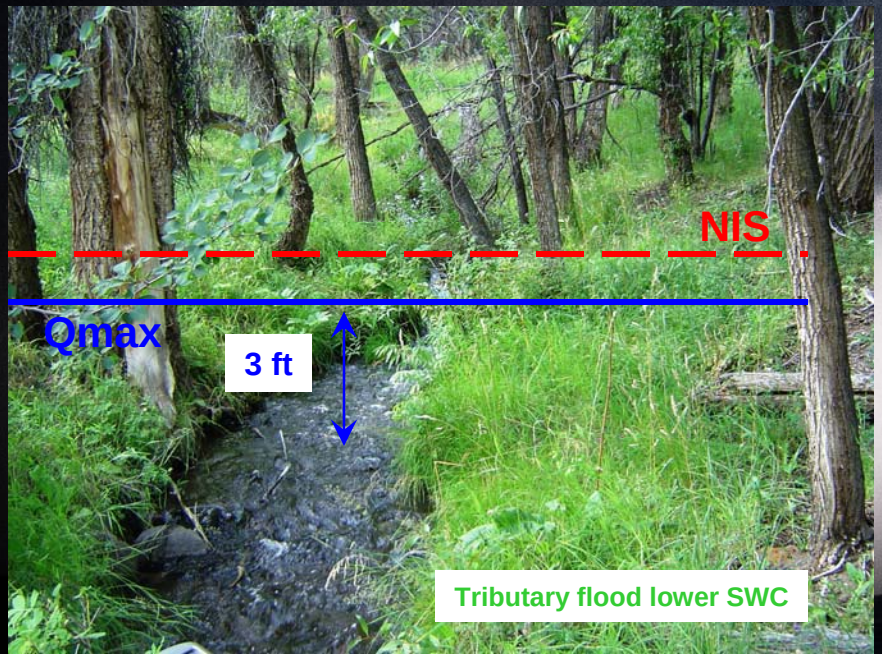
# Floods and paleofloods Sweetwater Creek and vicinity



