Geomorphic Responses of Burned Watersheds in the Modern Fire Regime: Floods, Debris Flows and Long-Term Recovery

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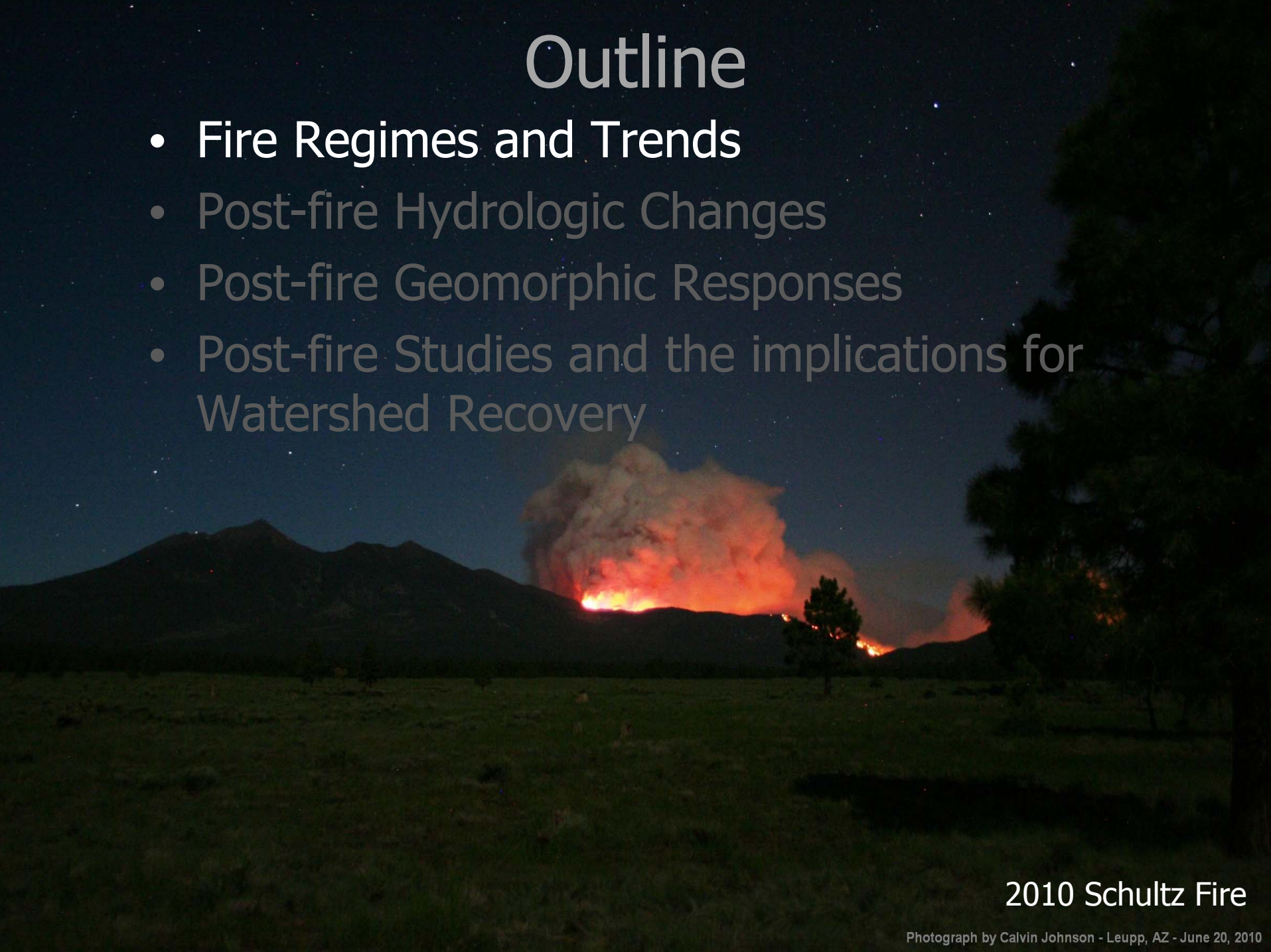
Arizona Geological Survey

Photo: Zac Ribbing
Horseshoe 2 Fire
June 8th, 2011

Outline

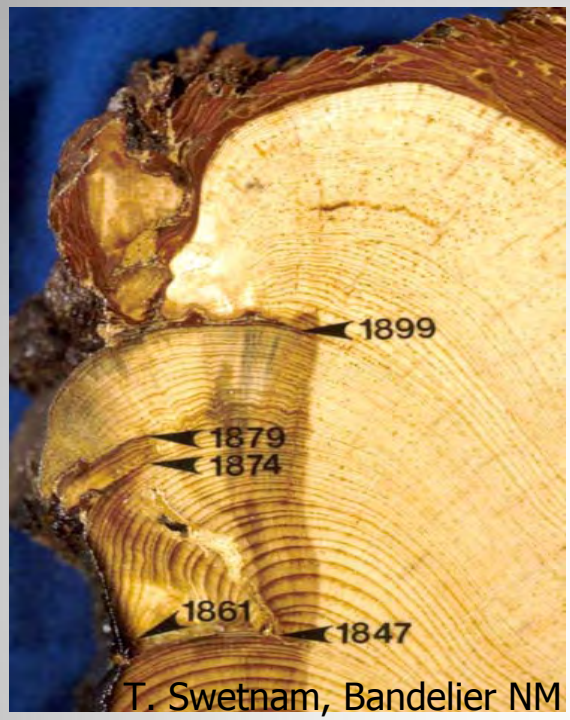
- Fire Regimes and Trends
- Post-fire Hydrologic Changes
- Post-fire Geomorphic Responses
- Post-fire Studies and the implications for Watershed Recovery



2010 Schultz Fire

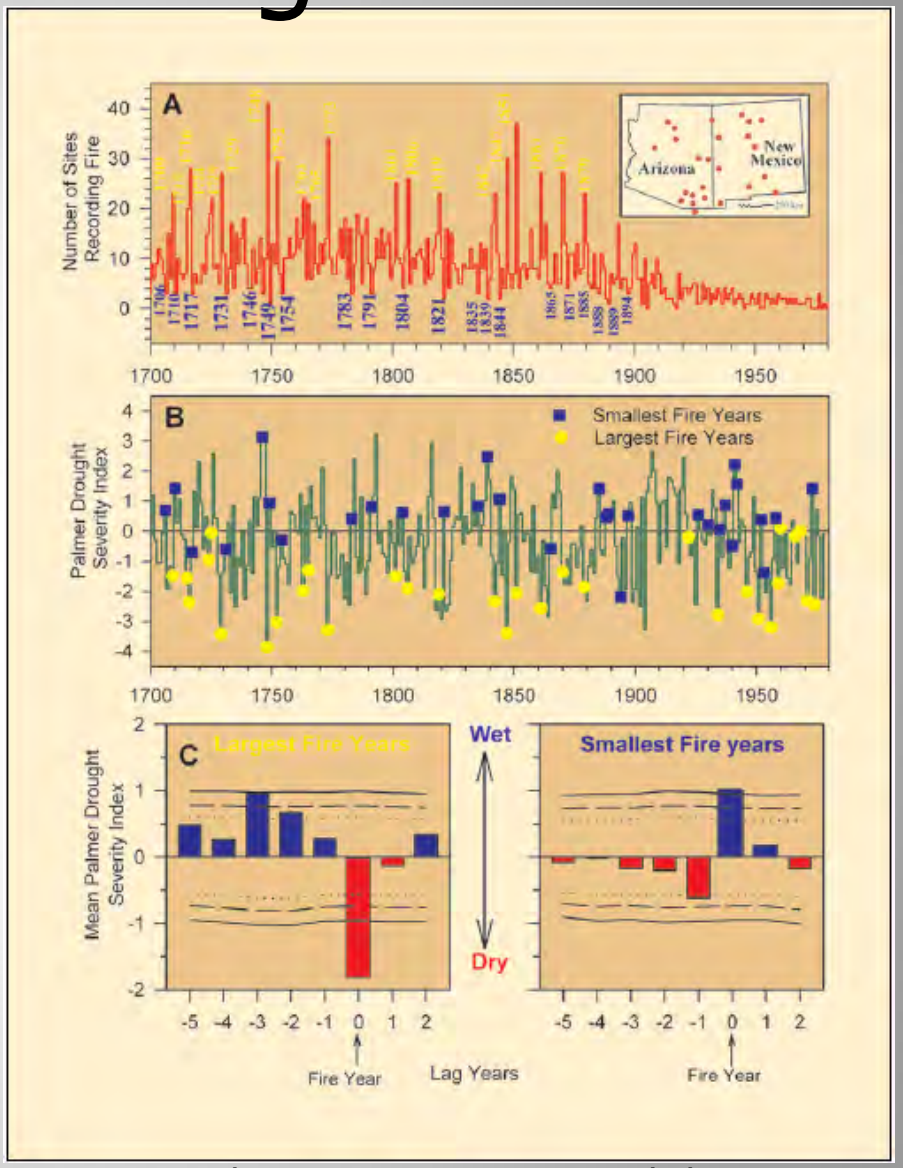
Photograph by Calvin Johnson - Leupp, AZ - June 20, 2010

Fire Regimes: Tree Ring Data



T. Swetnam, Bandelier NM

Fire scar on Ponderosa pine snag



Swetnam, Thomas W., 2002, Fire and climate history in the Western Americas from tree rings, PAGES News, 10(1), 6-9.

Fire Regimes: Pre-settlement

Fire Regime:

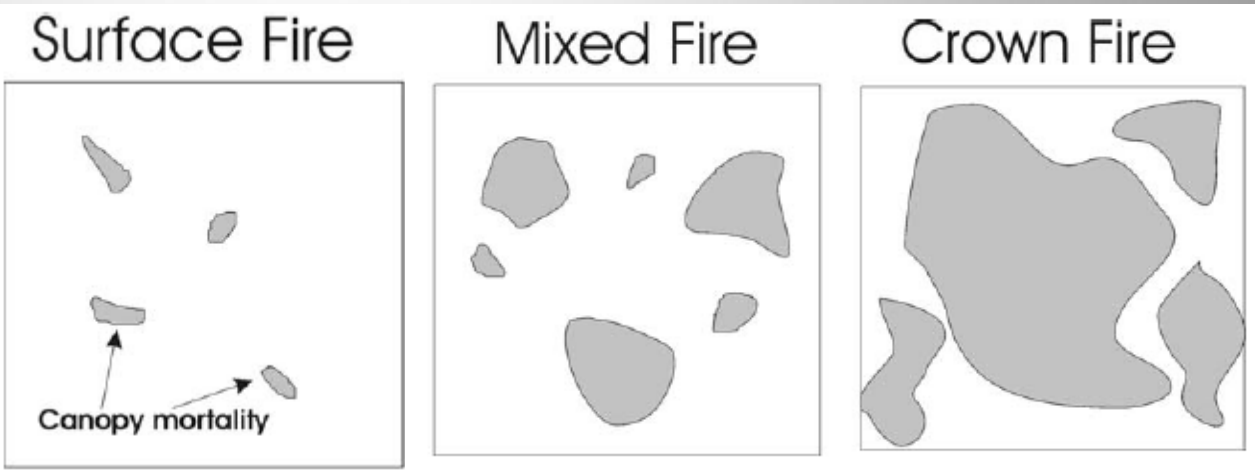
Elevation

Spruce-fir
Patch mosaic w/stands of varying ages
High-severity, stand-replacing fires
Recurrence: 100-300+ yrs

