Floods and Debris Flows in the Catalina Front Range

July 31, 2006

Bob Webb, Peter Griffiths, Chris Magirl, and Diane Boyer, USGS
Erik Pytlak, Craig Shoemaker, and Michael Schaffner, NWS
Phil Pearthree and Ann Youberg, Arizona Geological Survey

The Extreme Precipitation Event of July 31, 2006, and Its Effects

- In the early morning hours of July 31, following 4 days of rain, pulses of rainfall from mesoscale convective thunderstorms fell on the southern Santa Catalina and western Rincon Mountains.
- Record floods occurred in Rincon Creek, Pantano Wash, Tanque Verde Creek, Sabino Creek, and Rillito Creek.
- What was really spectacular, though, was what happened in Sabino Canyon and other nearby watersheds in the Front Range of the Santa Catalina Mountains.

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GOES Water Vapor Imagery from July 31, 2006

Upper-level low-pressure system over New Mexico steered moisture into southern Arizona over a five-day period.

Early in the morning on July 31, a series of thunderstorms moved southwards from the Phoenix area through northeastern Pima County.

Half-hour images; white indicates high atmospheric water content

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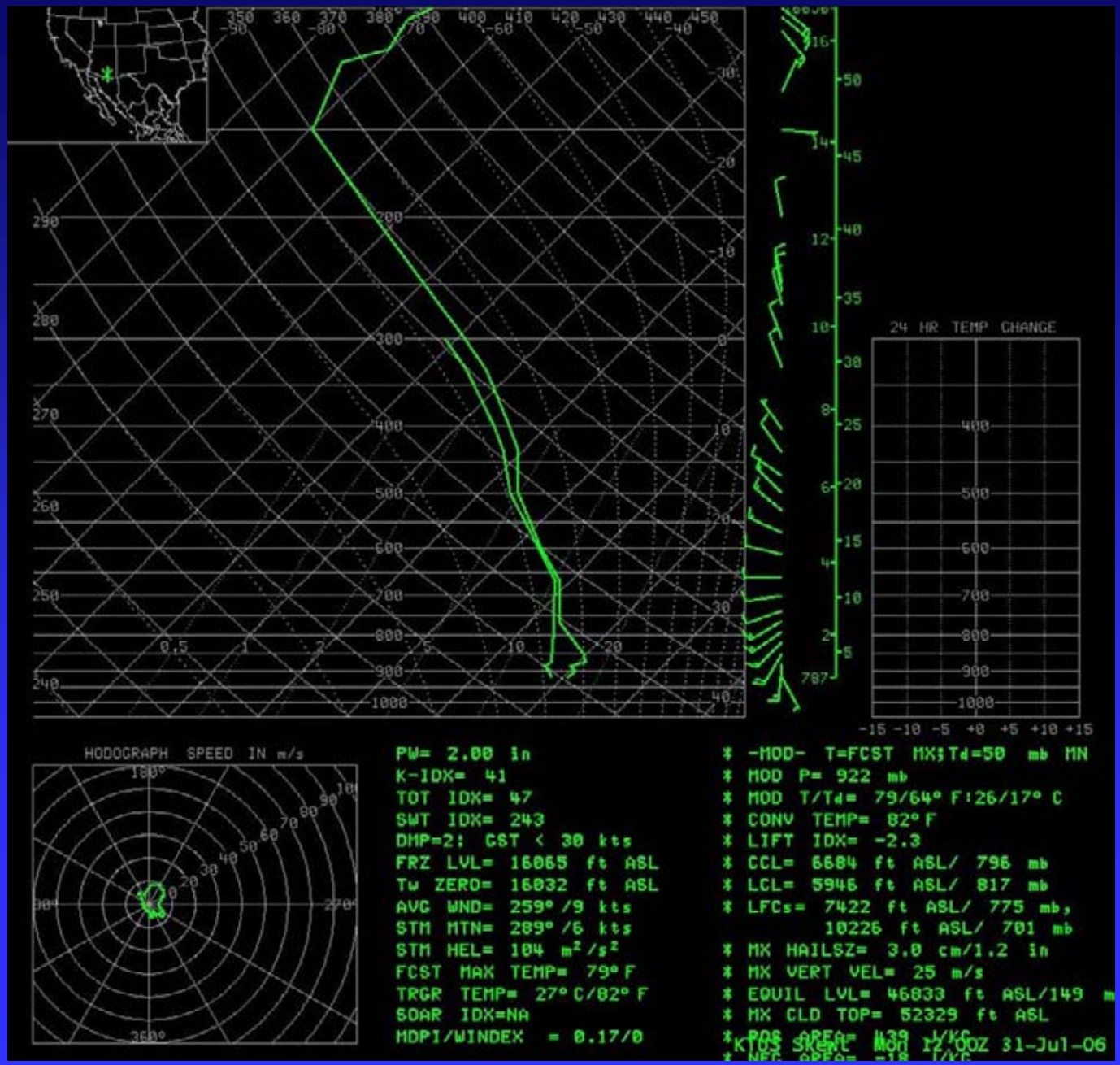
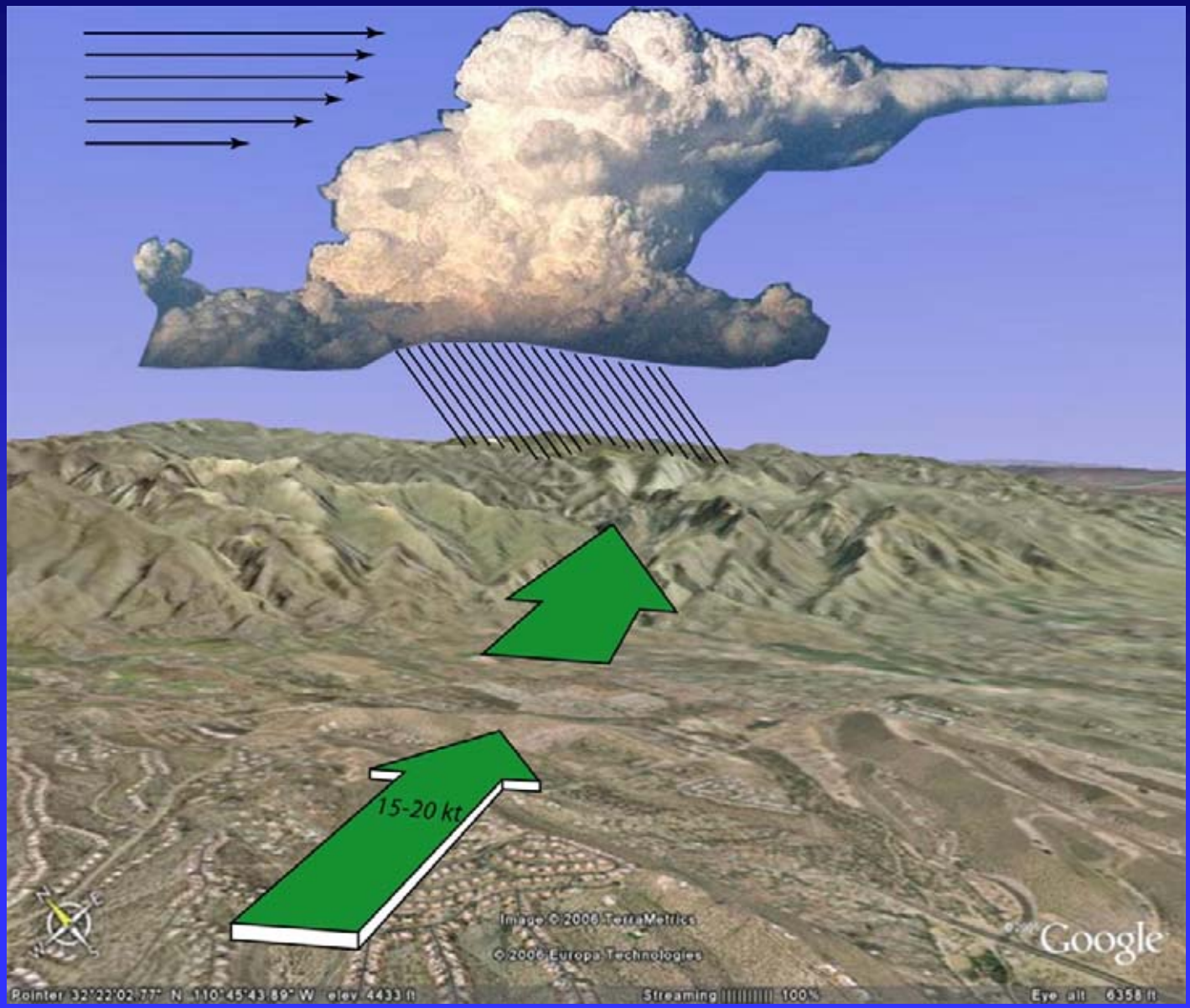
Morning Weather Balloon Sounding on July 31, 2006



Upper -Level Shear From Northwest; Lower-Level Jet from Southwest



Wind and water vapor movement was like a firehose aimed straight up over Sabino Canyon and other Santa Catalina Mountain tributaries the morning of July 31.

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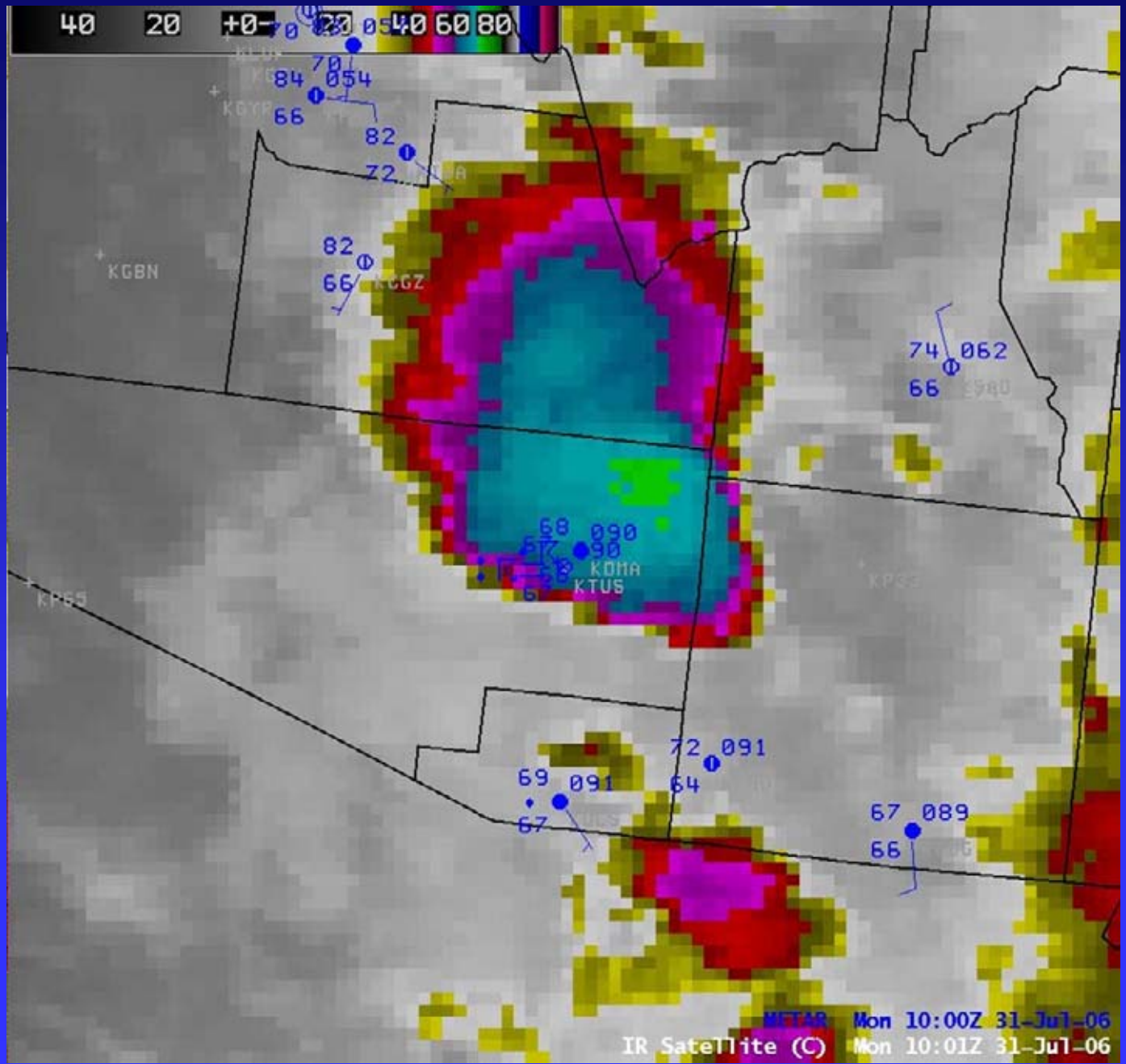
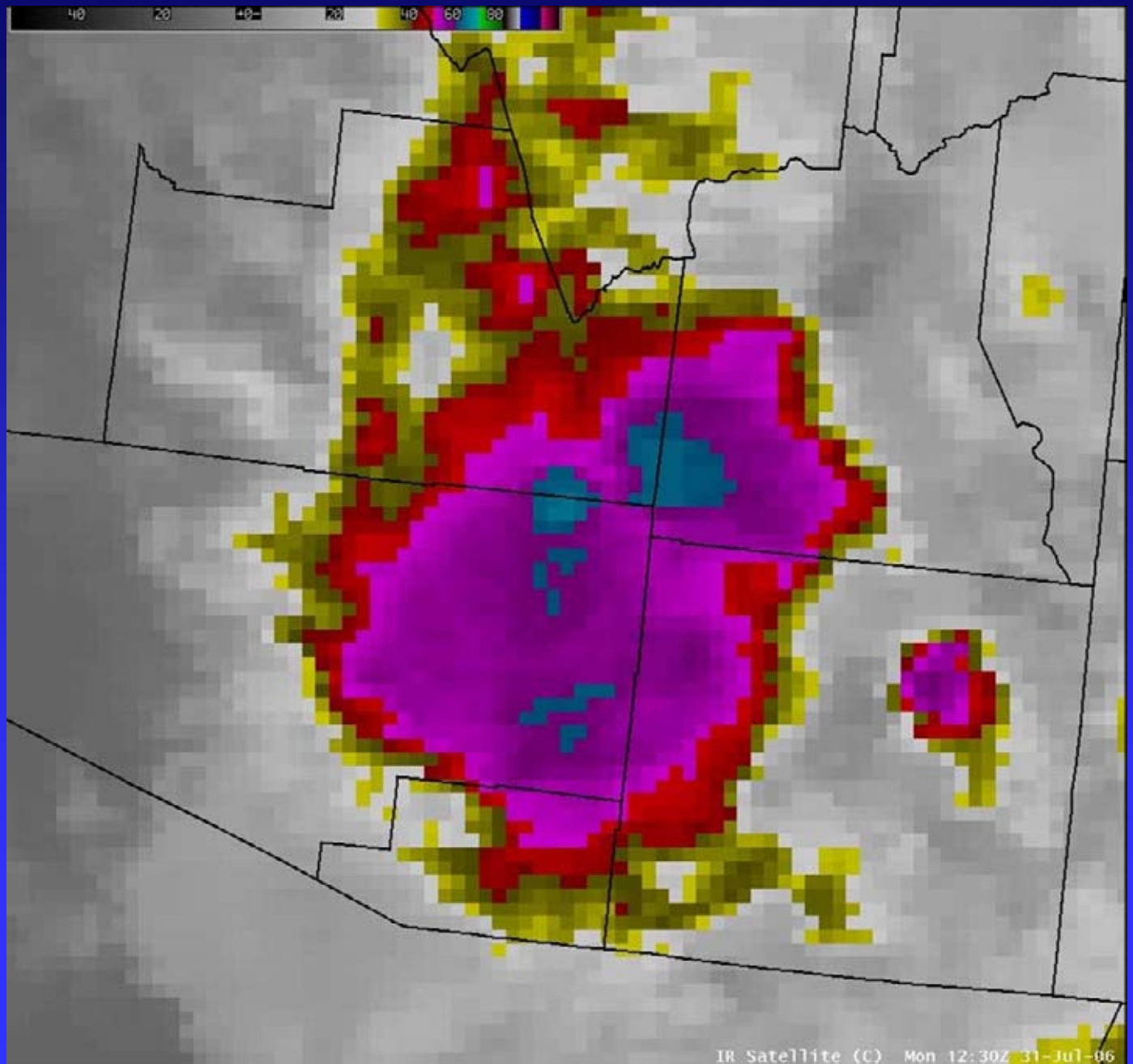
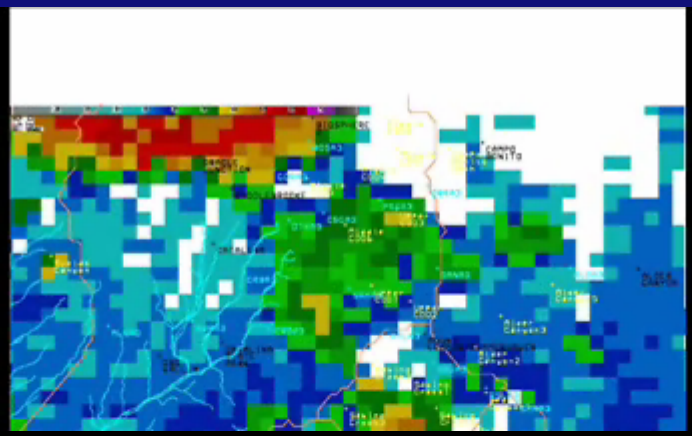
First Punch: Cold-Top Mesoscale Thunderstorm