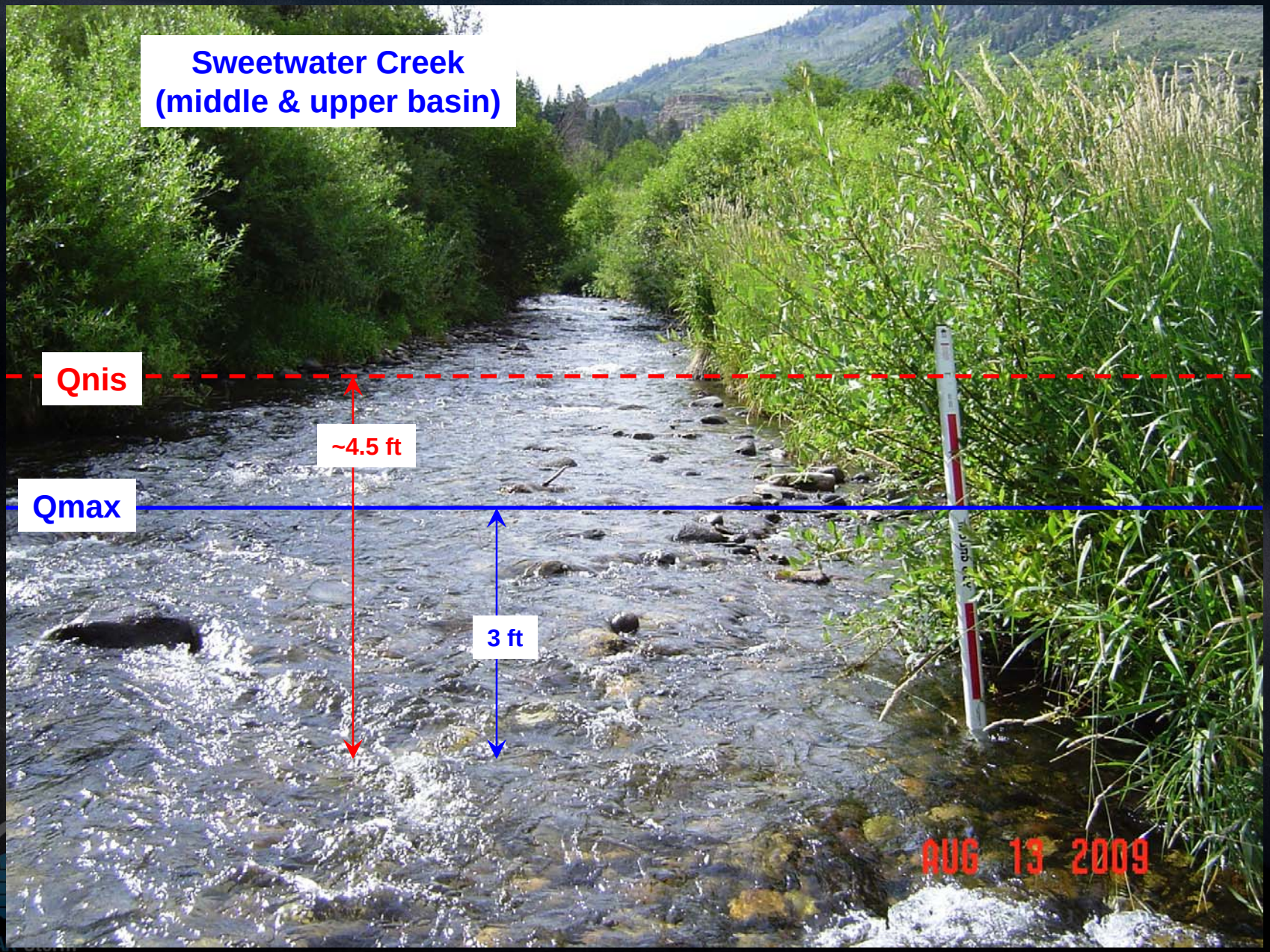
# Floods and paleofloods low & high Sweetwater Creek tributaries