Mixed conifer-Aspen
Complex variations in species composition and stand ages
Mixed fire severity, Surface and crown fires, Recurrence 25-100 yrs

Ponderosa Pine
Open, park-like setting w/abundant herbaceous understory
Low-severity fires
Recurrence: 5-25 yrs

Photo: Zach Ribong, Hispanic Cow Cabins

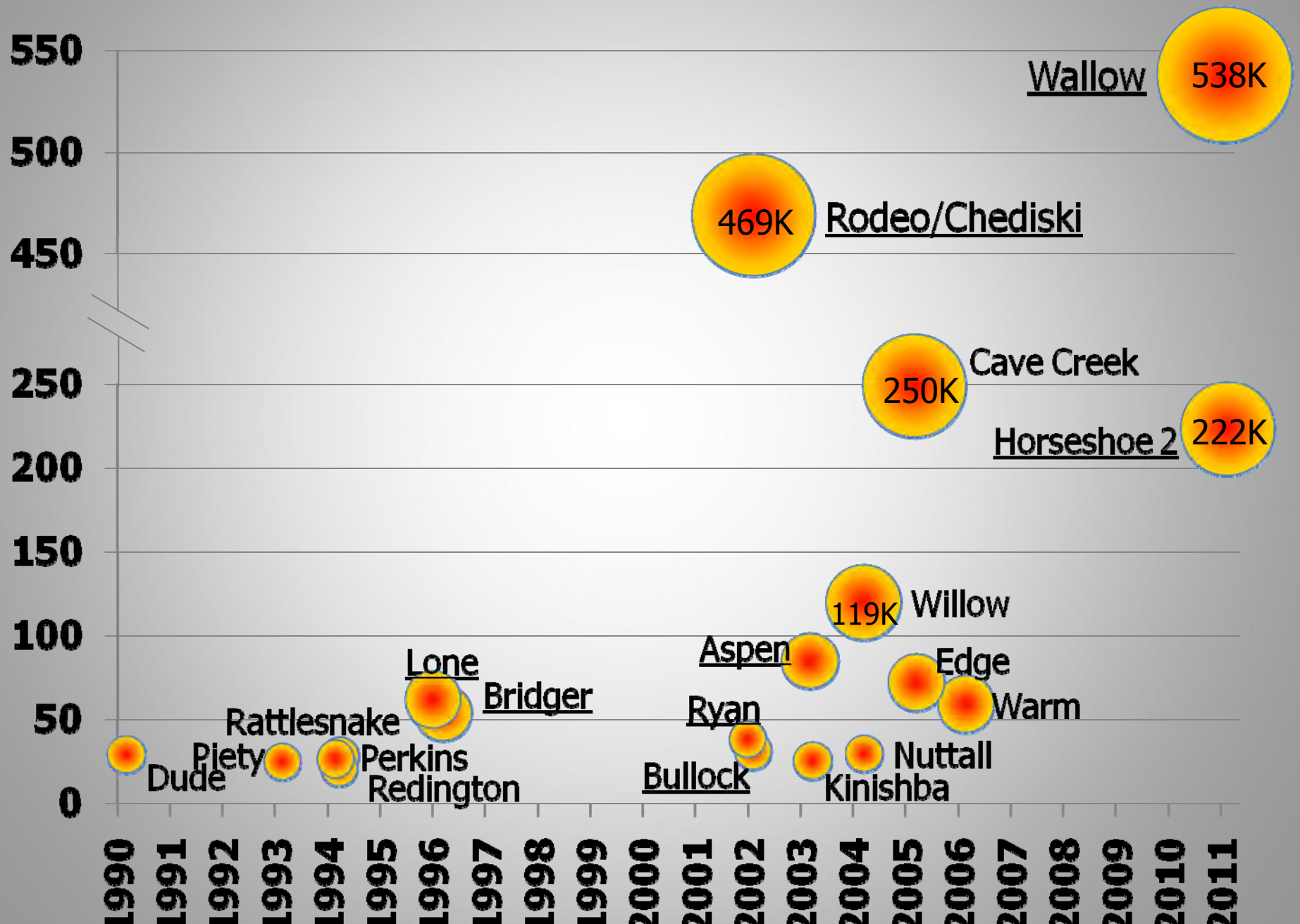


Canopy cartoons: T. Swetnam

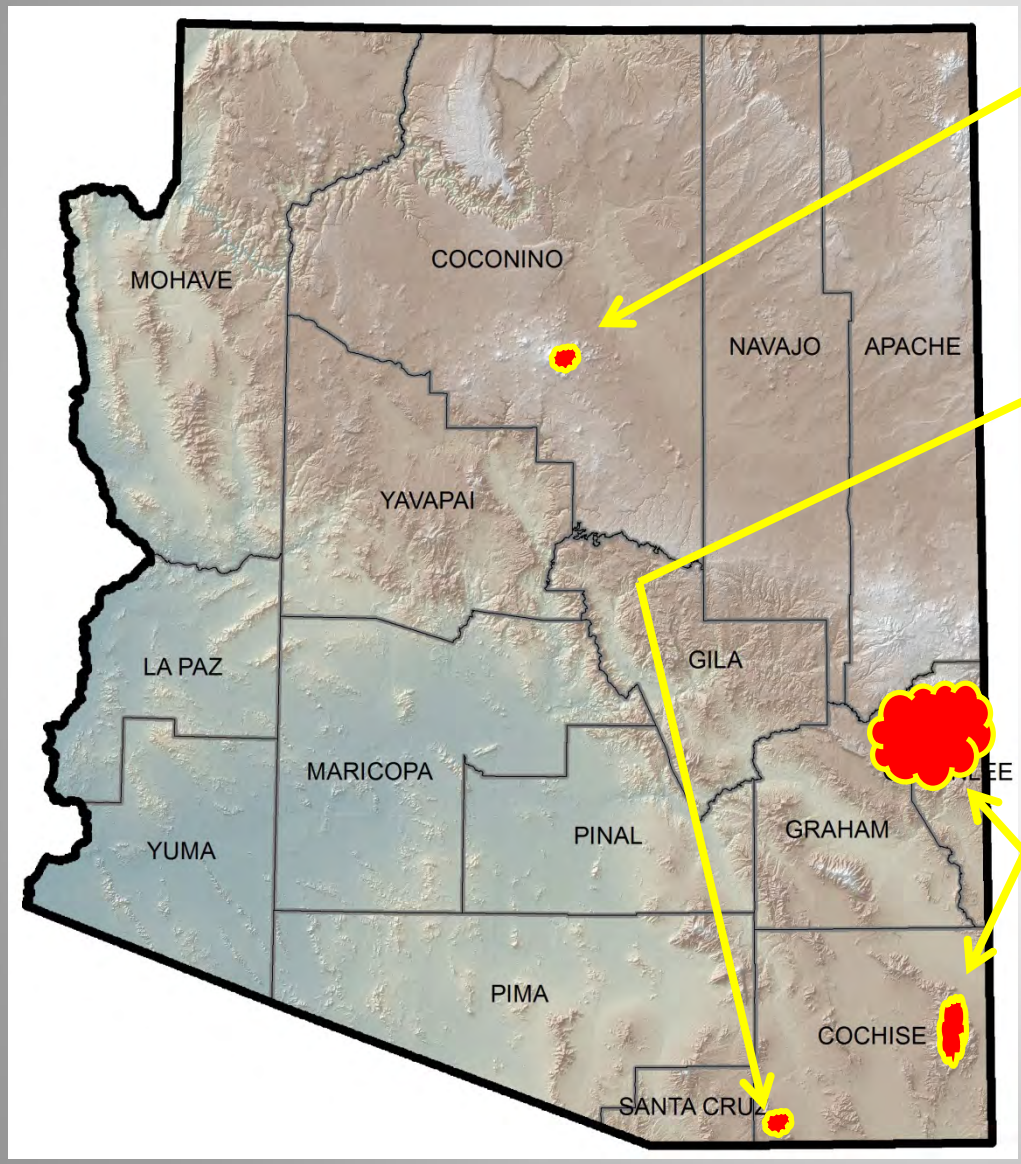
Slide adapted from S. Cannon

... leaving forests devastated
With huge canopy holes
Horseshoe 2 Fire, 18 July 2011

Largest Arizona Wildfires, 1990-2011 (SWCC Historic Data)