Second Punch: Warm-Top Mesoscale Thunderstorm



Composite NEXRAD Weather Radar, July 31, 00:00 – 08:00



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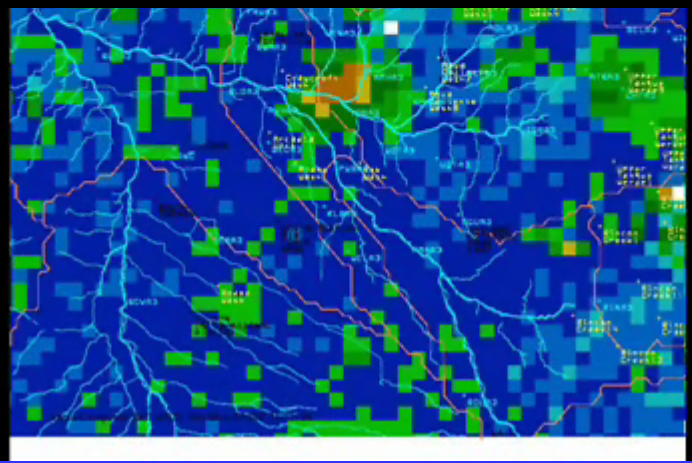
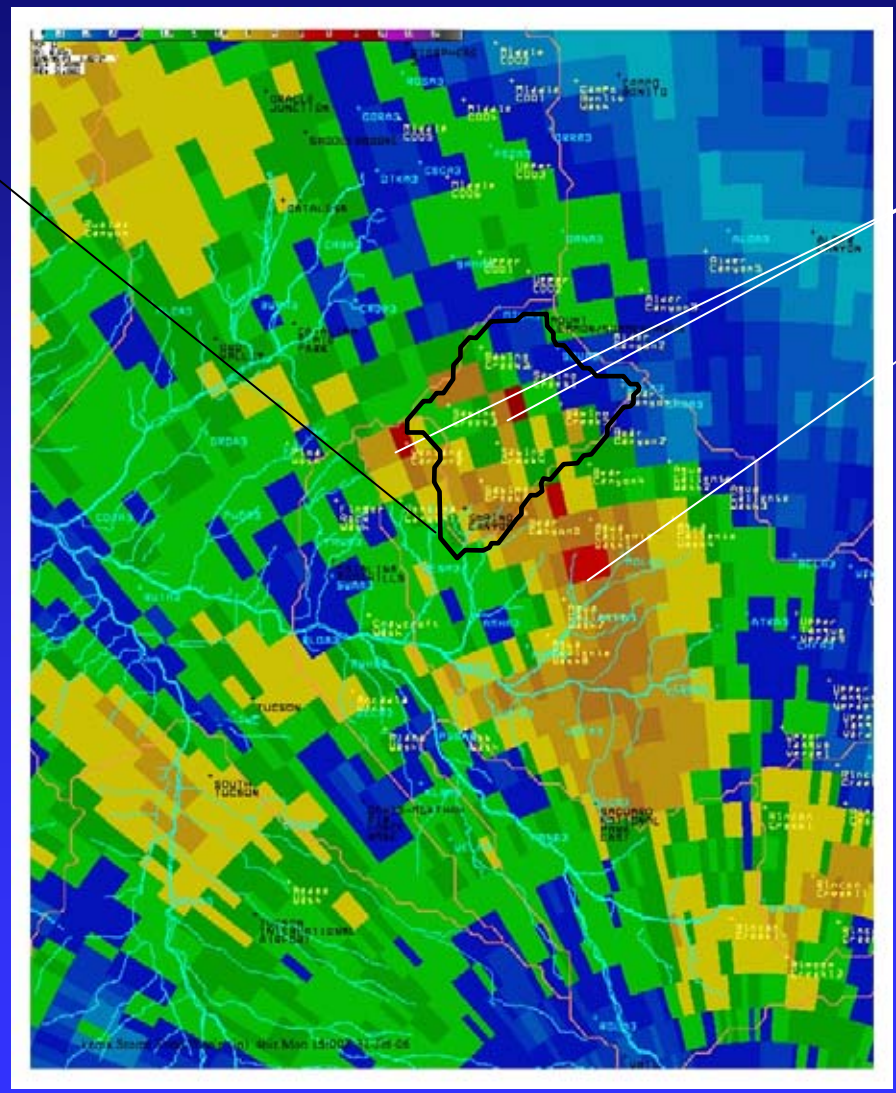


Total Storm Precipitation from NEXRAD Weather Radar



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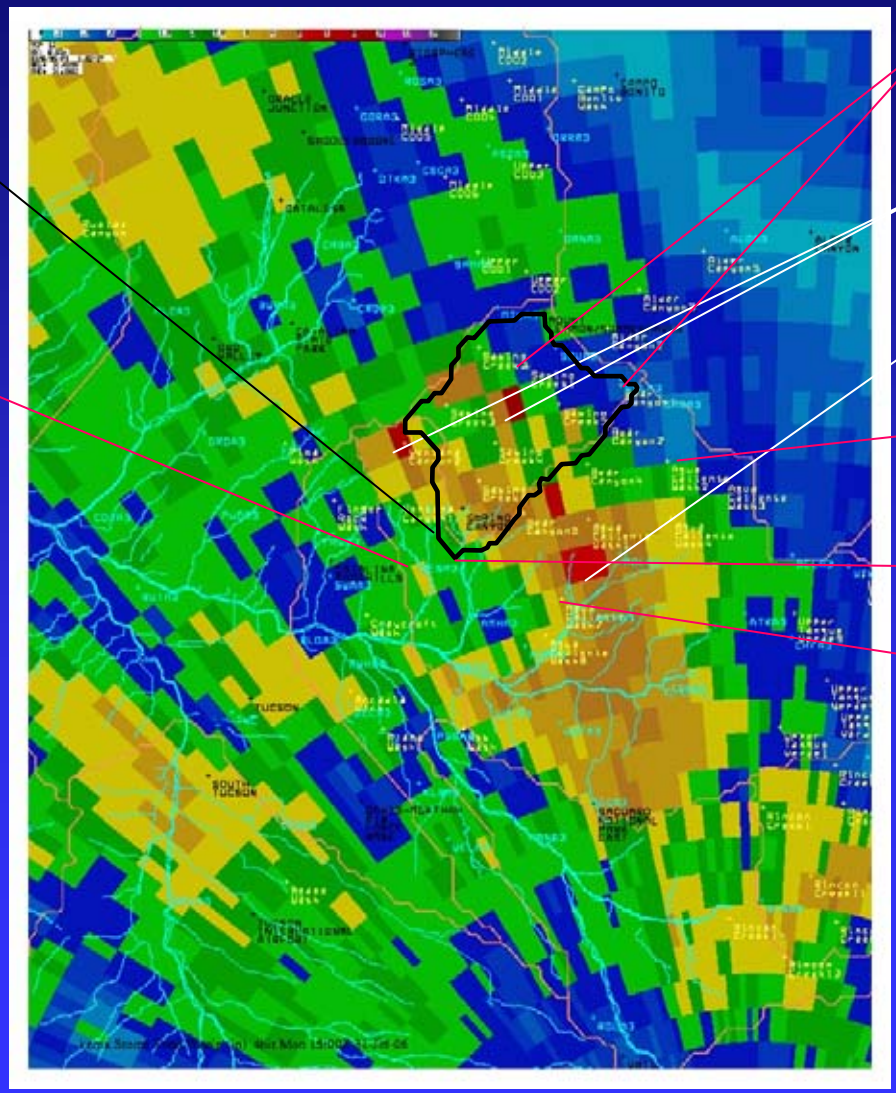
Total Storm Precipitation from NEXRAD Weather Radar and ALERT Rain Gages



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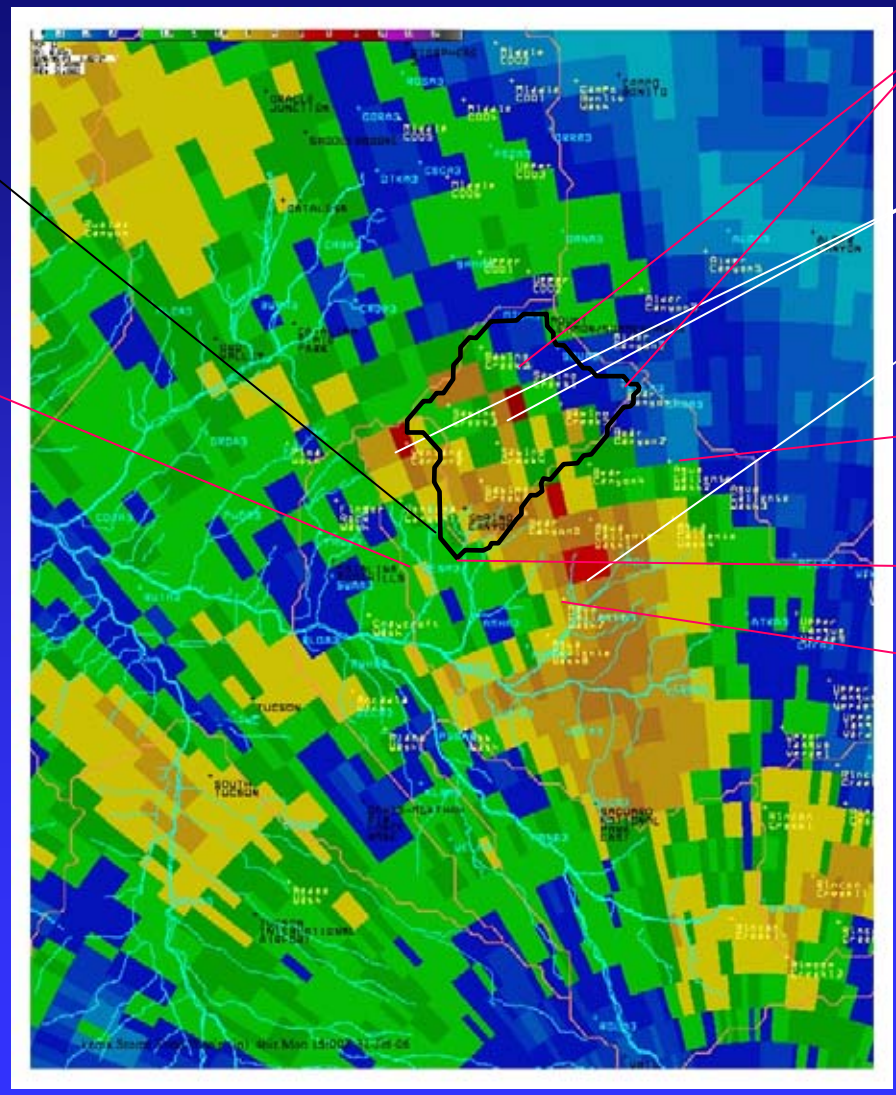
Total Storm Precipitation from NEXRAD Weather Radar and ALERT Rain Gages

Sabino watershed



1.7” – Mt Lemmon & Whitetail

8-10”

5-6”

Ventana - 1.3”

0.8” – Green Mtn.