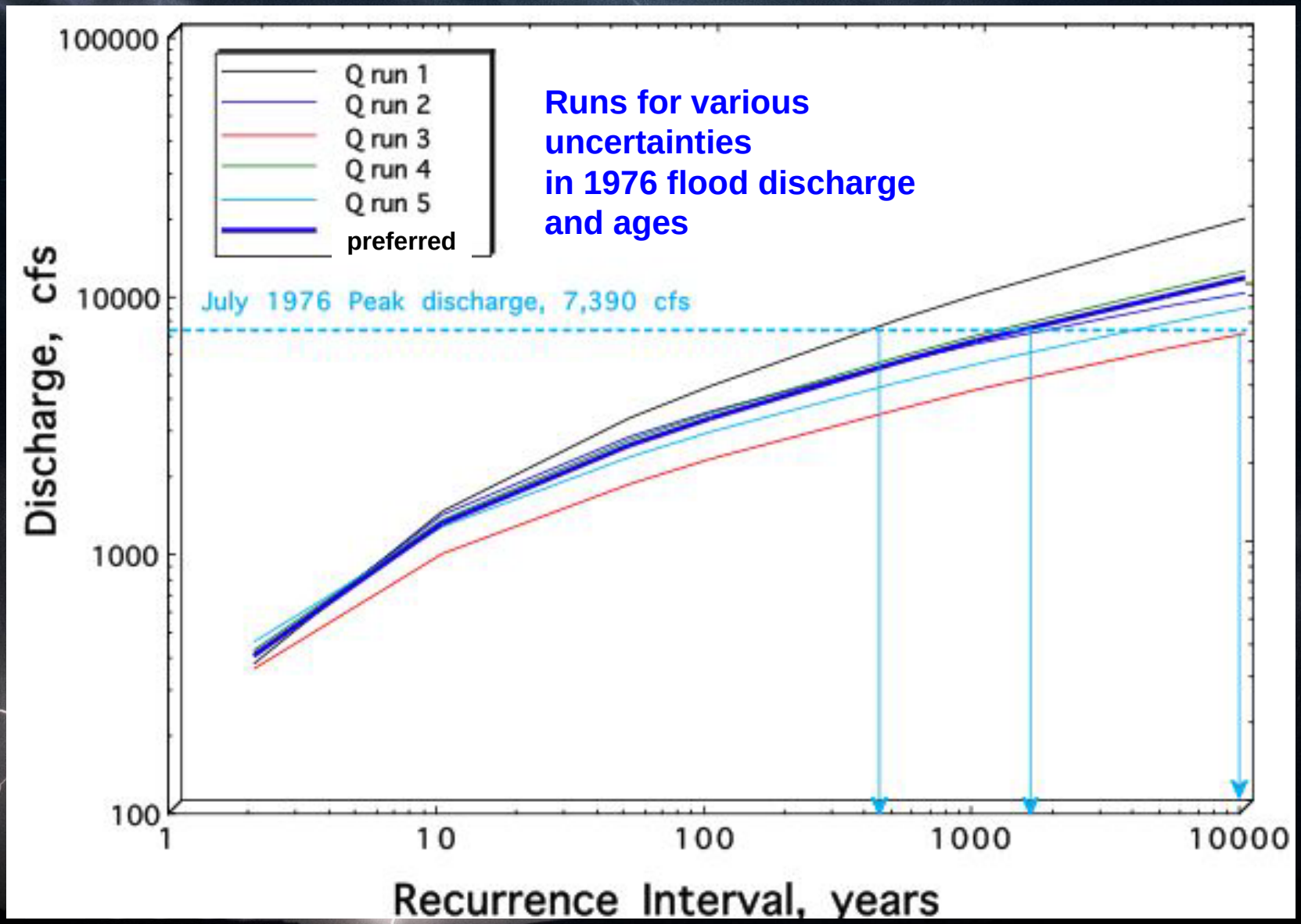





# Flood and paleoflood deposits Sweetwater Creek and vicinity



# Flood-frequency relations
# Sweetwater Creek at USGS streamflow-gaging station



## Flood frequency for Sweetwater Creek at gage

**Averaged B17B and EMA Flood-Frequency Analyses**

| Recurrence Interval Years | B17B results cfs | EMA results cfs |
|---|---|---|
| 2 | 300 | 390 |
| 10 | 920 | 1,100 |
| 50 | 2,000 | 2,300 |
| **100** | **2,600** | **2,900** |
| 500 | 4,700 | 4,800 |
| 1,000 | - | 5,800 |
| 5,000 | - | 8,600 |
| 10,000 | - | 10,000 |