Recent Fires of Note Across the State



2010 Schultz Fire
15,075 acres
40% high severity
27% moderate

2011 Monument Fire
32,074 acres
7% high severity
39% moderate severity

2011 Horseshoe 2 Fire
222,954 acres
(~70% of the mountain range)
12% high severity
30% moderate severity

2011 Wallow Fire
538,049 acres
16% high severity
14% moderate severity

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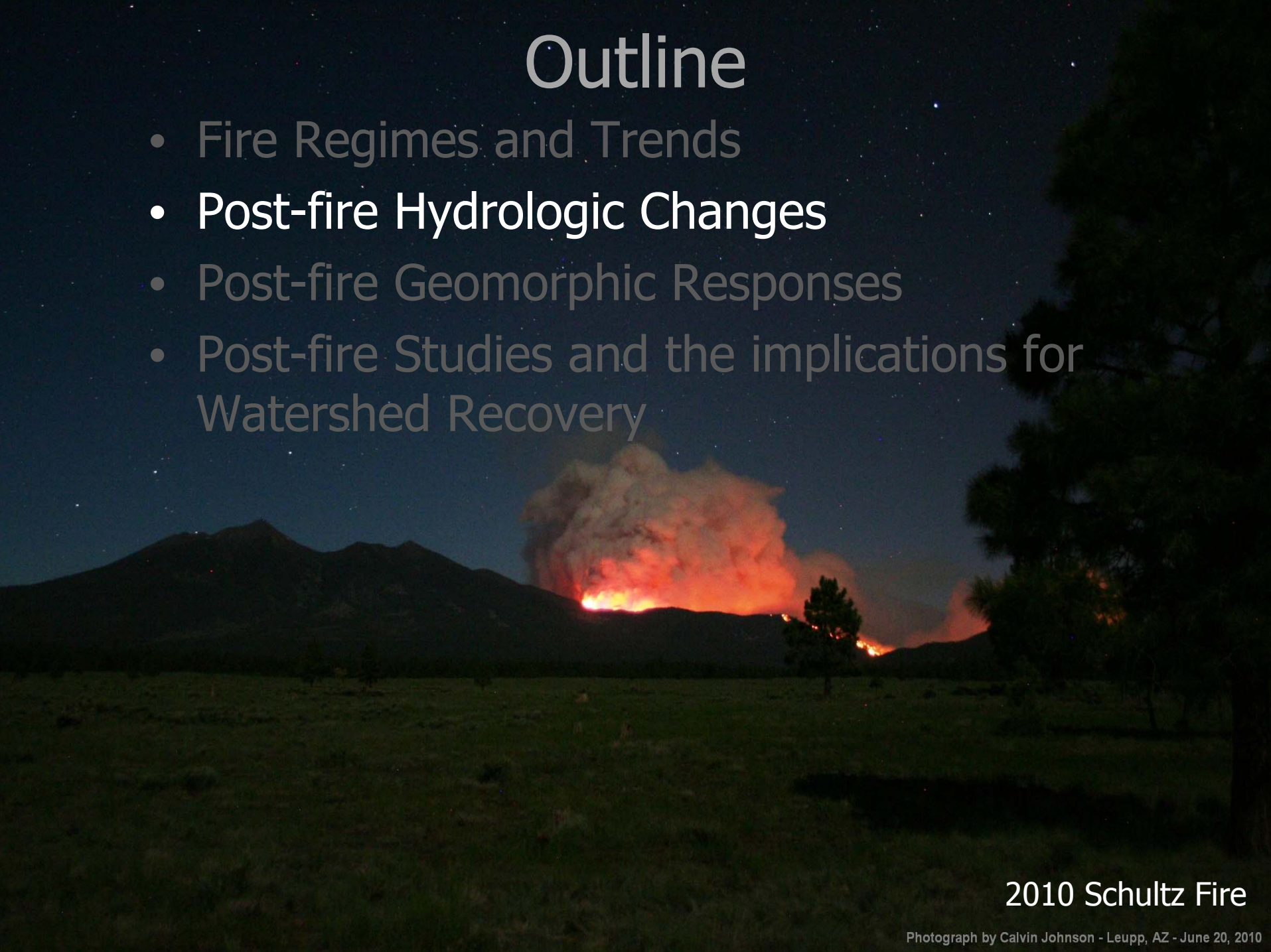
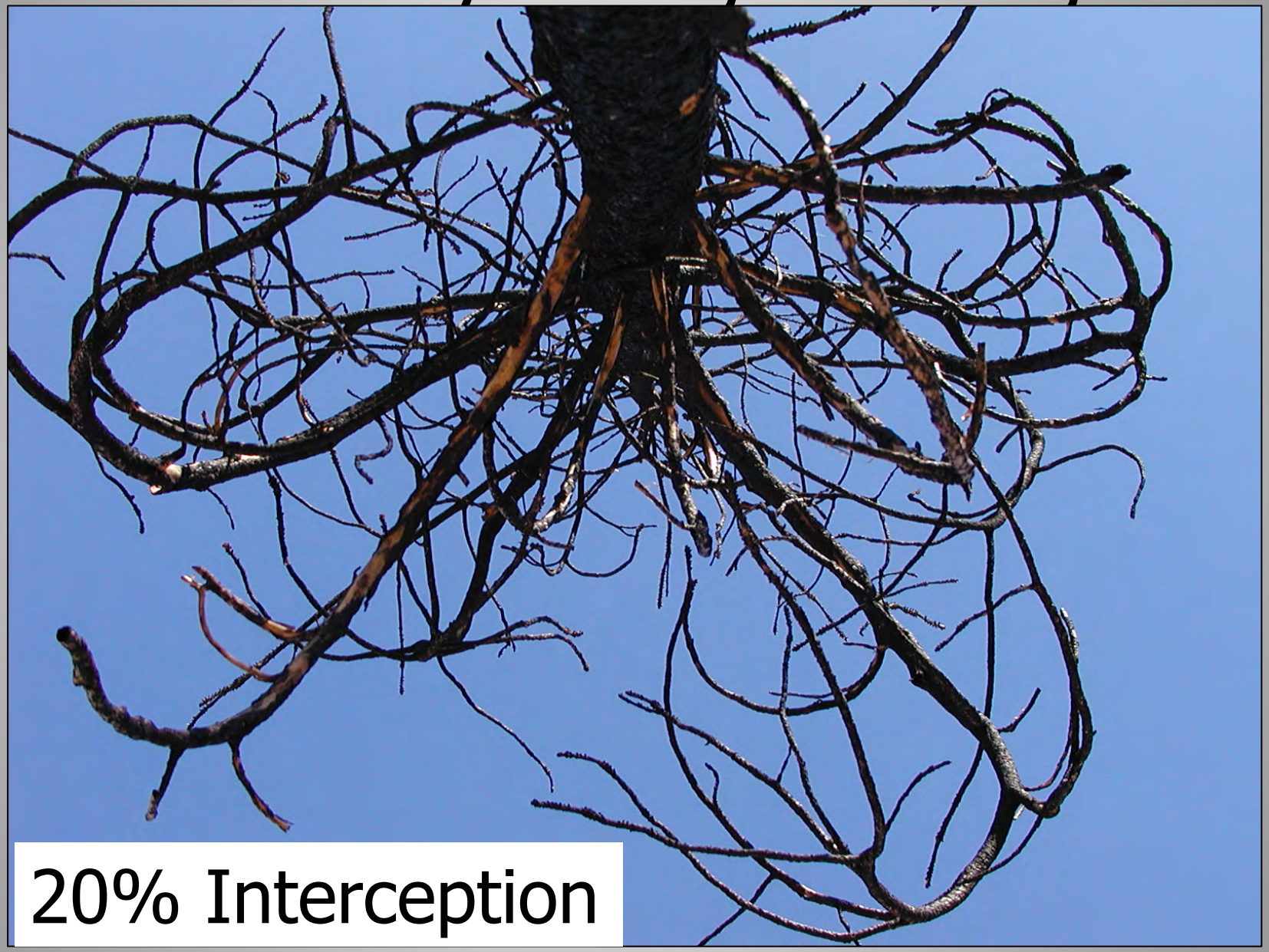


2010 Schultz Fire

Photograph by Calvin Johnson - Leupp, AZ - June 20, 2010

Post-fire Hydrologic Changes



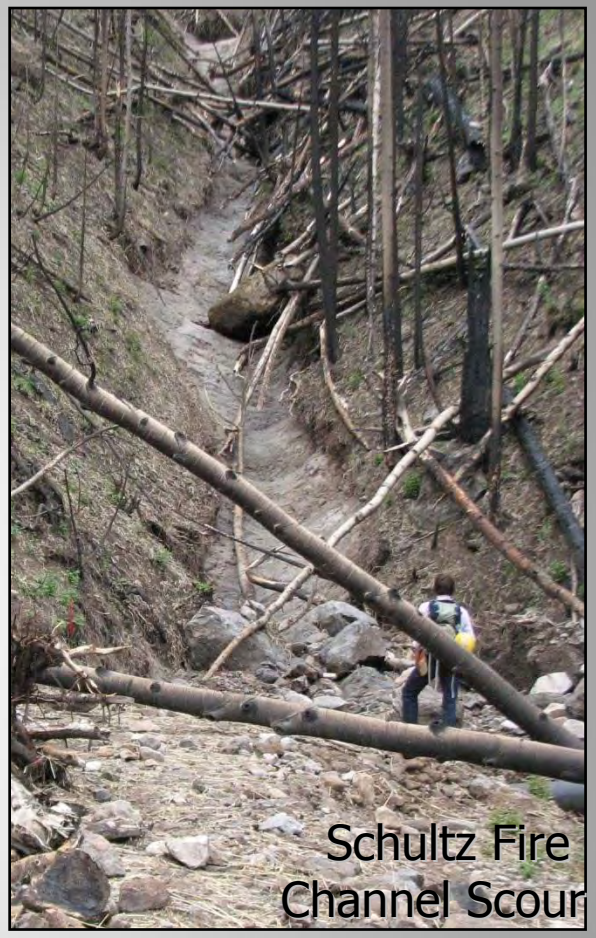
Slide from D. Martin, USGS

Post-fire Runoff

LOSS OF COVER

RAIN SPLASH IMPACT & SURFACE SEALING

WATER REPELLENCY & INCREASED CO



Schultz Fire Channel Scour

Schultz Fire Hillslope Rills

Garden variety storms can produce post-fire debris

Subsequent storms will have flashier hydrographs.

Modified from S. Cannon & D. Martin

Post-fire Hydrologic Changes

High frequency (<1-5 RI), low magnitude storms can result in tremendous post-fire responses.

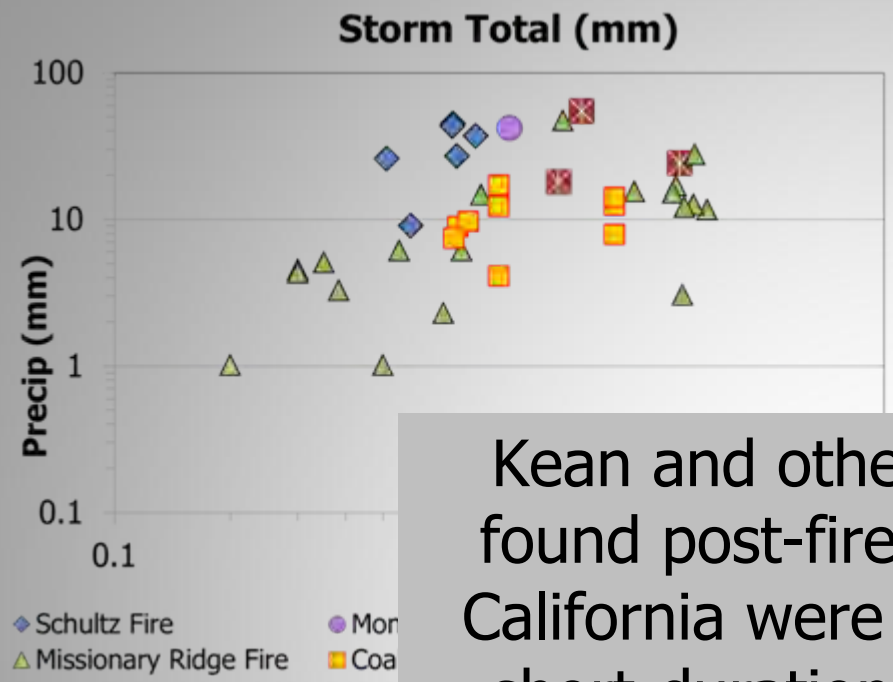
On this day Miller Canyon received 1.64" in an hour (2-yr, 60 minute storm)

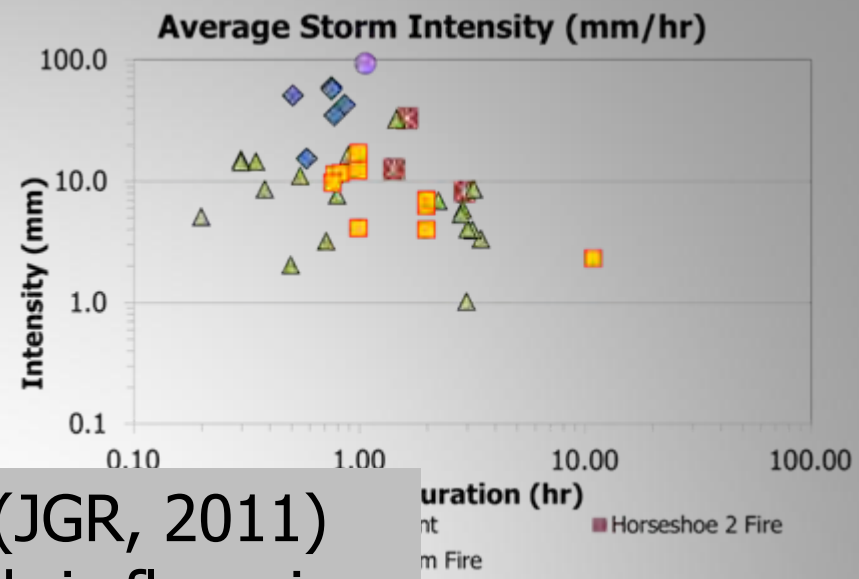
- Peak 15-minute intensity = 0.92"
- Peak 30-minute intensity = 1.36"
- Again 2-yr RIs