2.0” – Sabino

4.6” - Molino

ALERT System Peak Storm Intensities (in/hr)

Mt. Lemmon	0.4”
Whitetail	0.5”
Green Mtn.	0.3”
Ventana	0.5”
Sabino	0.5”
Molino	1.4”

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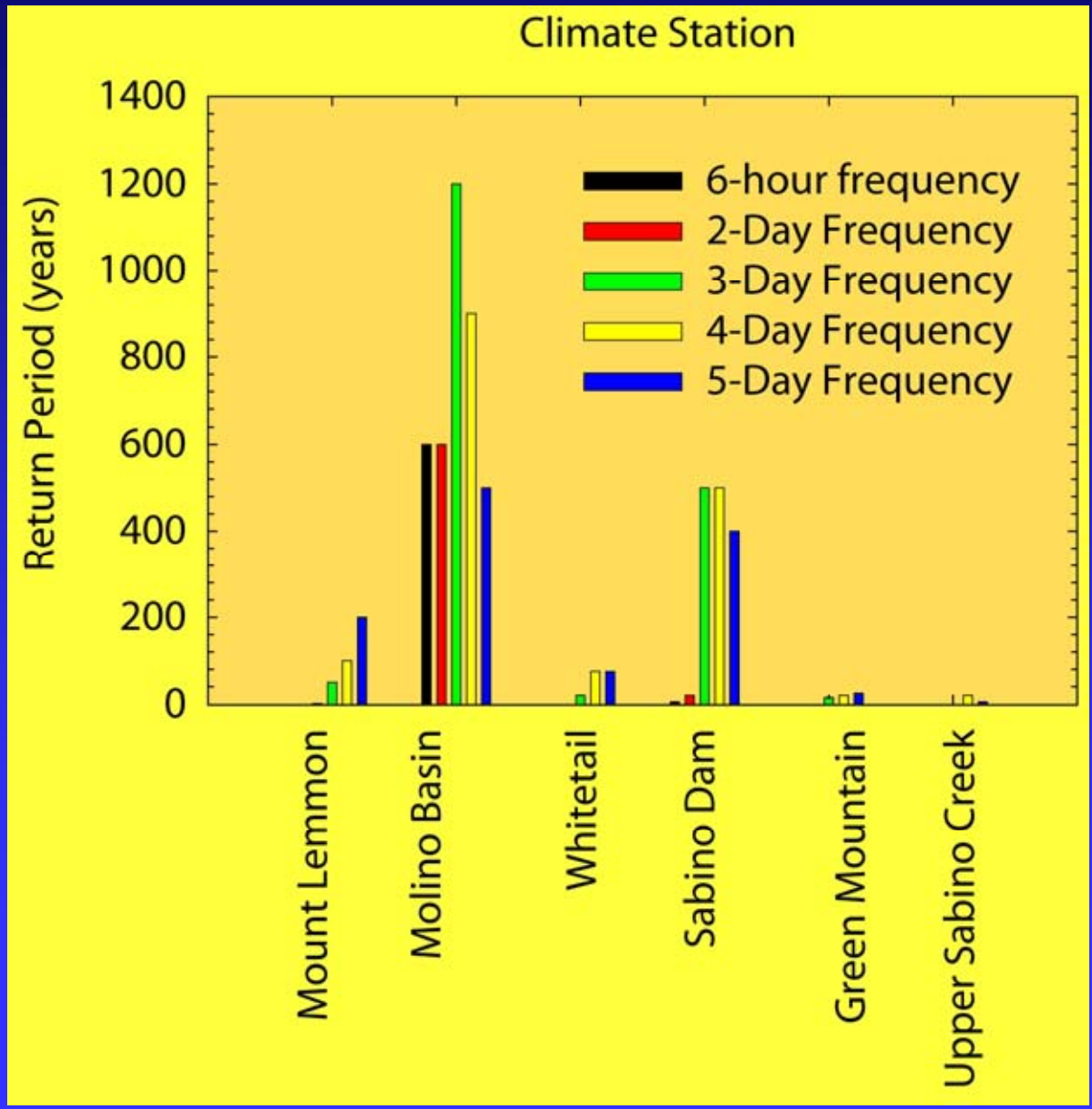
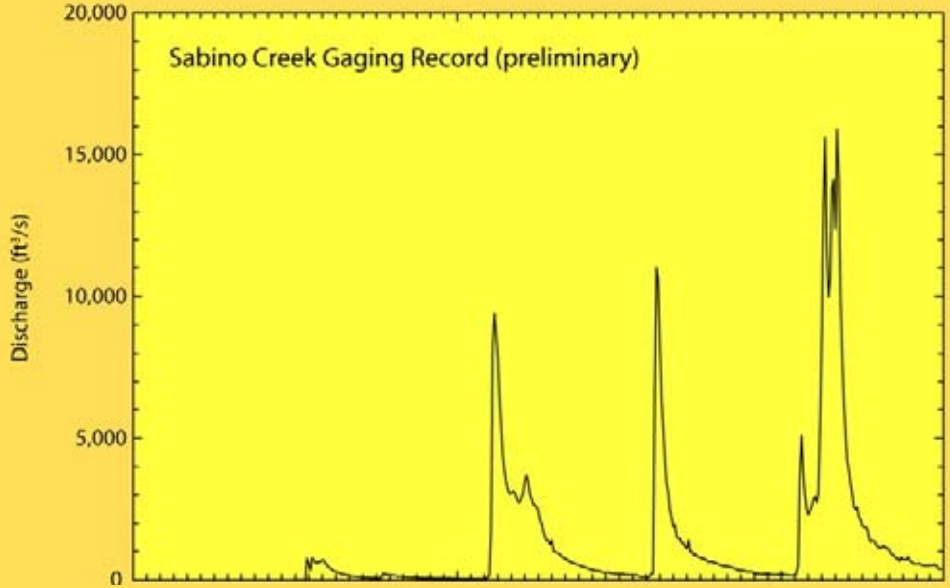
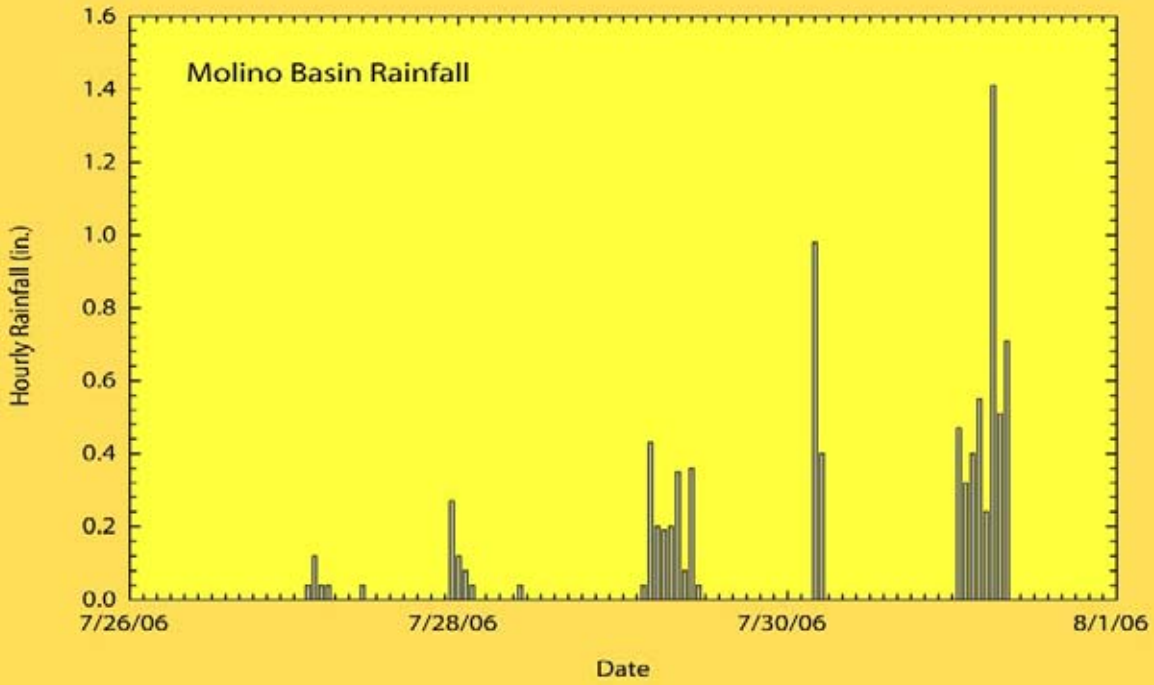
What is Impressive is the Multi-Day Storm Return Periods



Streamflow and Precipitation

July 26-July 31





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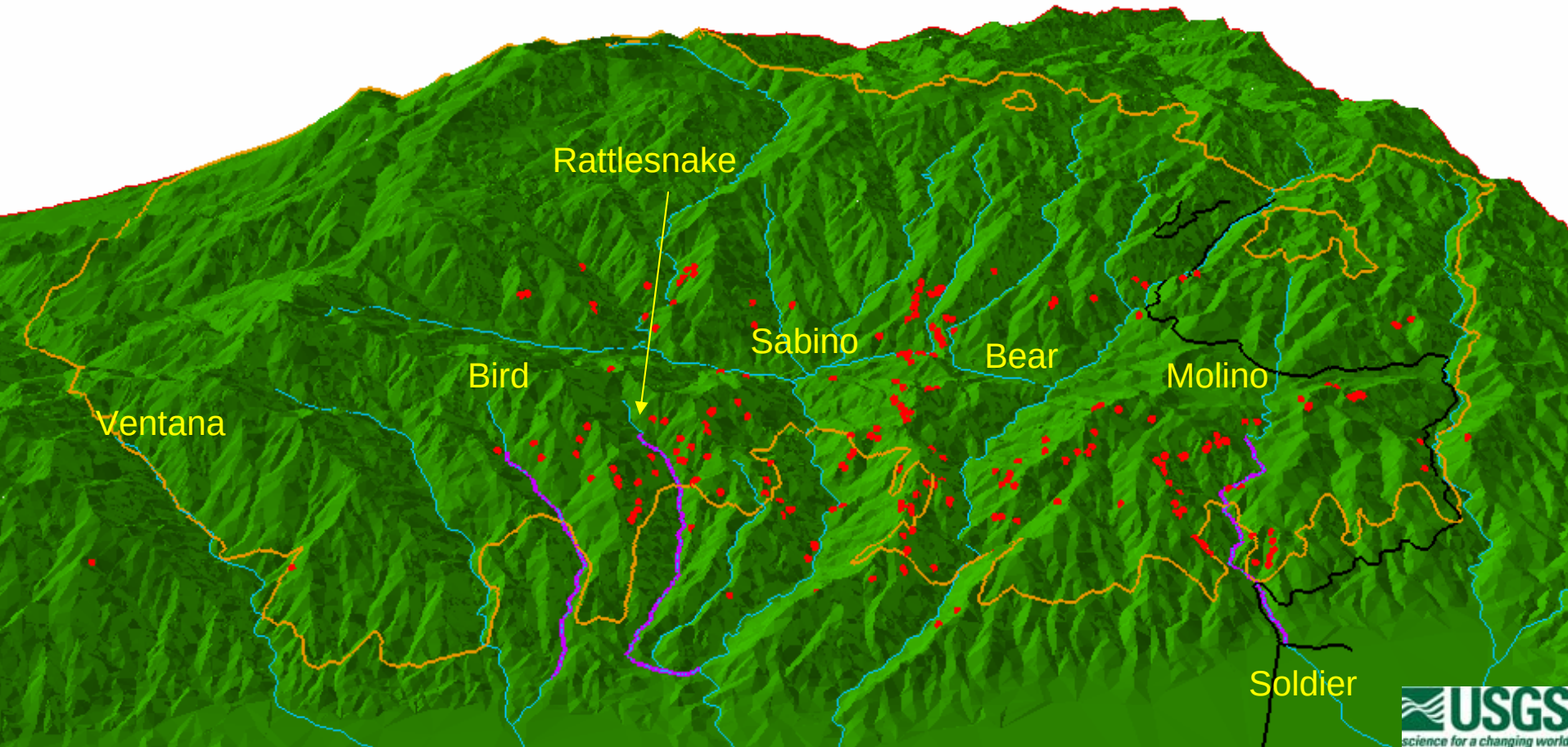
Debris Flows in the Catalina Front Range