**Recall flood-frequency range was 1,520 cfs to 2,800 cfs**

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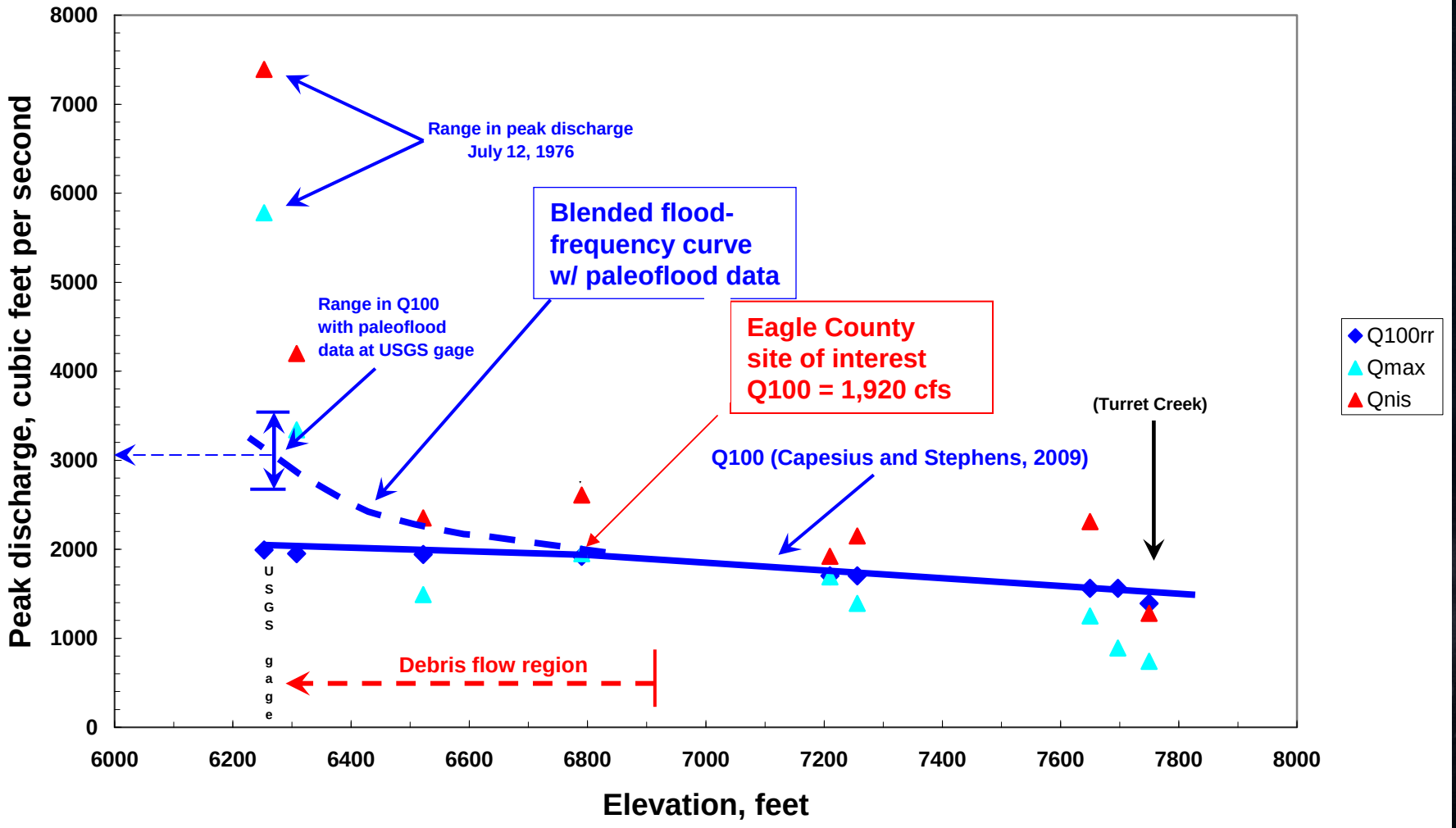
# Peak Discharge vs Elevation for Mainstem Sweetwater Creek
# Eagle County, Colorado