Photo: Chris Stewart, USFS, 10 July 2011, Miller Canyon

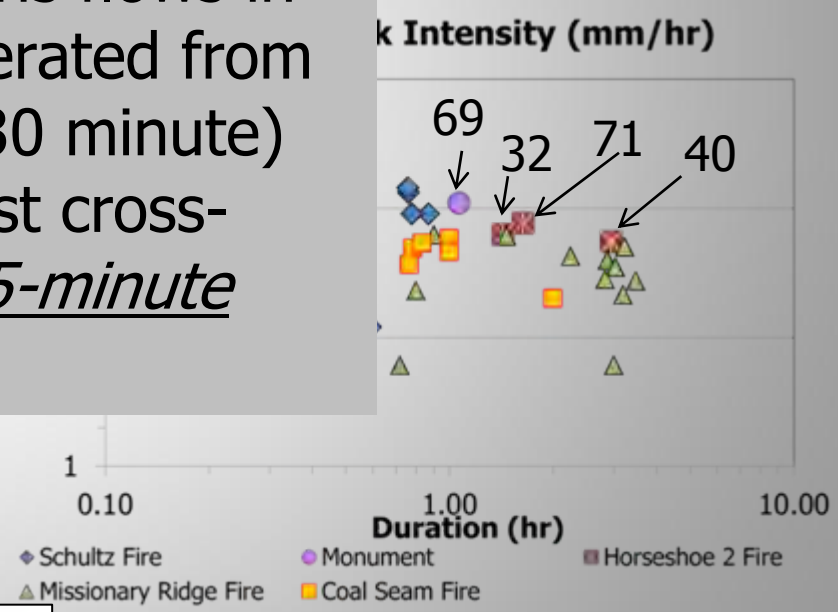
Miller Canyon, 10 July 2011

Post-fire Rainfall

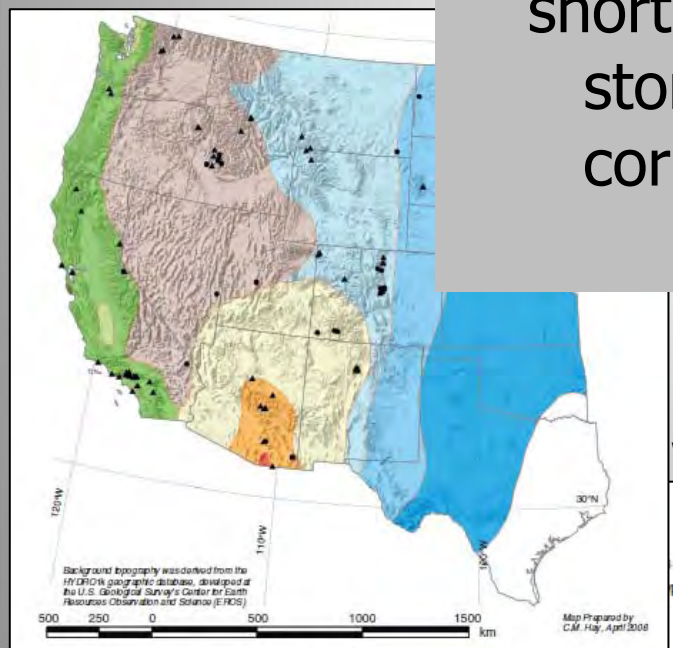




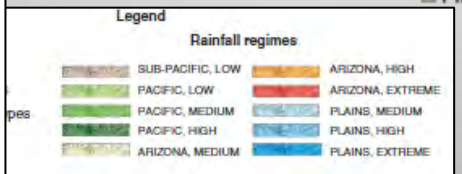
Kean and others (JGR, 2011) found post-fire debris flows in California were generated from short-duration (≤ 30 minute) storms with a best cross-correlated peak *5-minute* intensity.



Cannon and others, 2010, GSA Bull, v. 122.



Moody and Martin, 2009, J Wildland Fire, V. 18



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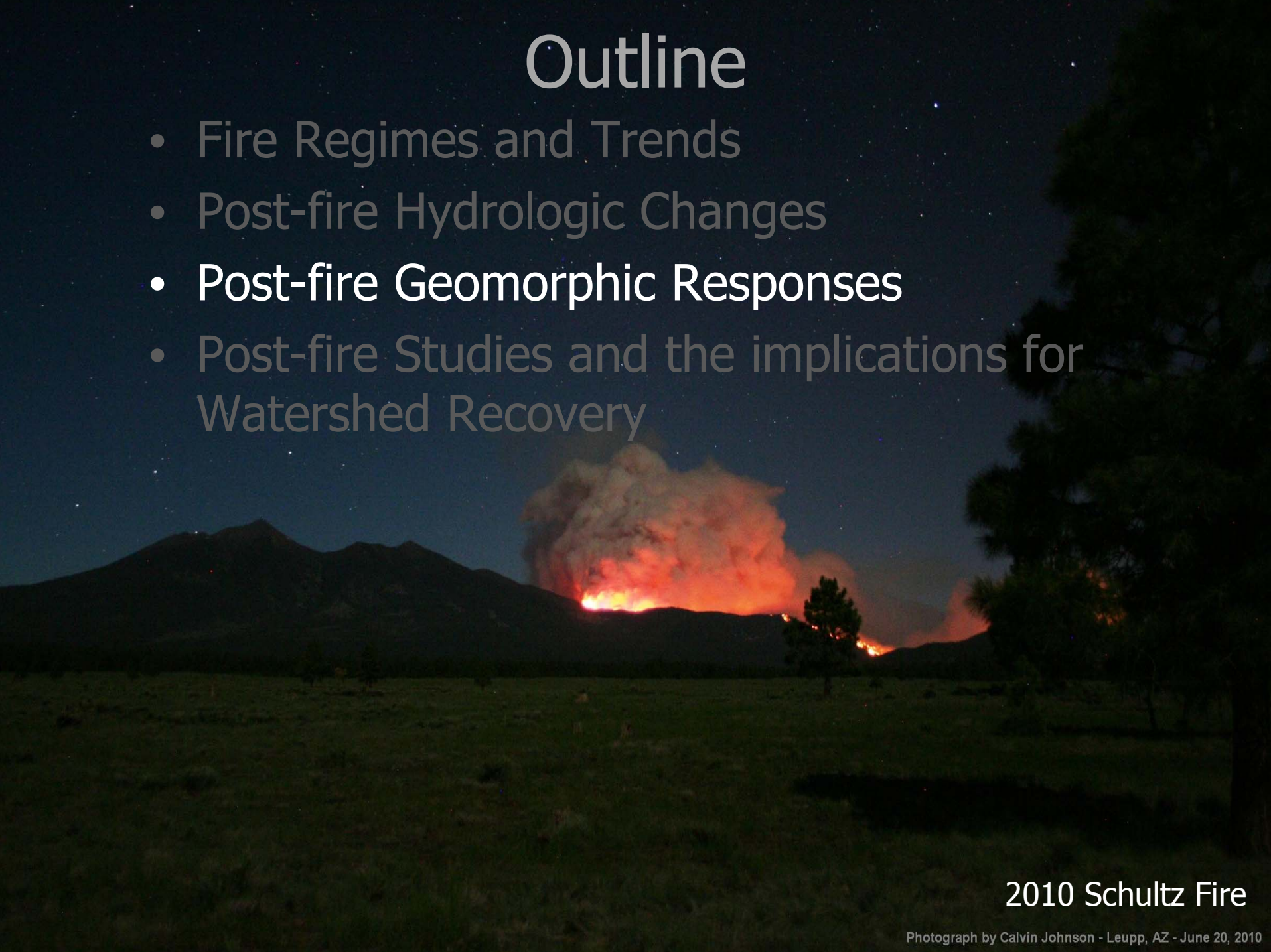


2010 Schultz Fire

Photograph by Calvin Johnson - Leupp, AZ - June 20, 2010

The Beatty's – Miller Canyon

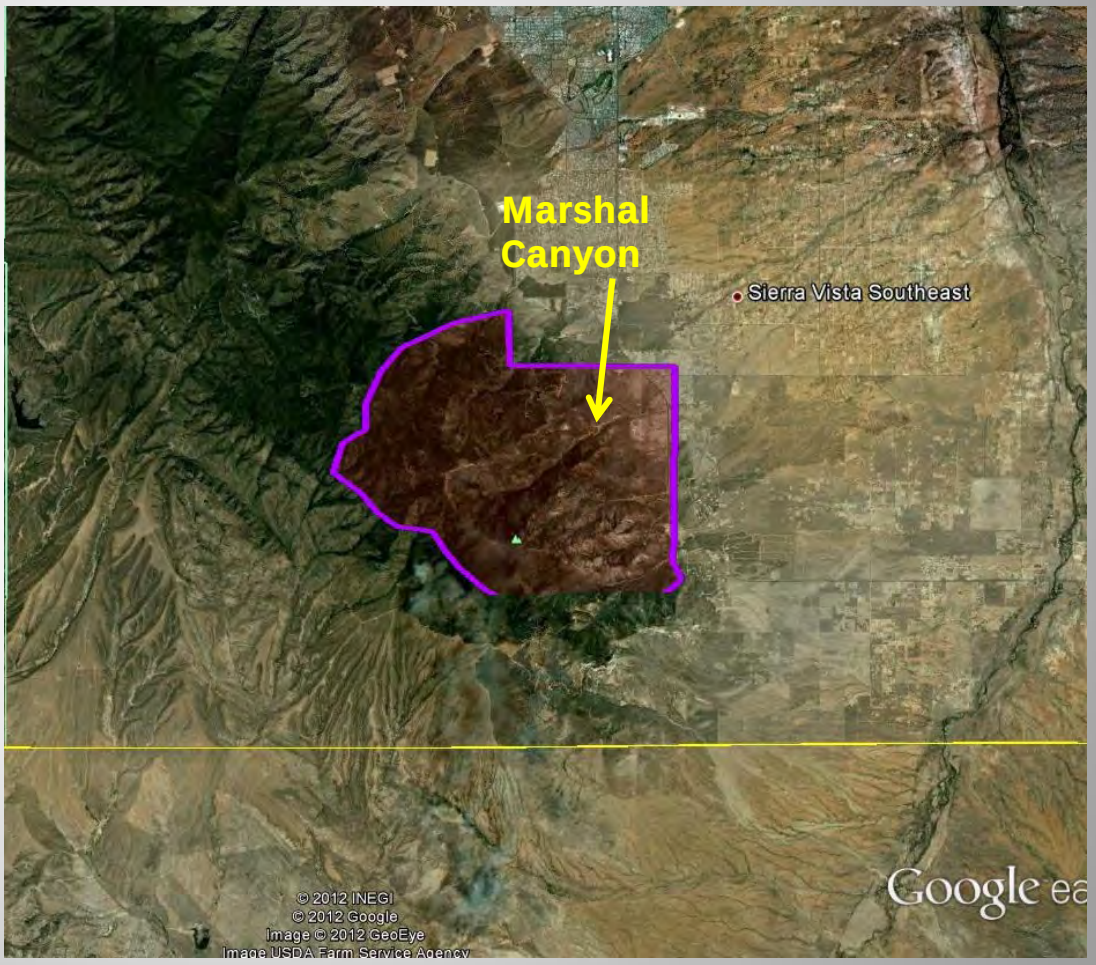
Beatty's Guest Ranch
View from footbridge over Miller Creek near campsites, July 8th.

But, this is nothing new…

Beatty's Guest Ranch
View of the same Miller Creek riparian area, July 11th, from river left.
This material came from Marshall Canyon.