Preliminary n = 240 slope failures

Most failures are between 4,000 – 6,000 feet elevation



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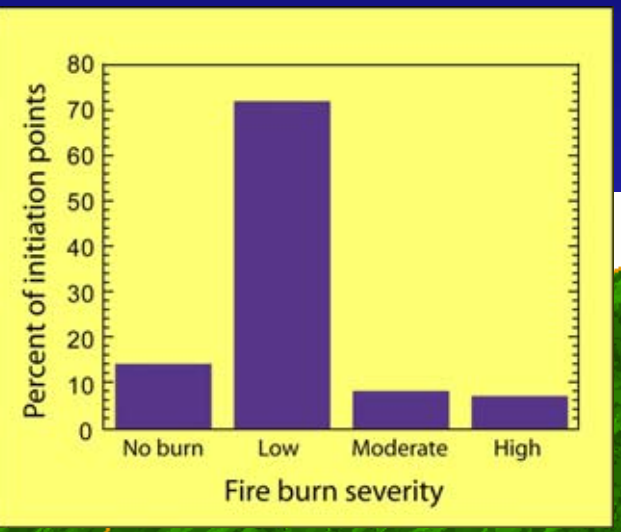

86% of failures were in areas little affected by the 2003 Aspen Fire

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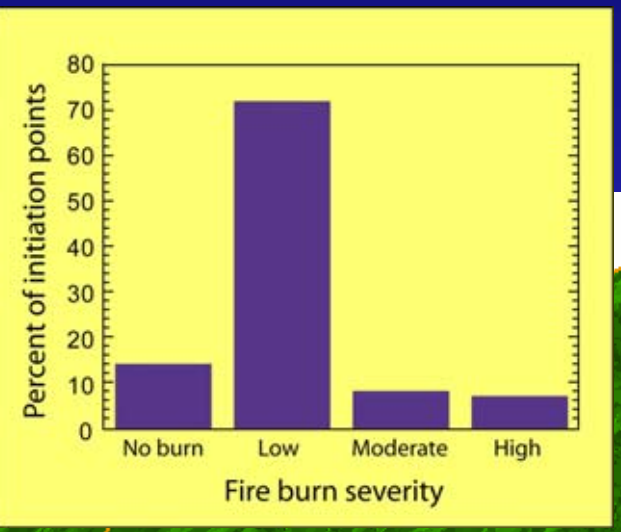

86% of failures were in areas little affected by the 2003 Aspen Fire

Three debris flows made it to or close to the mountain front.

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Debris-Flow History of the Santa Catalina Mountains: Little Known

- Before 2006, about five debris flows (all small) are known to have occurred in the Santa Catalina Mountains.
- In 2003, a small debris flow occurred near Tram Stop 9 in Sabino Canyon.
- A small debris flow occurred in a burned area following the 2002 Bullock Fire.
- In 1997, a small debris flow occurred in Rose Canyon.
- In 1993, another small debris flow occurred in Ventana Canyon.
- In 1983, several slope failures mobilized into debris flows in Bear Canyon.
- Depositional evidence south of the mountain front indicates a long (but perhaps dormant?) occurrence of debris flows.

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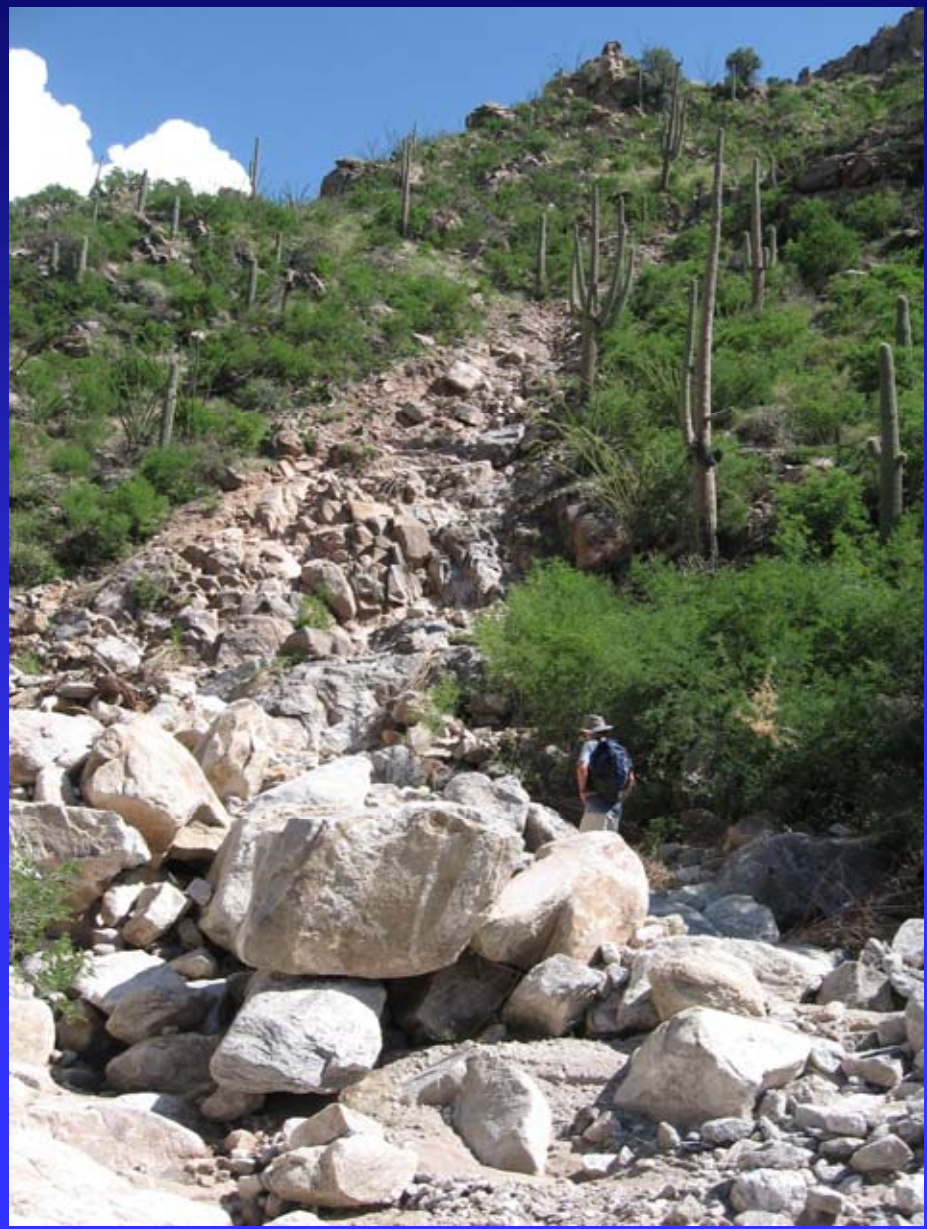
What is a Debris Flow?

- A **slurry** of sediment (70-90%) and water (10-30% by weight).
- Often initiated by the collapse of sediment on a steep slope during intense or prolonged **rainfall**.
- Sediment is typically **poorly sorted**, ranging from clay (< 0.001 mm) to very large boulders (> 1 m).
- A dense, viscous **matrix** can support very large **boulders** and transport them easily over several kilometers.
- A debris flows can deposit **levees** of sediment on either side of the flow, keeping the flow channelized and maintaining forward momentum, even over open ground.



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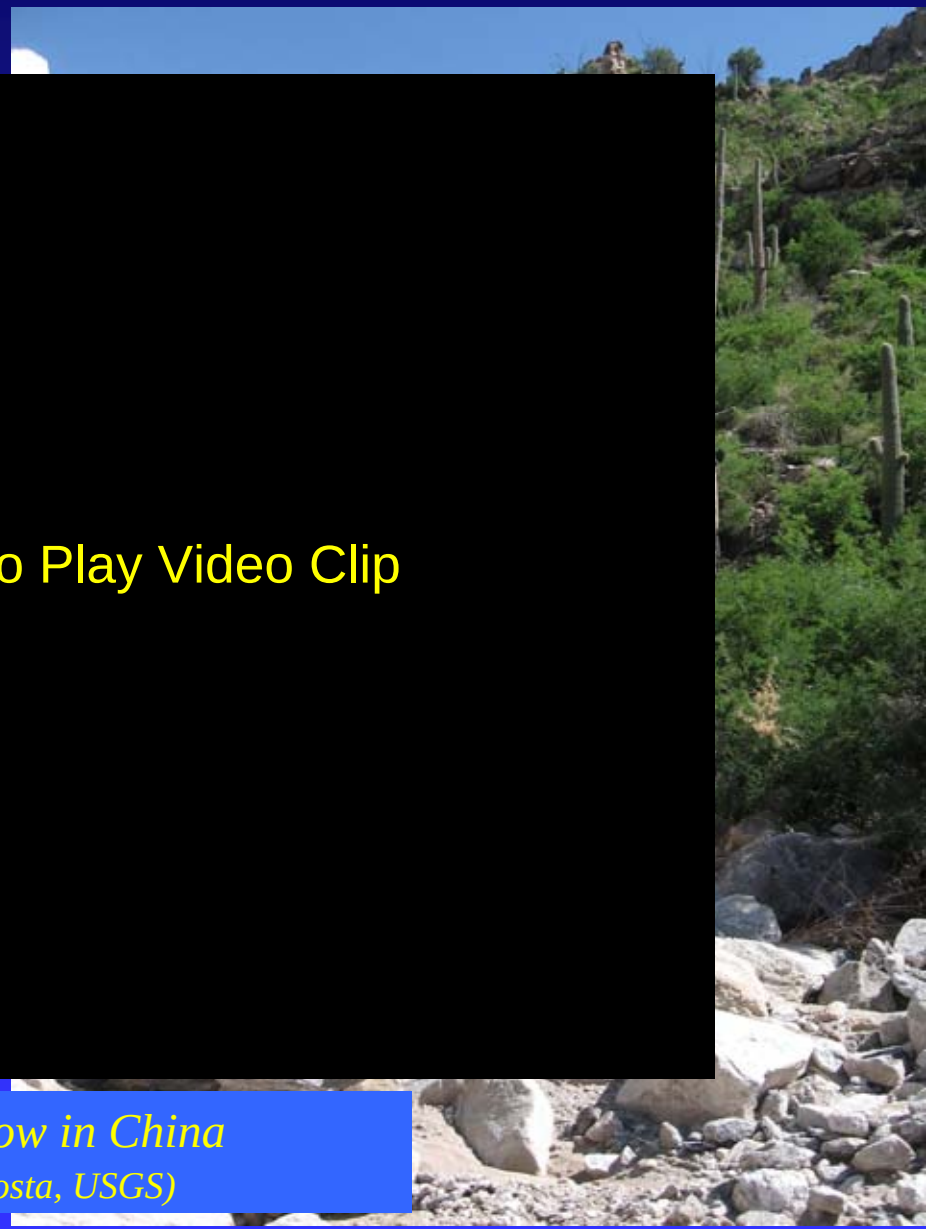
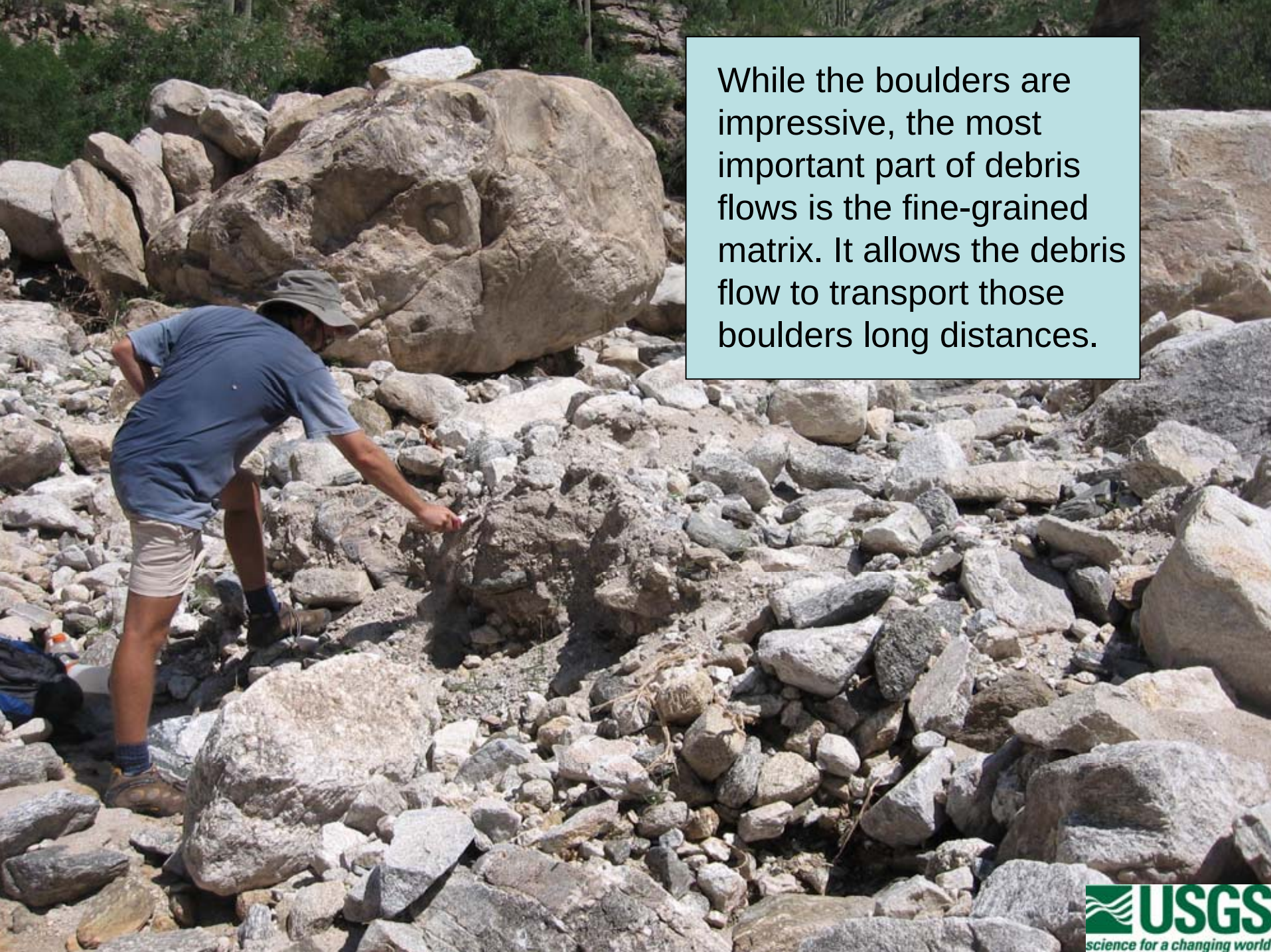


Debris flow in China
(John Costa, USGS)

What is a Debris Flow?