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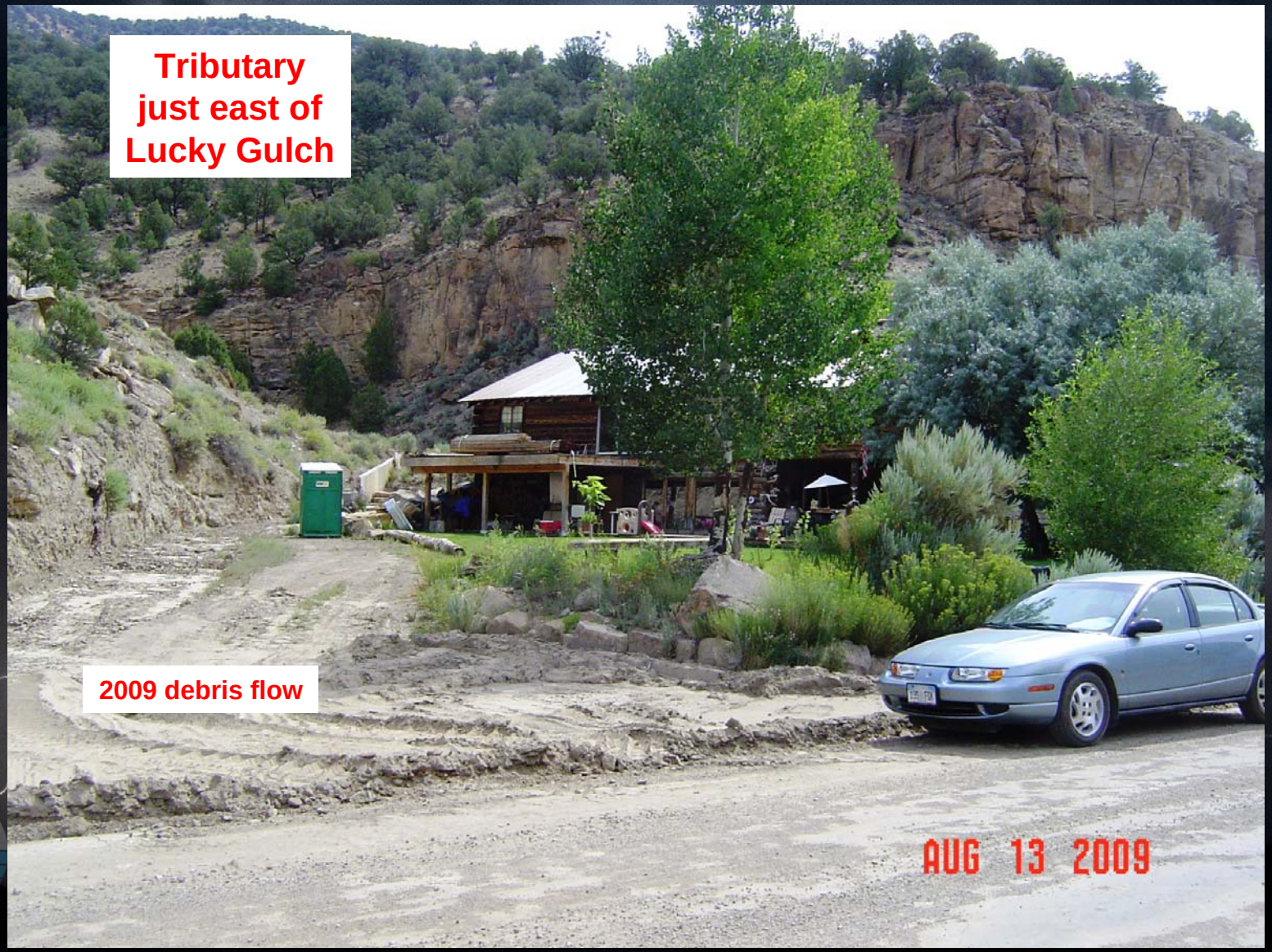
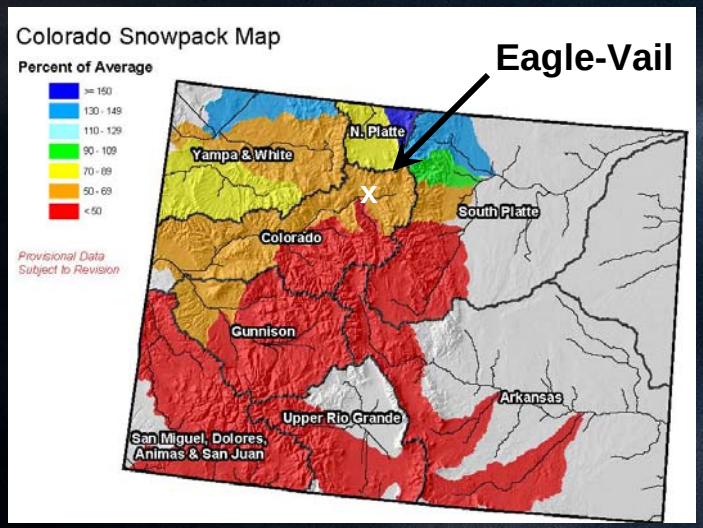
# Substantial debris-flow potential in lower/drier basins in Sweetwater Creek and Eagle County, Colorado