1977 Carr Fire

- Mid-June fire
- S edge Ramsey Canyon to N side Ash Canyon
- 8600 acre burn area
- About ½ moderate to high severity



Post-Carr Fire

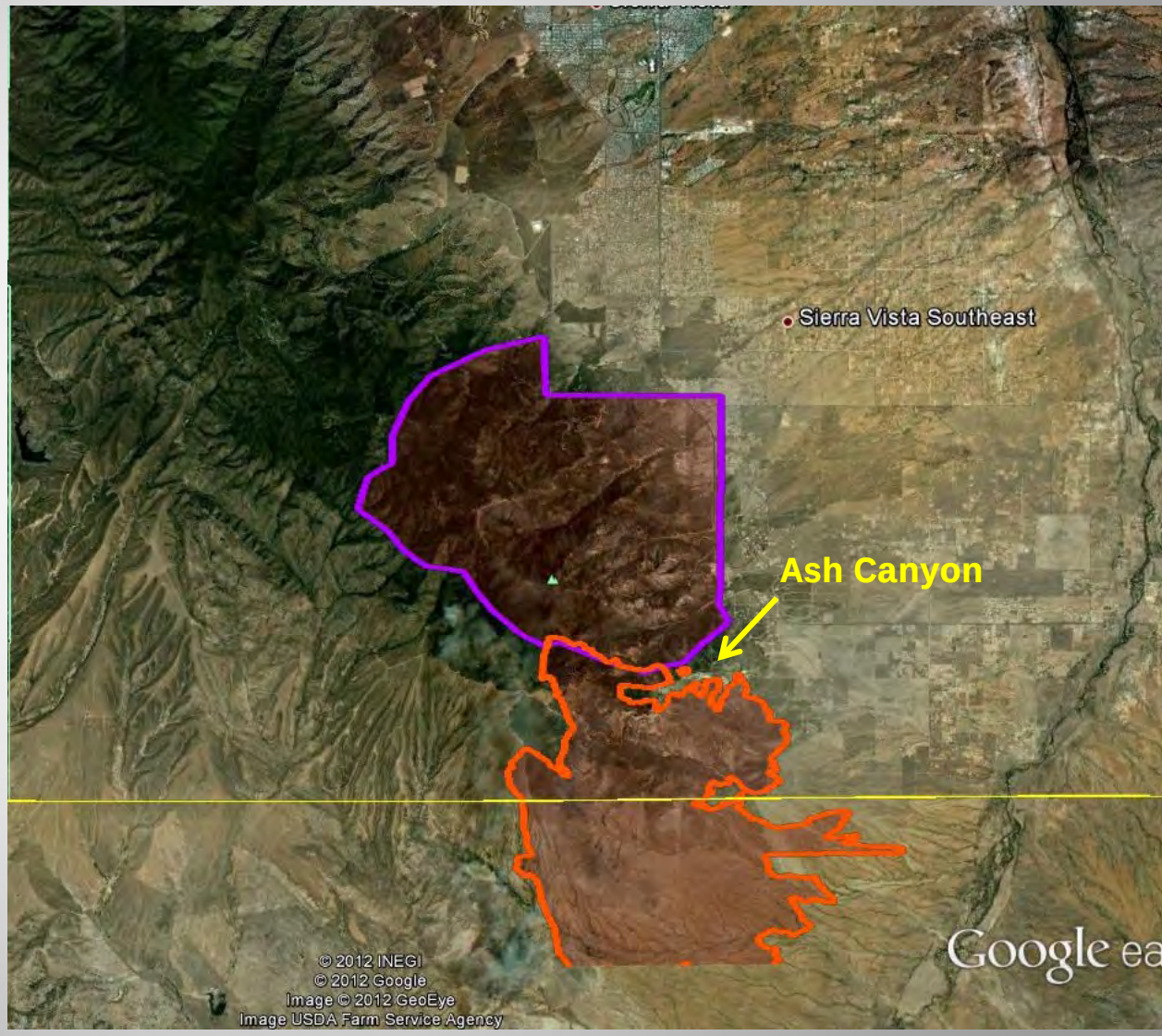
- July 12, 1977 – Marshal Canyon debris flow
- 0.7" daily total rain on Miller Peak
- 2nd significant rainfall of monsoon season
- Substantial damage to private inholding – Beatty's Guest Ranch
- City of Tombstone water supply impacted
- Possibly other debris flows in Carr watershed

Post-Carr Fire

Post-Monument Fire

1988 Peak Fire

- Mid-June fire
- Burned from Mexico to ~S perimeter of Carr Fire
- 16,310 acres
- 33 % high or moderate severity
- Homes in Ash Canyon preserved, but…

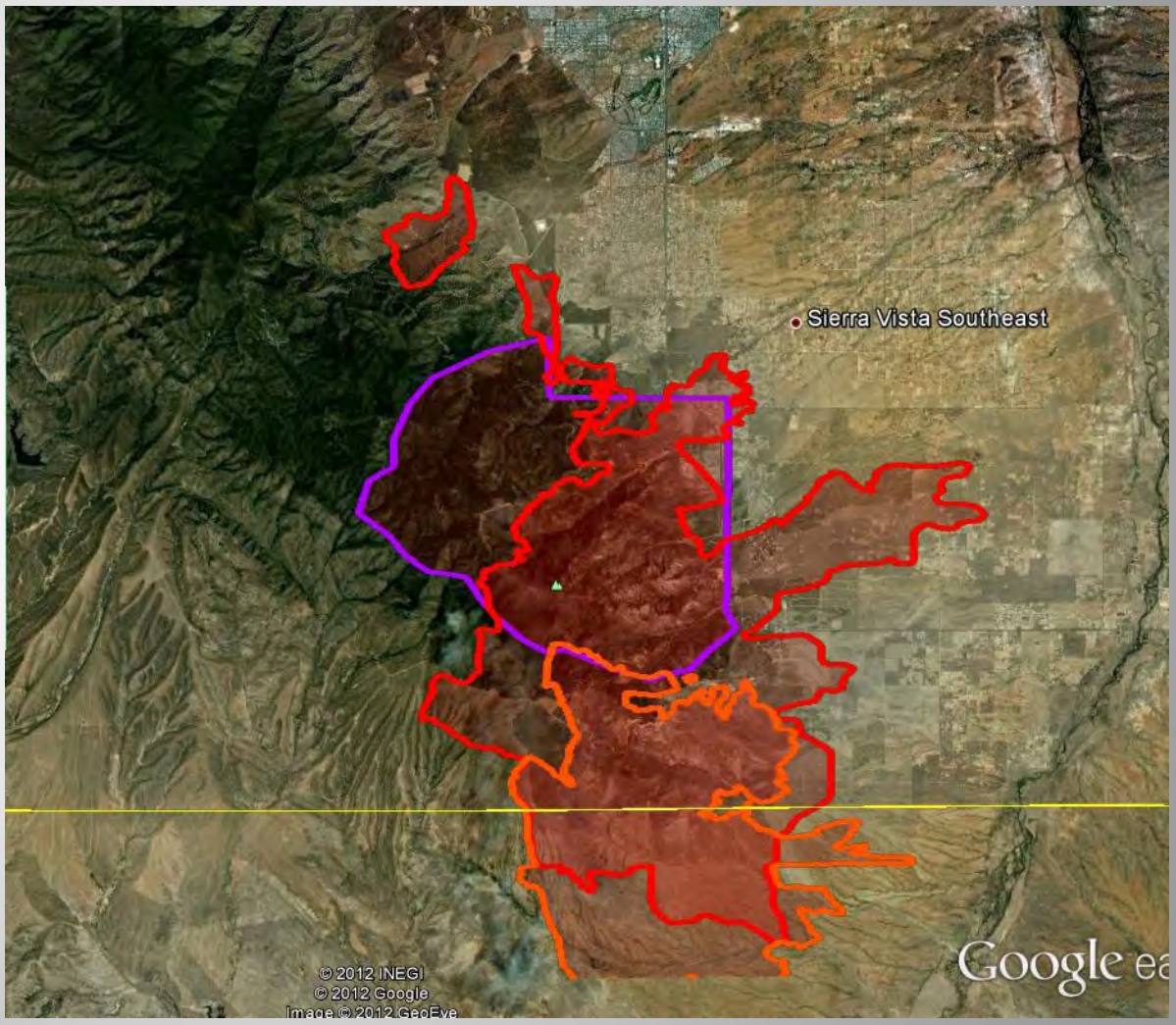


Post-Peak Fire

- July 11, 1988 – Dorothy Ryan Canyon debris flow
- Occurred after several moderately wet days in region
- Damage to several homes and property in Ash Canyon
- **Many other debris flows in burned area**

2011 Monument Fire

- Latter ½ June fire
- Fire area 30,050 acres
- 46% fire area moderate to high severity burn
- Re-burned most of Peak and Carr fire areas
- Homes in Ash Canyon, along mountain front burned

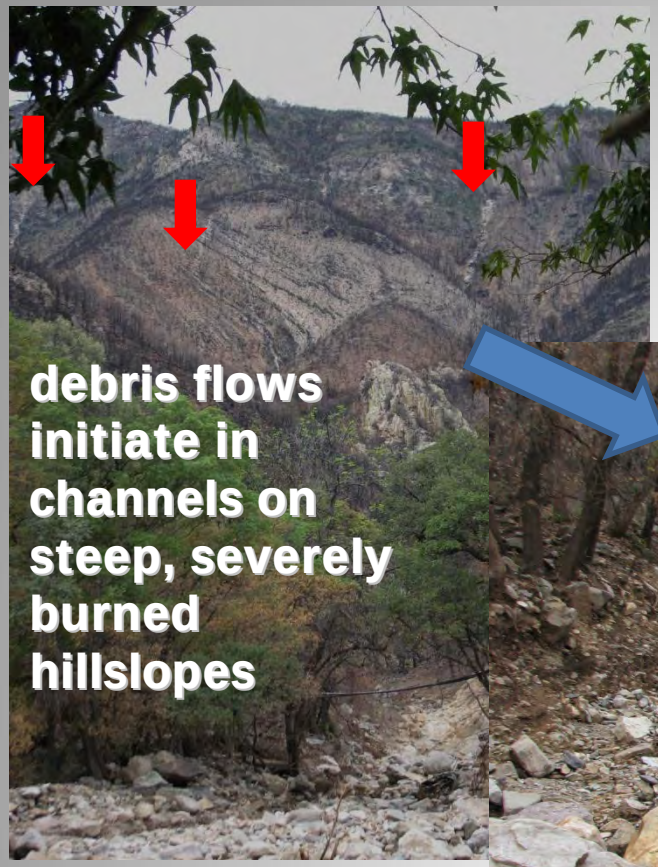


Post-Monument Fire

- July 10, 2011 Marshal Canyon debris flows (again)
- Other Miller Canyon debris flows
- 1.6” rainfall in ~1 hr
- First significant monsoon rain
- Damage to Beatty’s and Tombstone water pipe (again)

Post-fire debris flows:

- intense runoff
- channel bank failure
- channel scour

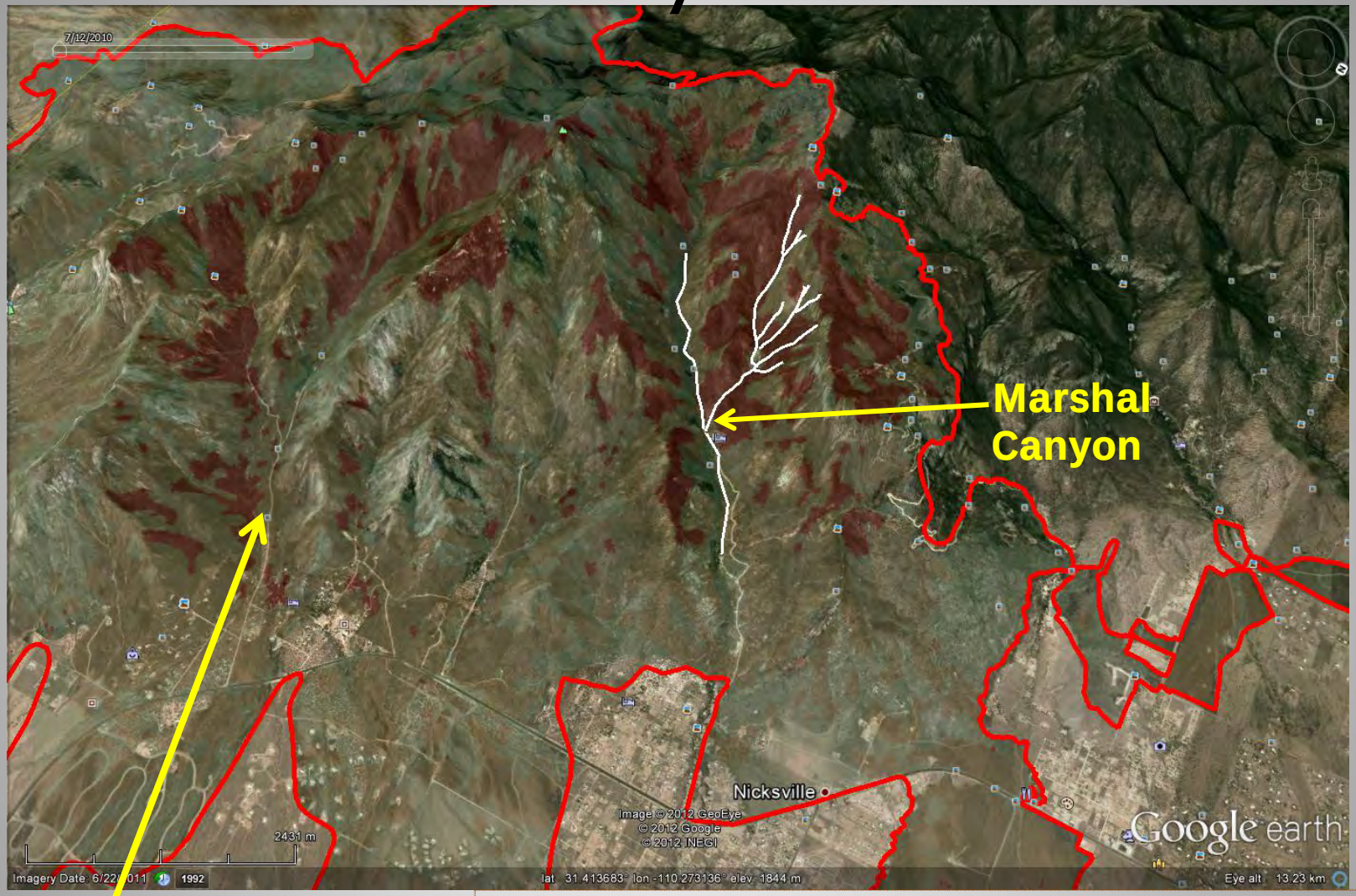


Marshall Canyon channel reloaded since 1977 and had enough sediment for debris flows in 2011.

1988 Fire and Debris Flows

- ~40 debris flows initiated – Wohl and Pearthree 1991
- in areas with high and moderate burn severity
- on steep slopes

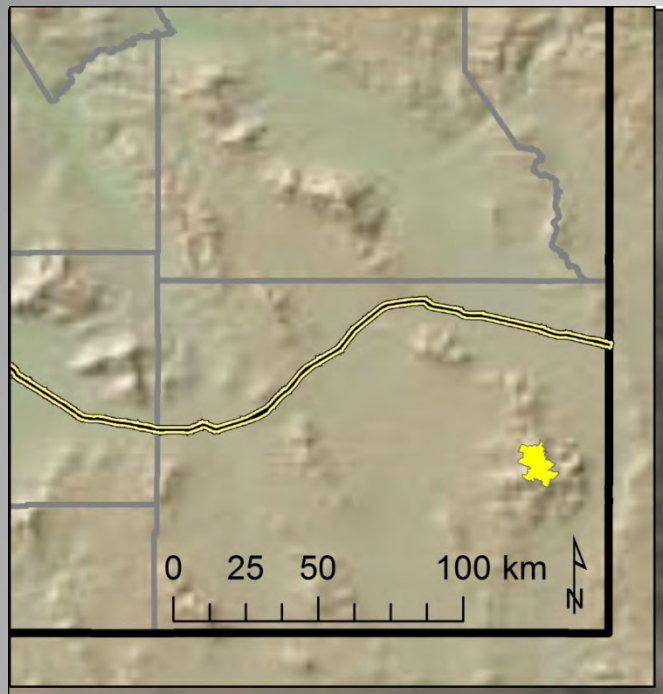
2011 Burn Severity and Debris Flows

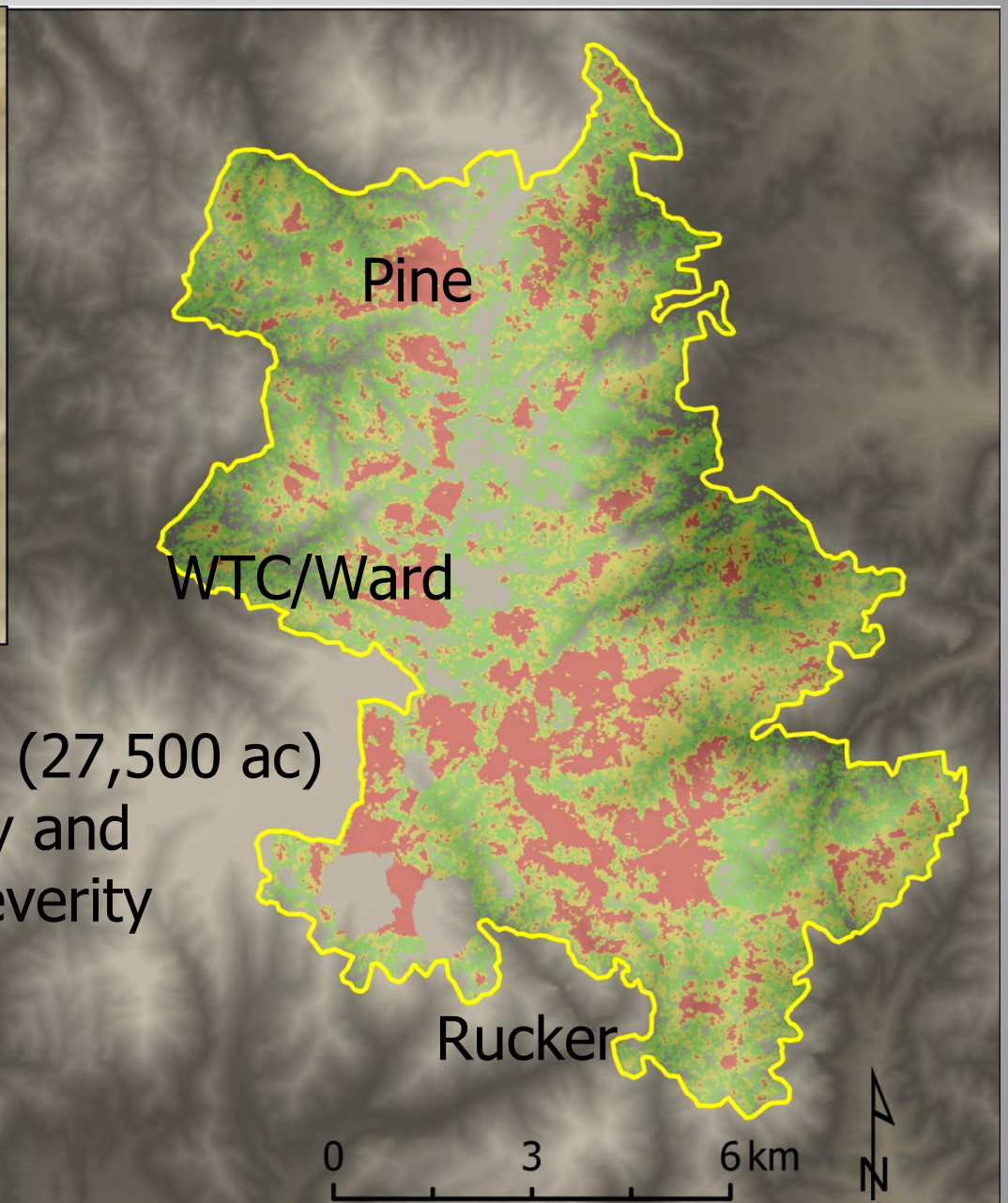


Few or no new debris flows in Ash Canyon, at least one in Lutz.

- debris flows less extensive than in 1988
- several debris flows initiated in Miller Canyon
- areas with high and moderate burn severity
- on steep slopes

1994 Rattlesnake Fire





Total Area: 11,110 ha (27,500 ac)
~21% at high severity and
~12% at moderate severity

Chiricahua – 1994 Rattlesnake Fire

Photo: C. Baisan, June 2004

Photo

Photo

09/09/2011 12:46

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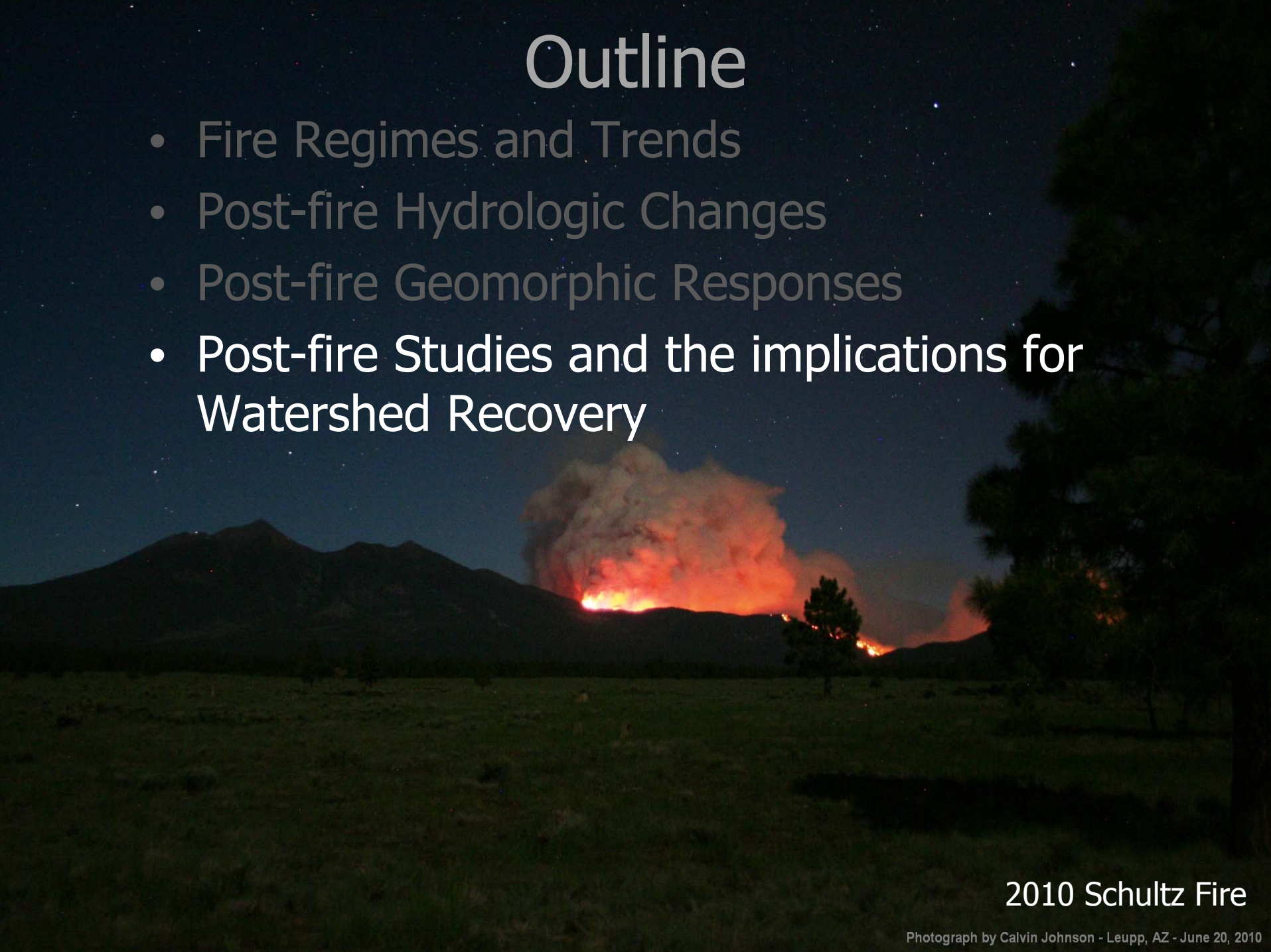