Other debris flows can travel relatively long distances on low slopes.

Debris flow in southern California
(Mr. Davis)



While the boulders are impressive, the most important part of debris flows is the fine-grained matrix. It allows the debris flow to transport those boulders long distances.

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Mt. Lemmon
CATALINA MOUNTAINS
Rattlesnake Canyon
Sabino Canyon
Bear Canyon
Soldier Canyon
N Sabino Canyon Rd
N Webster St
E Summer Trl
Image © 2006 TerraMetrics
© 2006 Navteq
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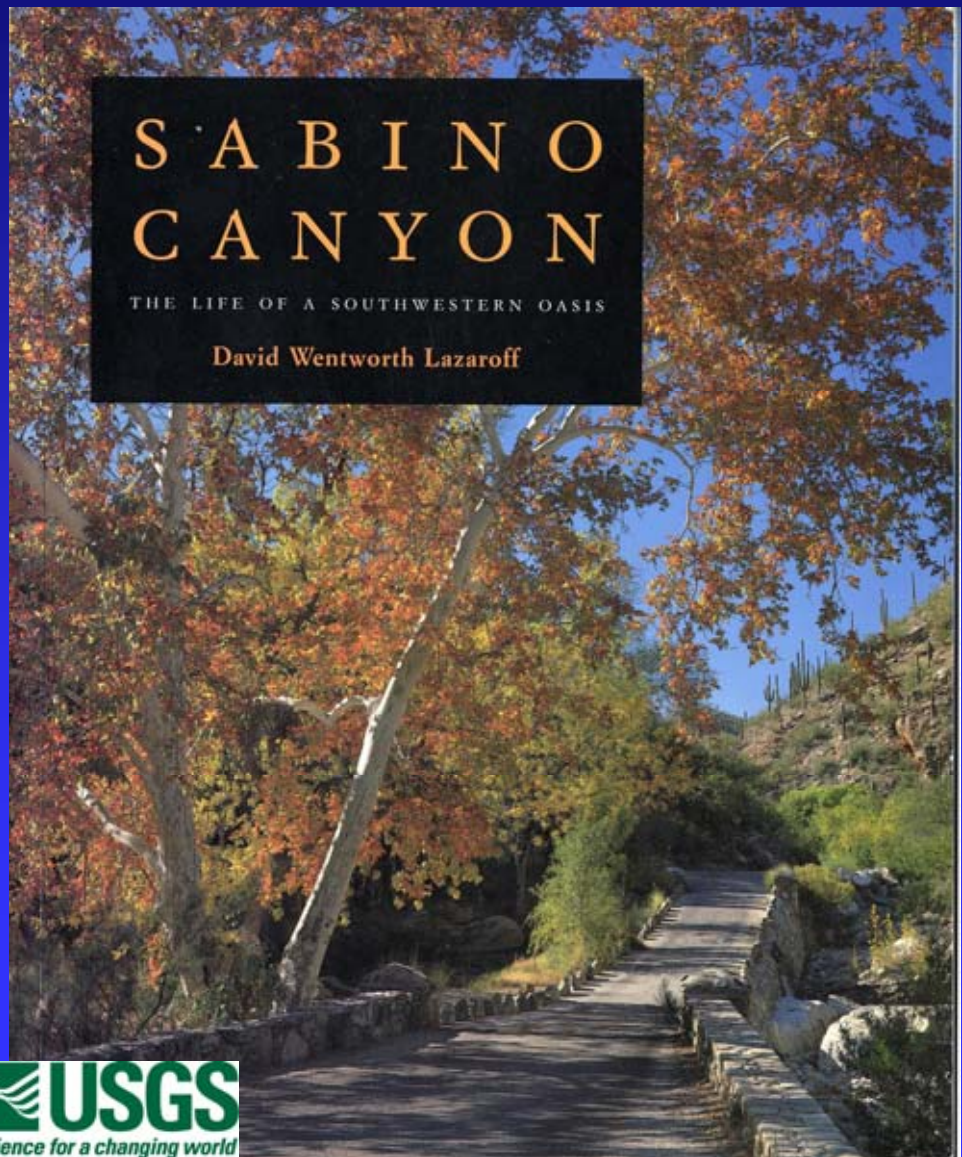
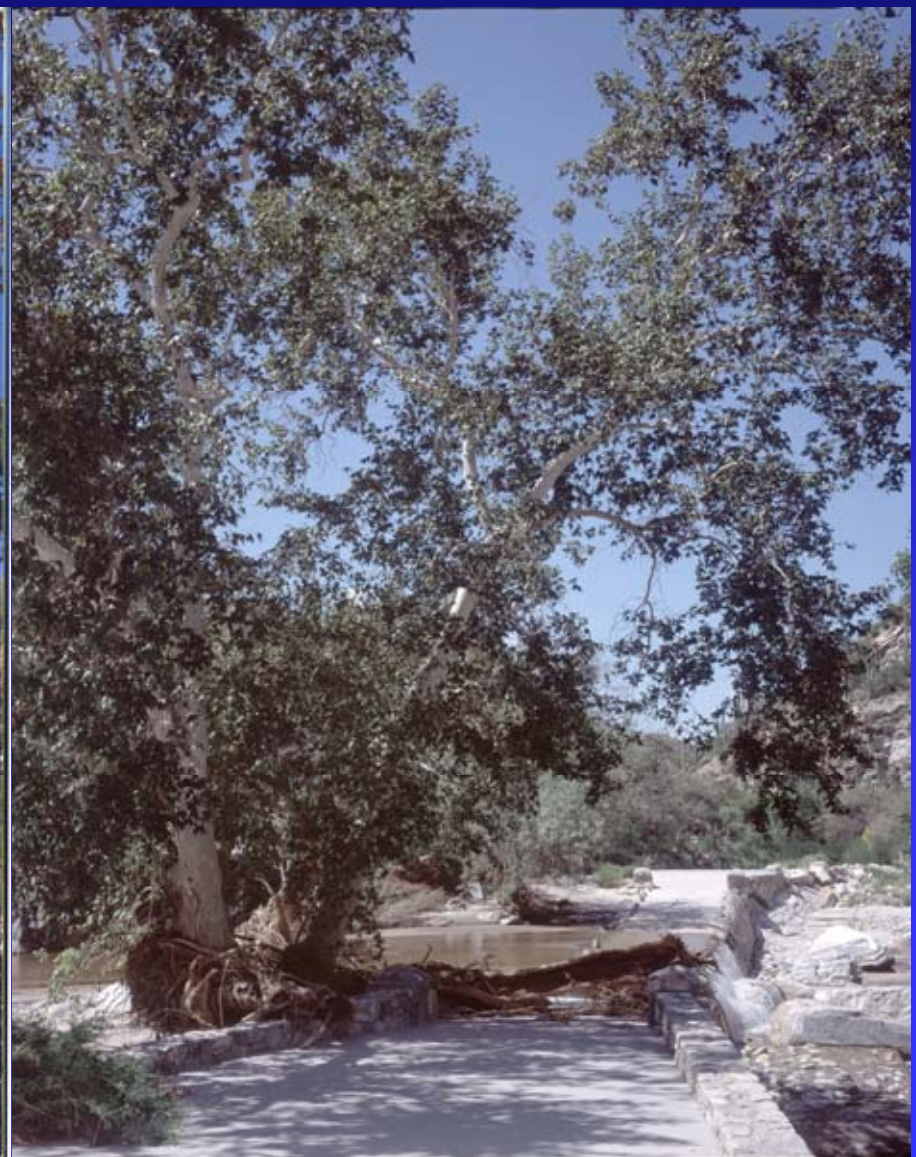
Pointer 32°19'06.98" N 110°47'09.99" W elev 2983 ft
Streaming 100%
Eye alt 13541 ft

Sabino Canyon: Highly Valued Recreation Area for Southern Arizona





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Debris Flows in Sabino Canyon
Rattlesnake
Sabino
Bear
18
14
13
10
17
16
12
8
11
9
7
6
4
5
3
15
2
1
Repeat photo pairs
09484000
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On the ground in Sabino Canyon
DF #4, #5
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DF #4 slide

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DF #6
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DF #7

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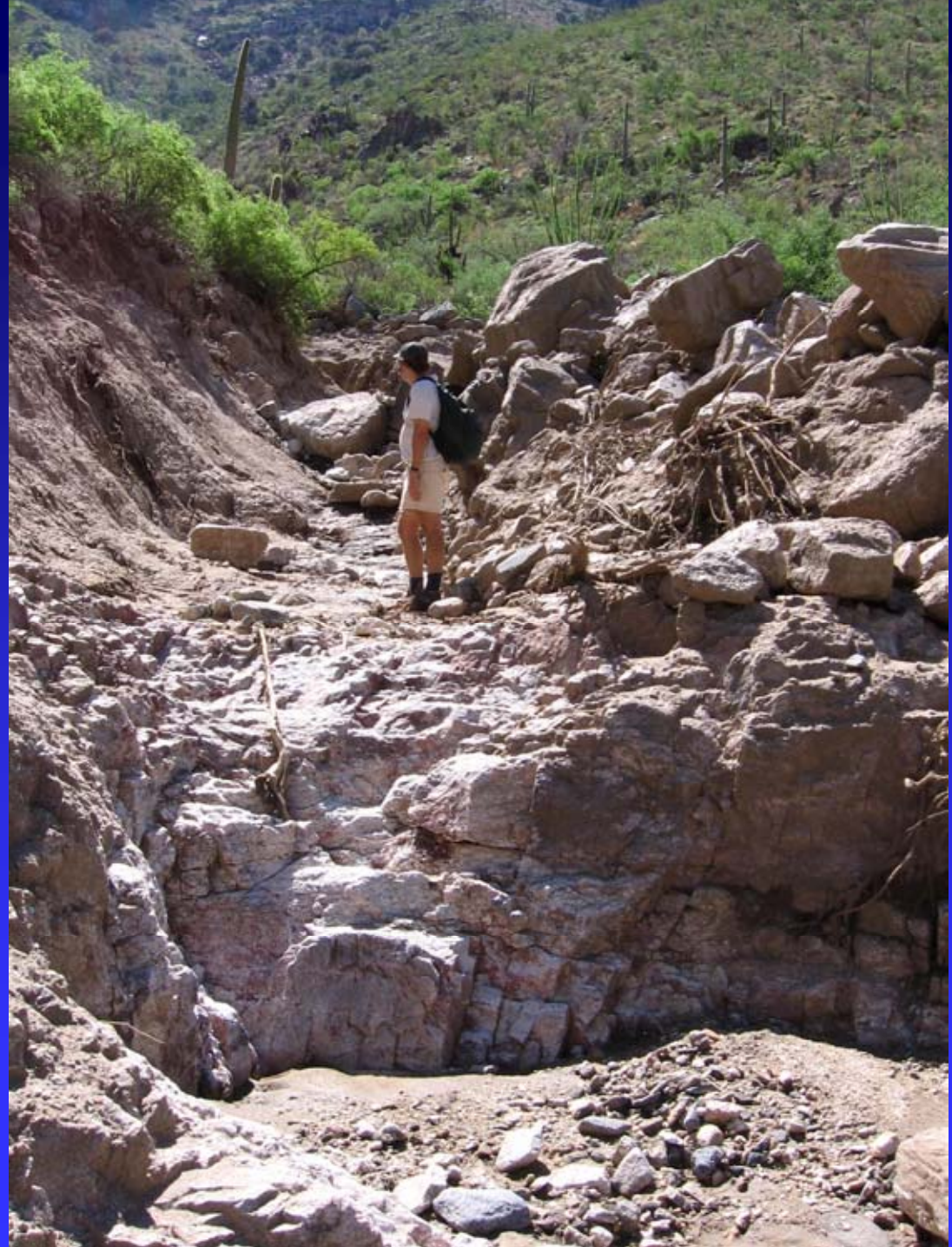