# Substantial debris-flow potential in lower/drier basins in Sweetwater Creek and Eagle County, Colorado

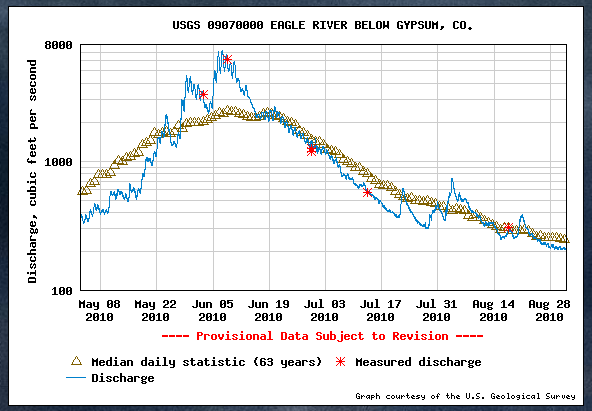


# June 1, 2010 snowpack

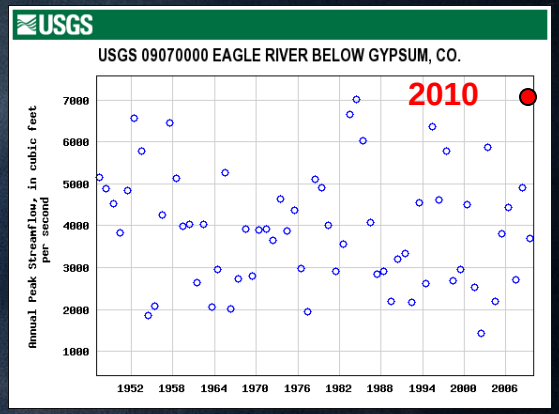


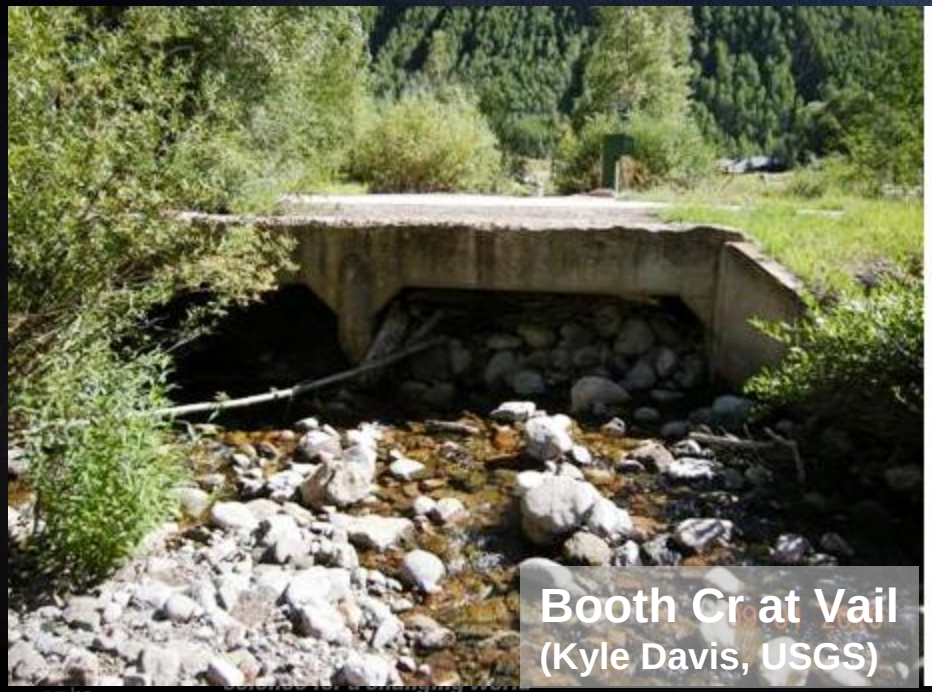

# Eagle River blw Gypsum, CO

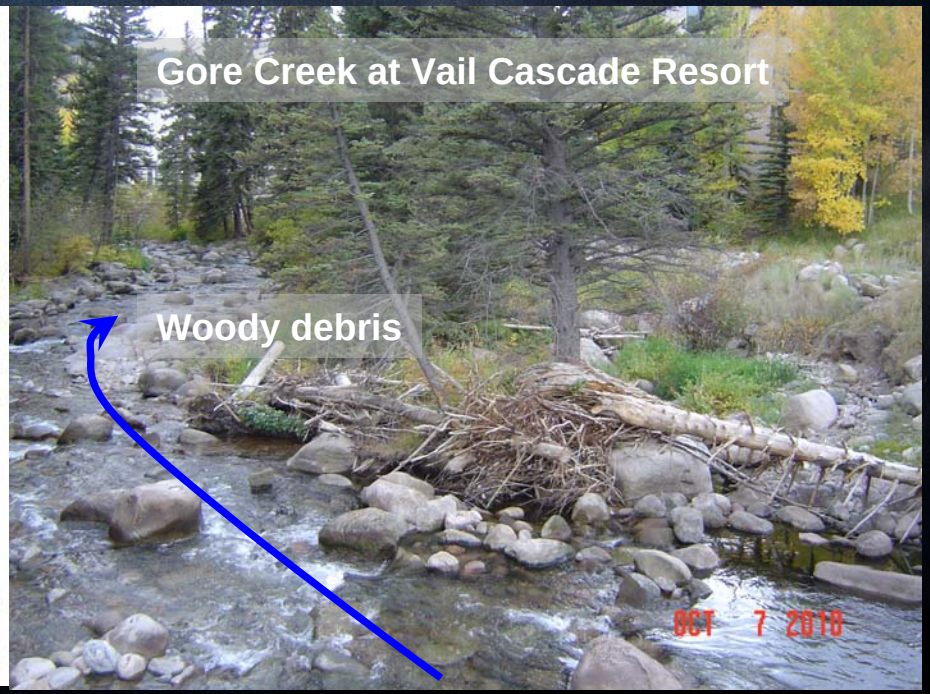
## Hydrograph, Qp= 7,050 cfs




## graph of annual peaks

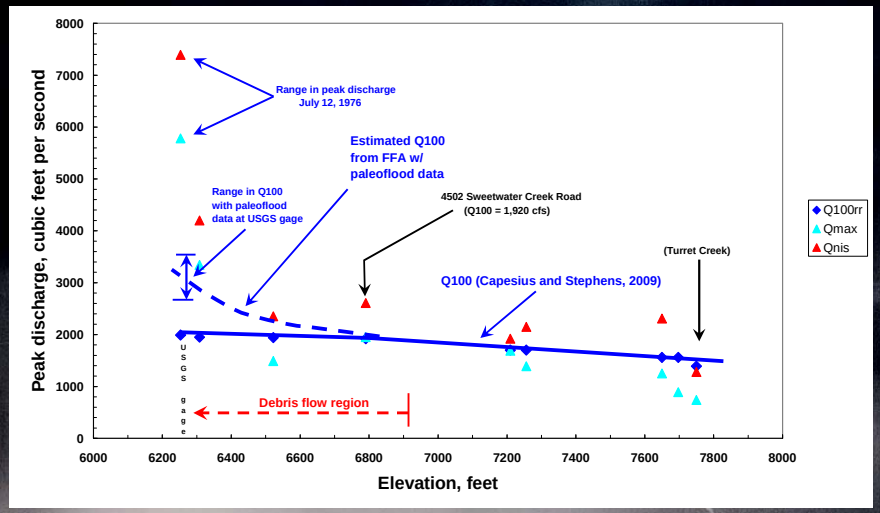


# Concluding Remarks

- Overview of paleoflood hydrology
- Better define flood and debris-flow hazards
- New insight of flood hydroclimatology
- Improves flood frequency with paleoflood data




- Methods are cost-efficient, validated, and were developed for hydrologists, geomorphologists, etc. Data collection (20-30 sites) about 2-3 days.

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# Thanks

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