2010 Schultz Fire

Photograph by Calvin Johnson - Leupp, AZ - June 20, 2010

Watershed "Recovery"

Conventional Wisdom -> 3-5 Years

But What Does Recovery Mean?

Vegetation + ~pre-fire Q_p levels = Recovery??

Sediment Pulses

Cerro Grande Watershed…3 years after the fire.
Hayman Fire…8 years after the fire.

Timberline, August 16, 2010

Post-fire Effects: Time

Sediment Response to Fire

Aft

Fro

Marshall Canyon Debris Fan

View up-fan to the apex and channel.

July 11, 2011

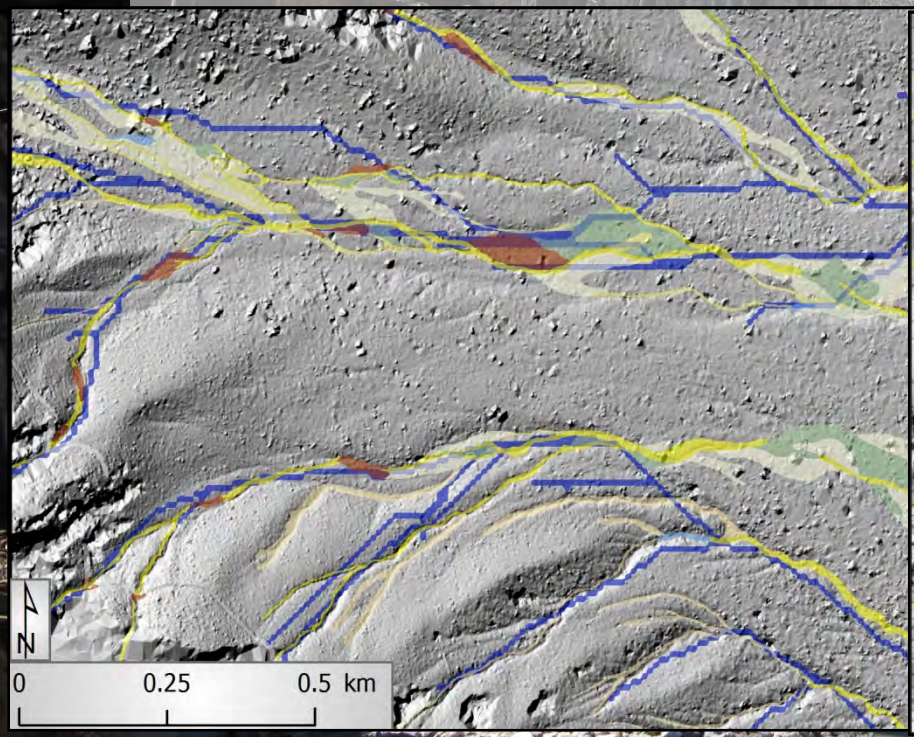
August 3, 2011

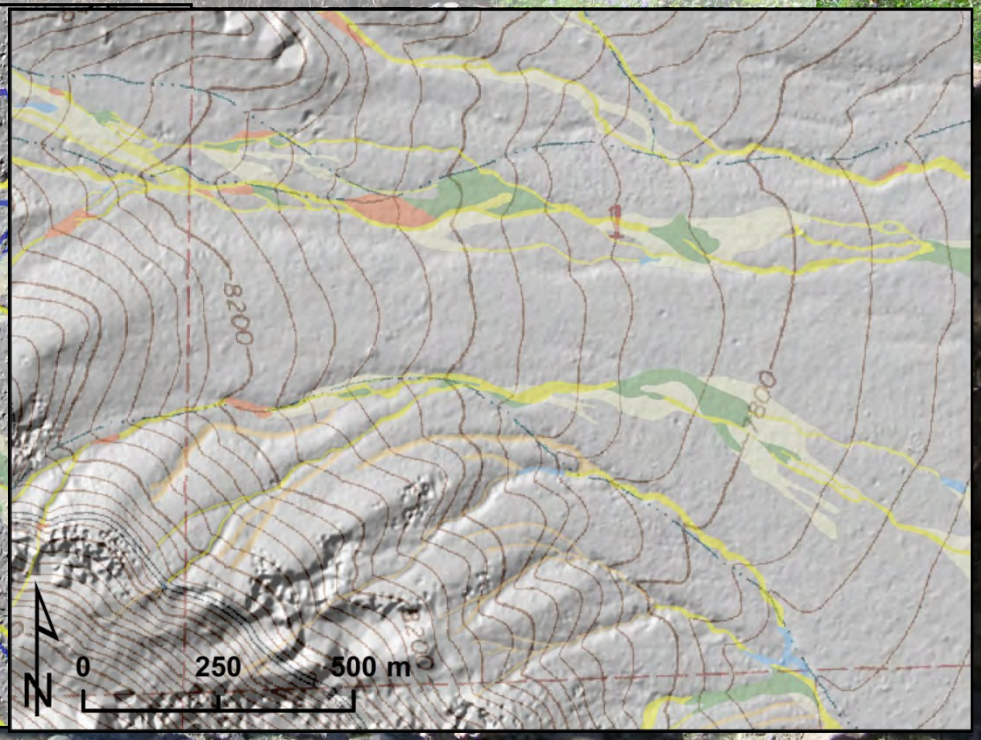
September 1, 2011

Monitoring Post-fire Erosion and Watershed Responses

How can we monitor and assess post-fire erosion on a shoestring budget with limited time and personnel?

Approach: First used to assess the 2010 Schultz Fire





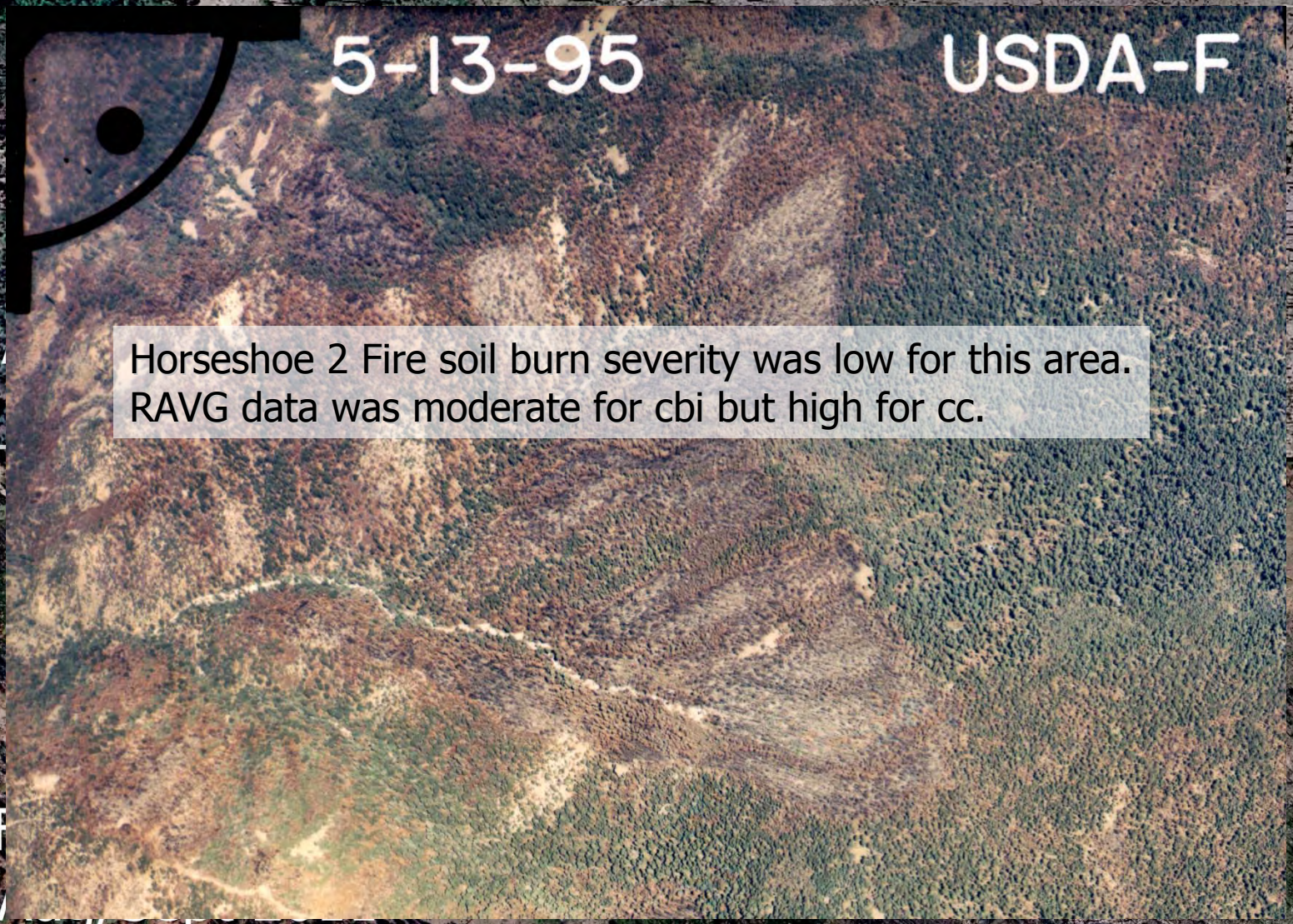
2010 Schultz Fire Erosion

Repeat Aerial Photography

- The Coronado NF, with help from the Regional Office, had cyclical resource photos flown in August and September. The next photo flights will be in late May/early June.

Aug/Sept, 2011

July 8th, 2011



Horseshoe 2 Fire soil burn severity was low for this area.
RAVG data was moderate for cbi but high for cc.