Scour from DF #7

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“Ocho Grande” pushed into creek channel
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Tram stop #9: Lots of Boulders
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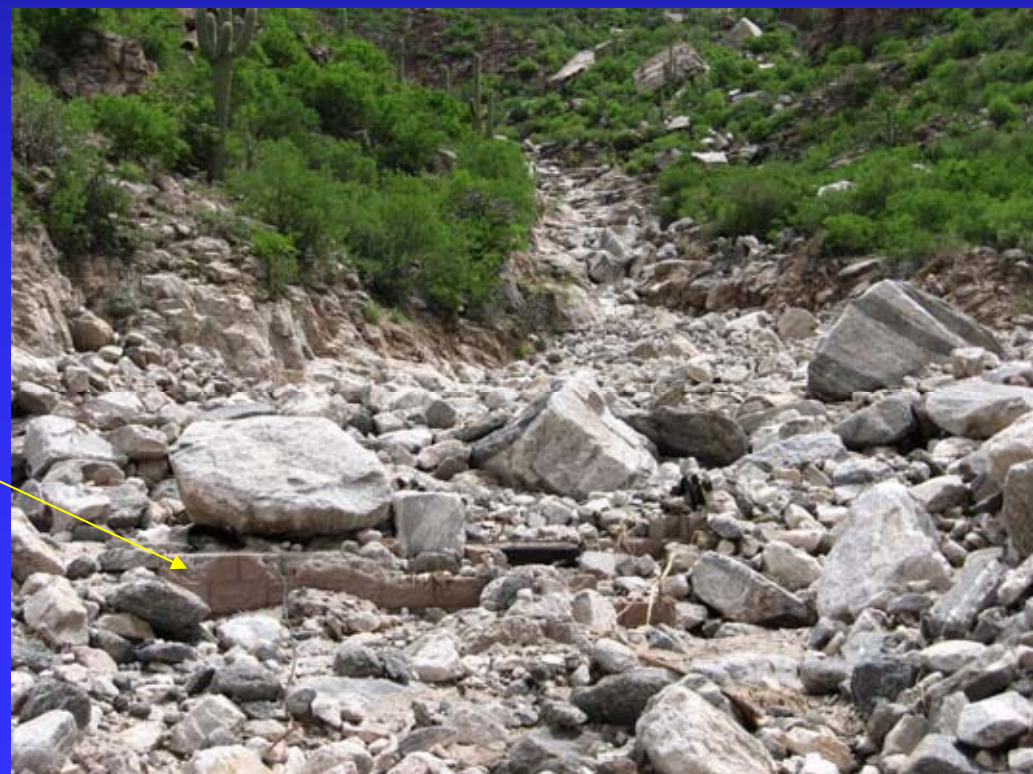
Bridge outlet is choked with boulders

New rest station is required (trash cans too)



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"Please Stay on Trails
Short Cutting Causes Erosion!"
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Debris Flow #10 and Sabino Creek

- A lot of sediment entered into the mainstem of Sabino Creek.
- A process known as reworking entrained the finer sediments, washing them downstream.
- The high sediment load led to deposition far downstream in Sabino Creek.


Sabino Canyon -
Western wall
DF #9
DF #10
DF #16
DF #17
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Phone Line Trail
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Sabino Canyon – west wall

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Rattlesnake Canyon upstream

Rattlesnake Canyon debris flow

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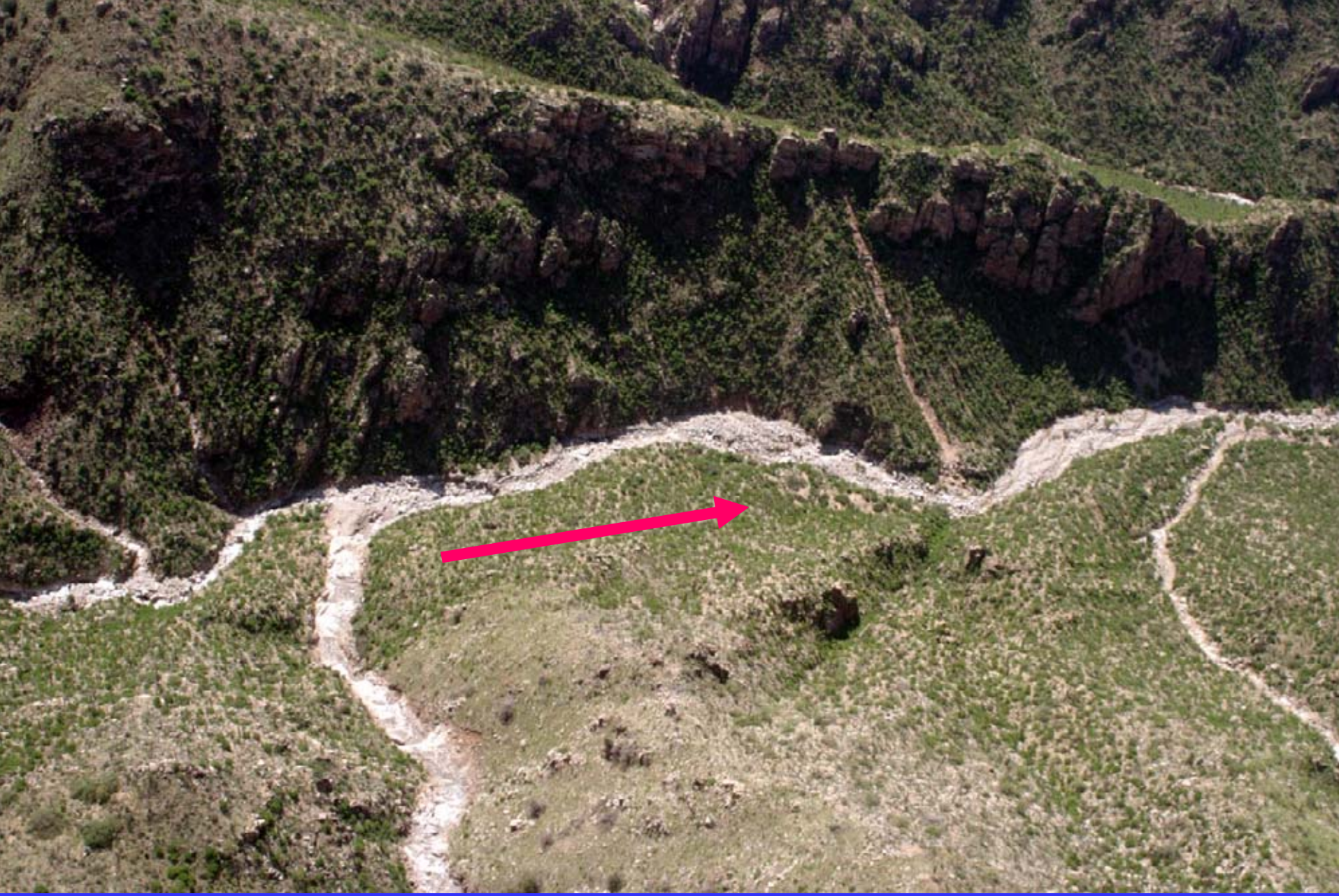

Debris-flow levees in Rattlesnake Canyon

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On the ground in Rattlesnake Canyon

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Alternating debris-flow and hyperconcentrated-flow impulses

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Fresh debris-flow levees were deposited onto old DF levees

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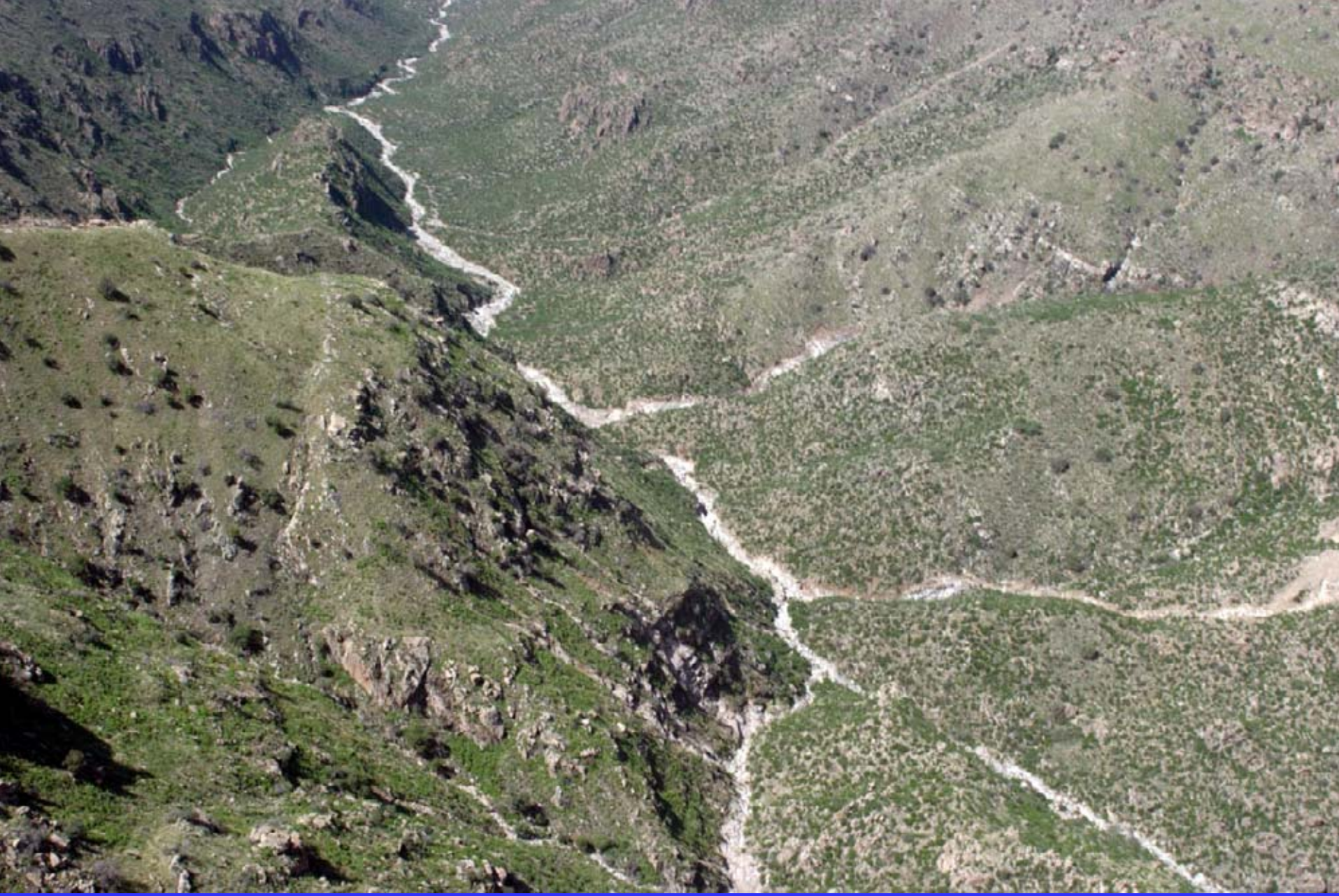

Rattlesnake Canyon

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Max depth of the Rattlesnake debris flow was modest…

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…but the damage was significant

Sabino Canyon tram road at Rattlesnake

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Flood Effects Below Rattlesnake

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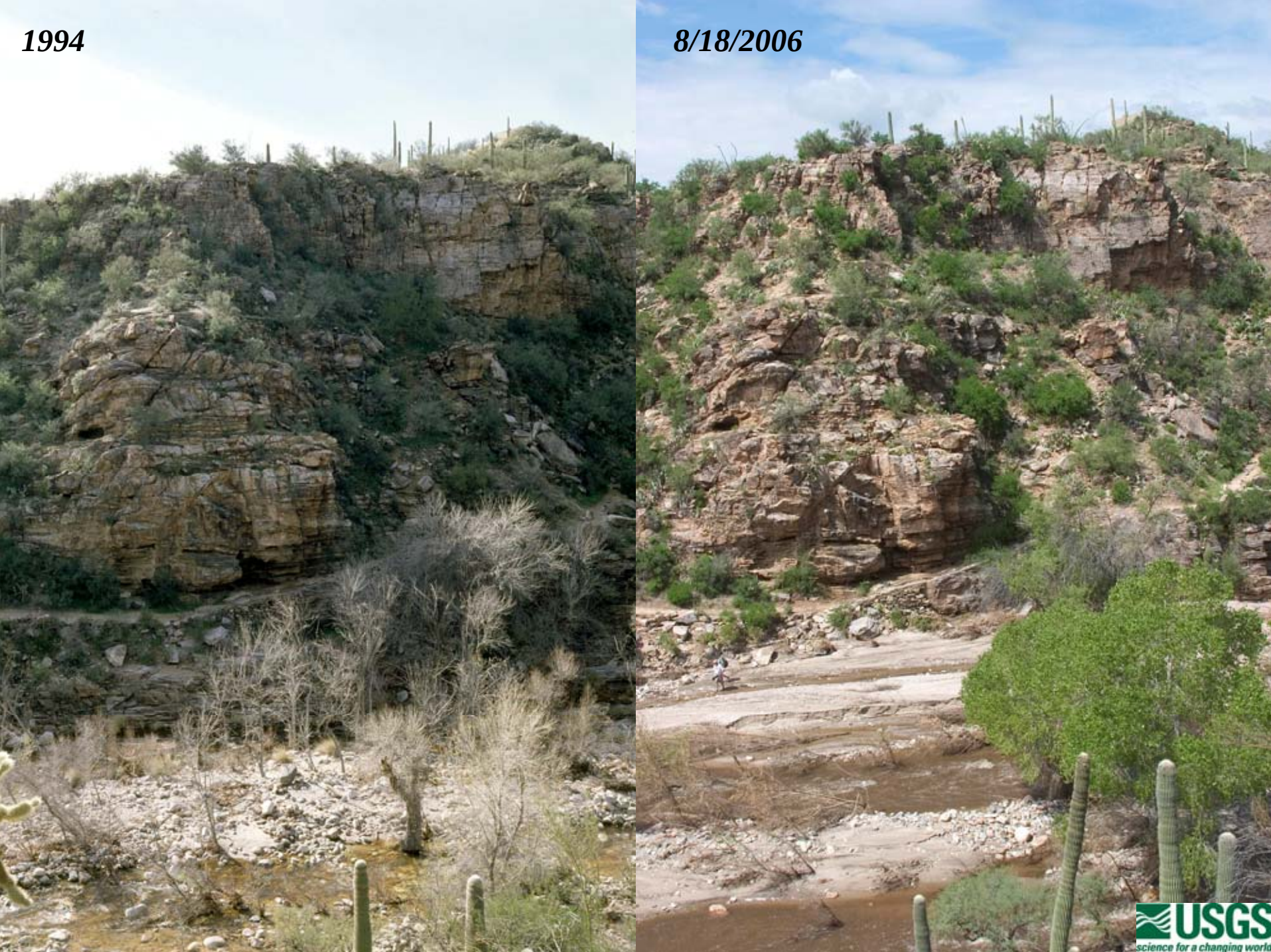
1994
8/18/2006
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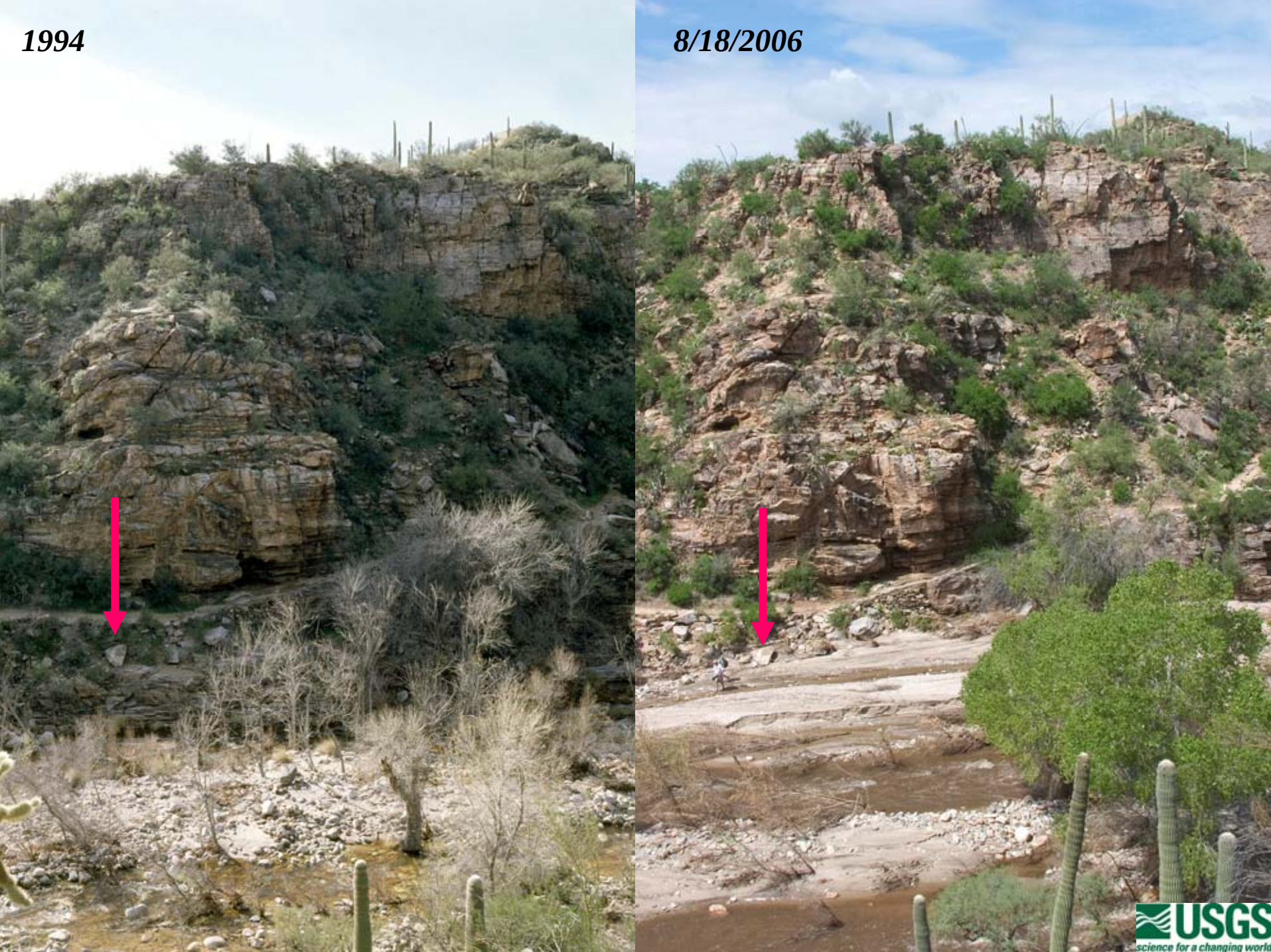
1994
8/18/2006
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Above Rattlesnake: Upstream View Near Bridge 2

1901

2003

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Above Rattlesnake: Upstream View Near Bridge 2

2003

2006

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Above Rattlesnake: Upstream View Near Bridge 2

2003

2006

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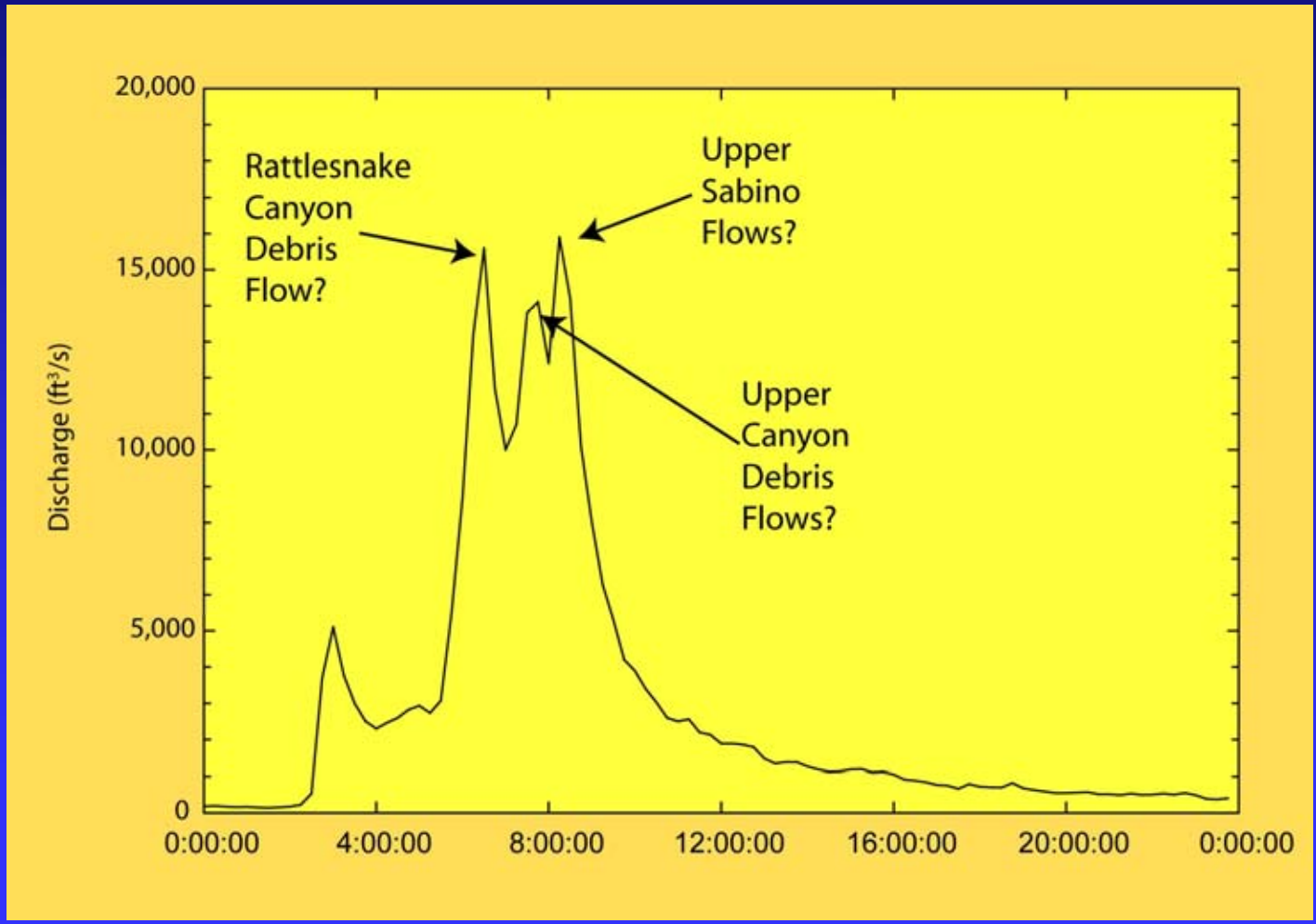
Preliminary Hypothesis on Sabino Creek Hydrograph



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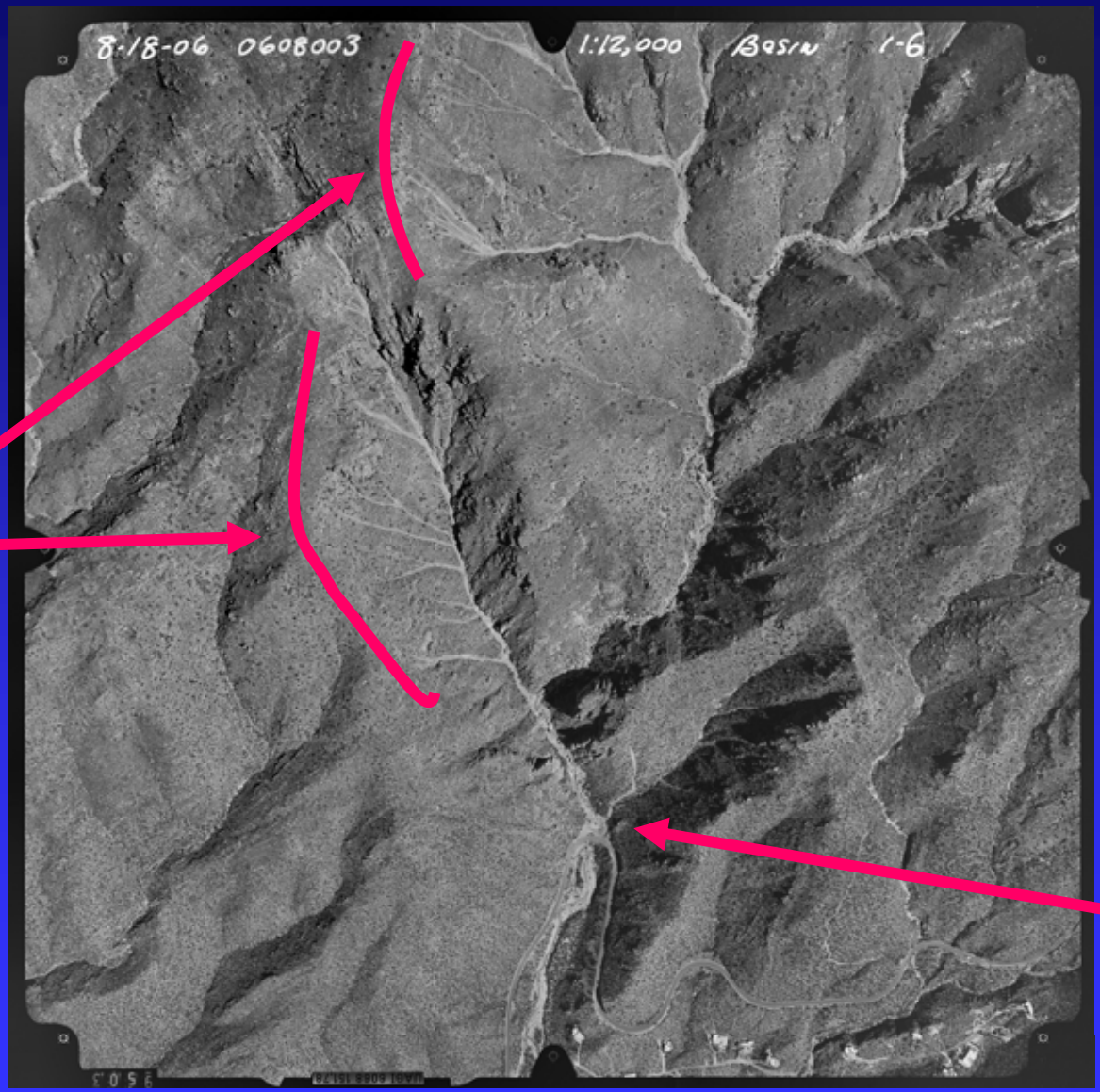
Post-storm aerial photo of Soldier Canyon



Multiple slope failures on west side of canyon

Infra-structure damage at Catalina Highway crossing

(Pima County Flood Control)

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Soldier Canyon

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Soldier Canyon:
Debris flows and control structures

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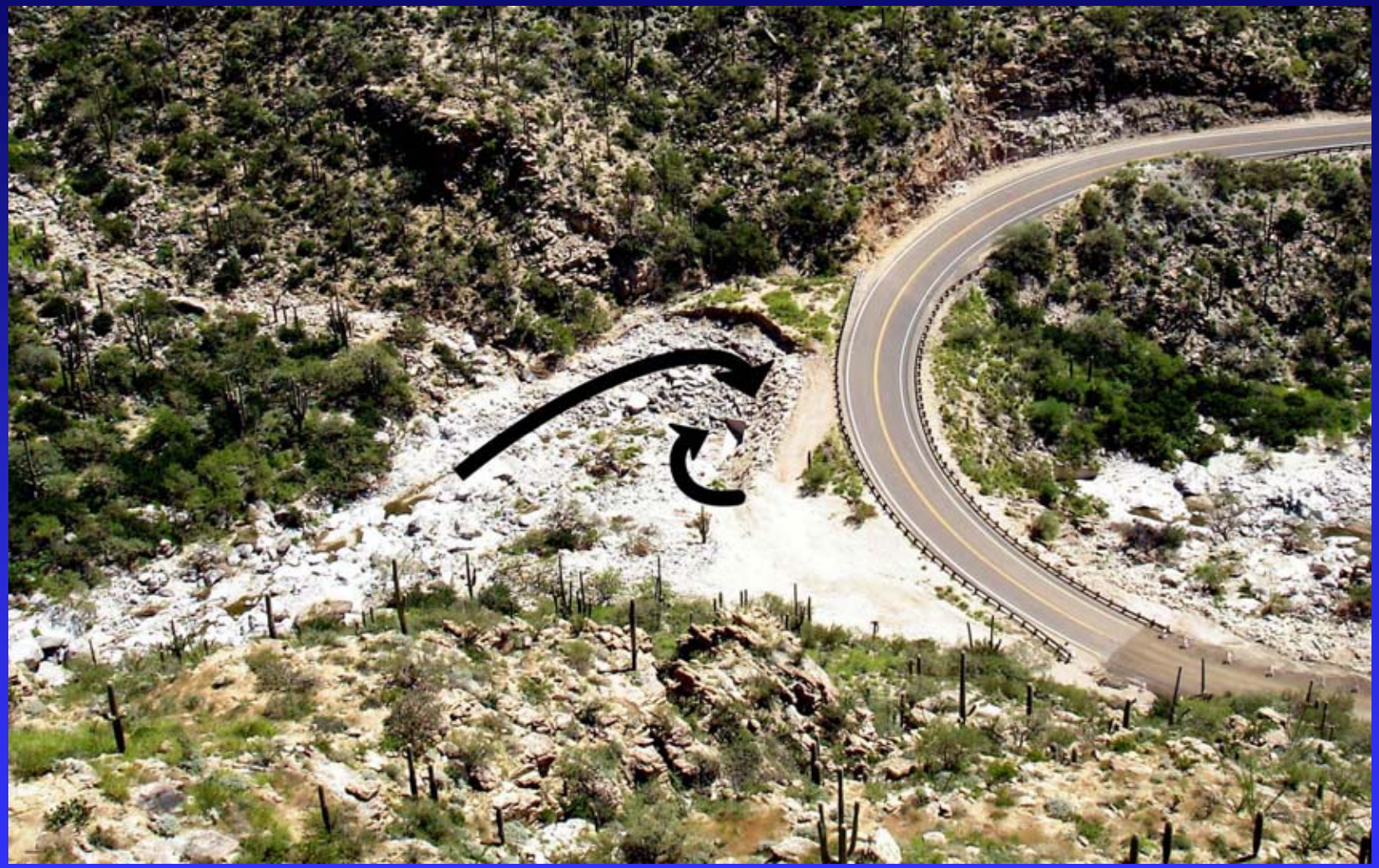
Whirlpool developed at the Catalina Highway culvert



Little deposition above culvert;
mostly erosion

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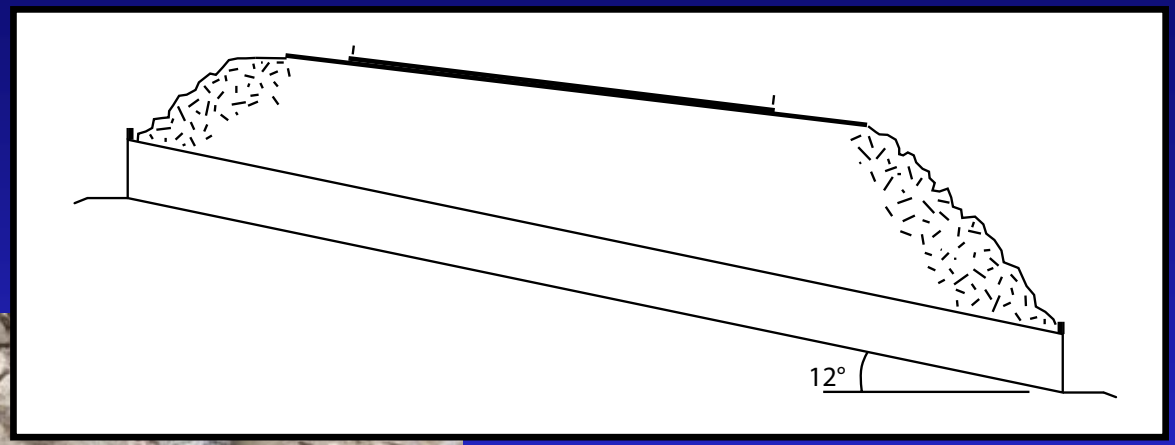
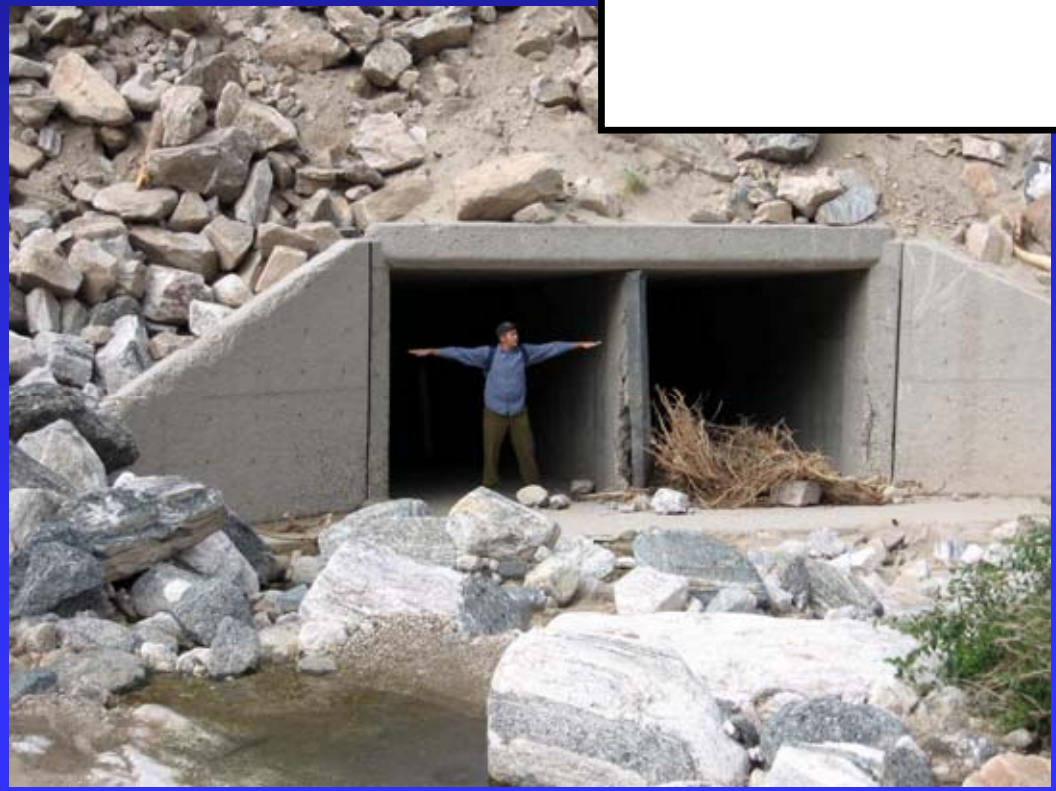
Catalina Highway culvert damaged but worked beautifully

2.5 m double box culvert





- Damage to metal plated divider
- Culvert acted as a 2.5 m sieve
- Steep slope sucked DF down

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Culvert at Mt. Lemmon Short Road quickly plugged with debris-flow snout

Sands, gravels, cobbles, boulders all in matrix

Debris-flow levee topped the guard rail

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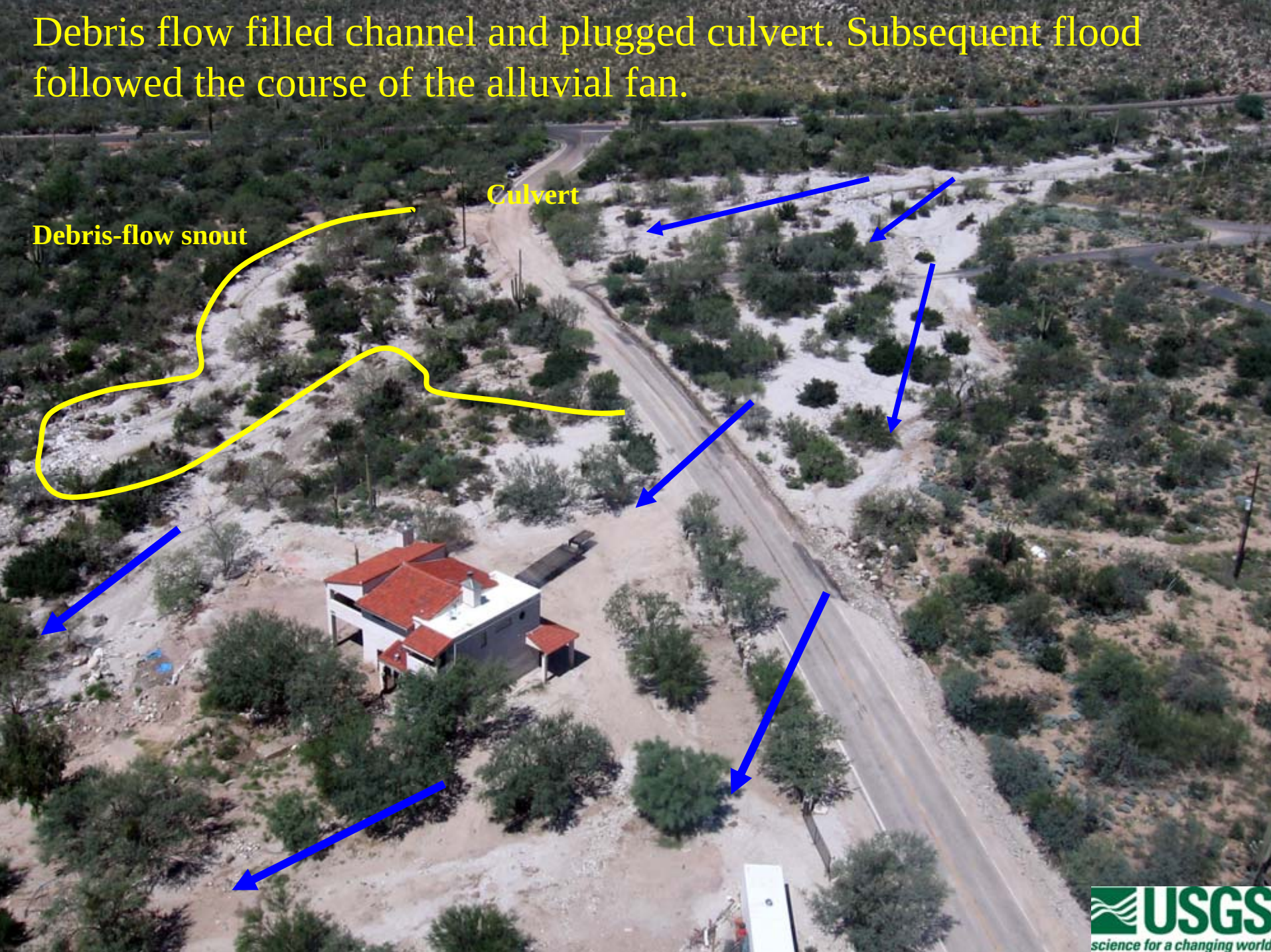
Debris flow filled channel and plugged culvert. Subsequent flood followed the course of the alluvial fan.



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Paleo debris-flow levees near Finger Rock trail…

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Paleo debris-flow levees near Finger Rock trail…

How old?

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…at the top of Alvernon

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Summary and Some Questions

- The extreme storm event of July 31 caused >240 slope failures in the Front Range of the Santa Catalina Mountains.
- Before this event, about five debris flows are known to have occurred historically in this area.
- Deposits south of the mountain front suggest a long history of debris flow occurrence, but what relevance does that have to future debris-flow hazard?
- The destabilized watersheds suggest high potential for more debris flows in the immediate future; how real is this threat?
- Debris flows greatly increased the sediment load to channels draining the Front Range of the Santa Catalina Mountains. What is the fate of that sediment? Does it increase flood hazard downstream?