N

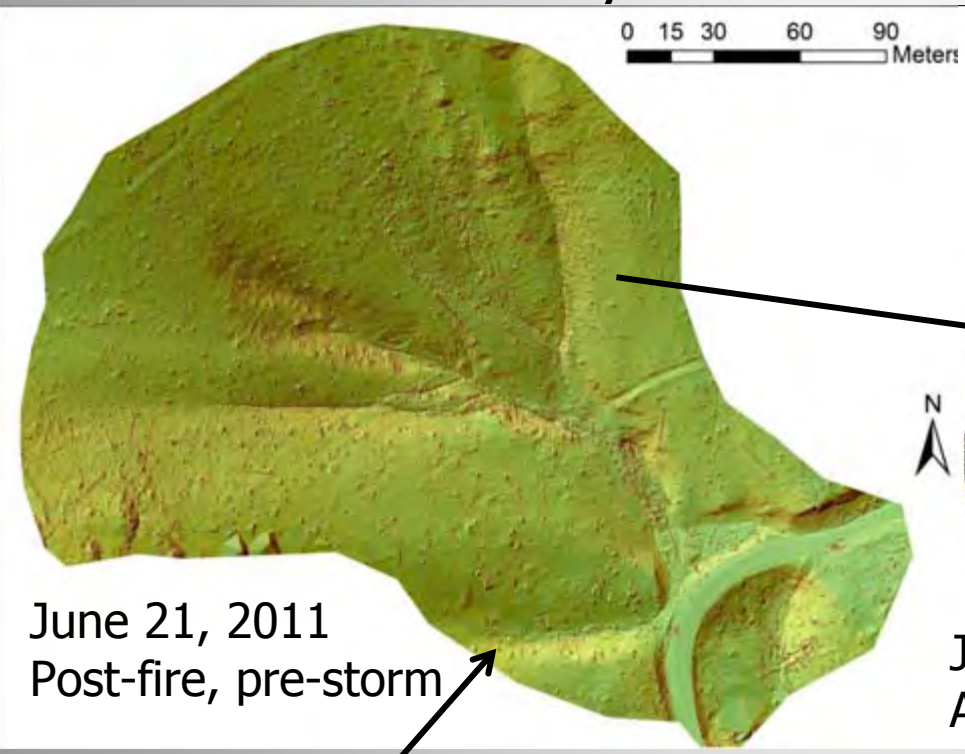
0 100 200 m

18 June 2011

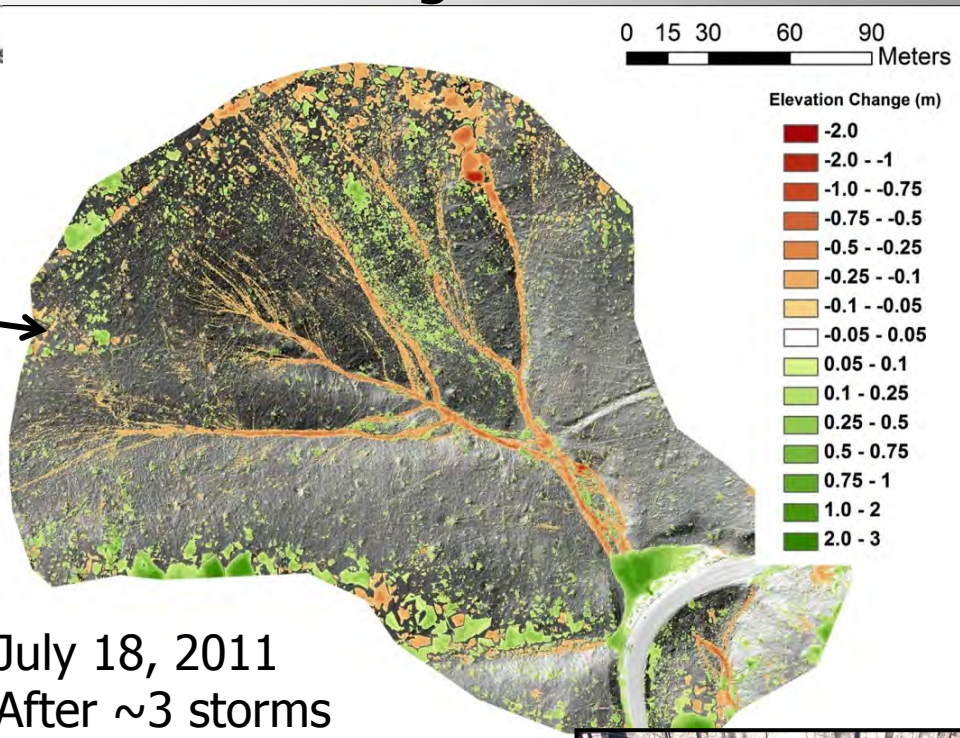
Other Post-fire Research

From the 2012 Southwest Wildfire Hydrology and Hazards Workshop
(to see these and other presentations go to: http://repository.azgs.az.gov/)

Assessing post-fire landscape change in a steep headwater catchment burned by the Horseshoe 2 Fire using terrestrial LiDAR



June 21, 2011
Post-fire, pre-storm



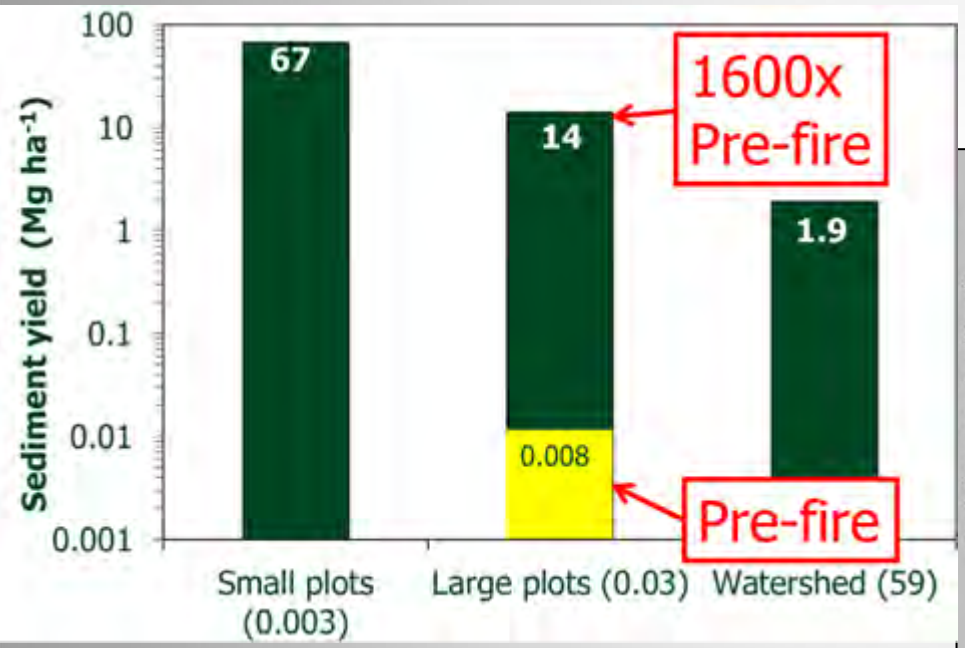
July 18, 2011
After ~3 storms

Steve DeLong and others, UofA, Biosphere 2, Landscape Evolution Observatory (http://leo.b2science.org/)

Other Post-fire Research

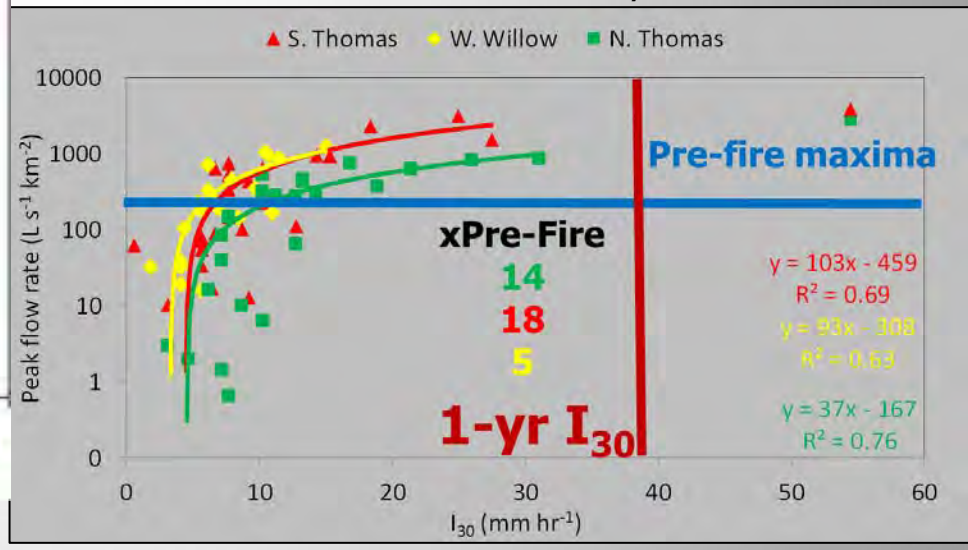
From the 2012 Southwest Wildfire Hydrology and Hazards Workshop
(to see these and other presentations go to: http://repository.azgs.az.gov/)

Post-Wallow Fire peak flows and hillslope sedimentation from 3 re-instrumented experimental watersheds



Sediment yields (2.2 Mg ha^{-1} = 1 ton ac^{-1})

Pre-fire peak flows = snowmelt
Post-fire = monsoon, so far.



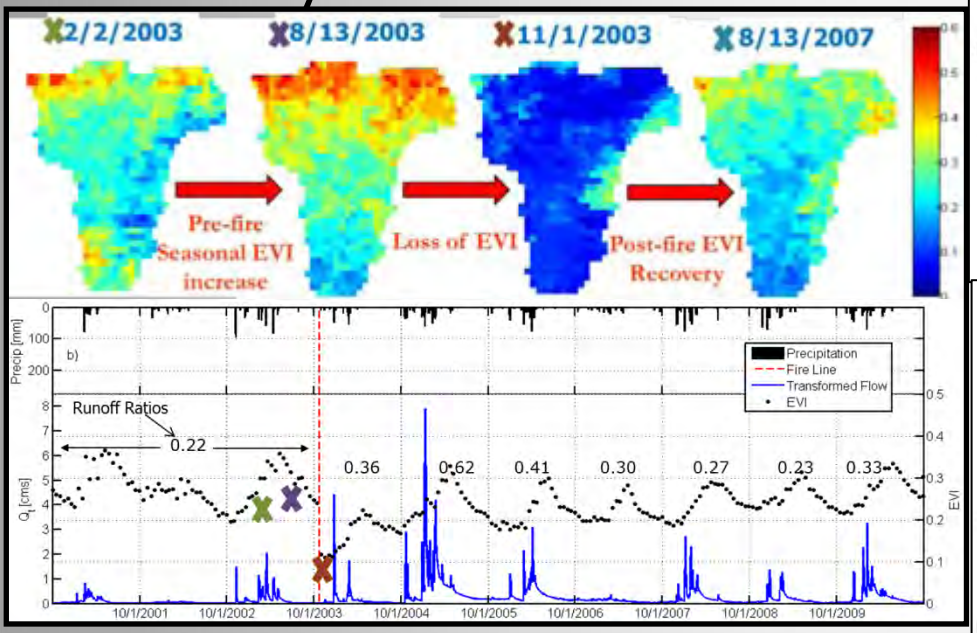
Peak flows (11 L s^{-1} km^{-2} = 1 ft^3 s^{-1} mi^{-2})

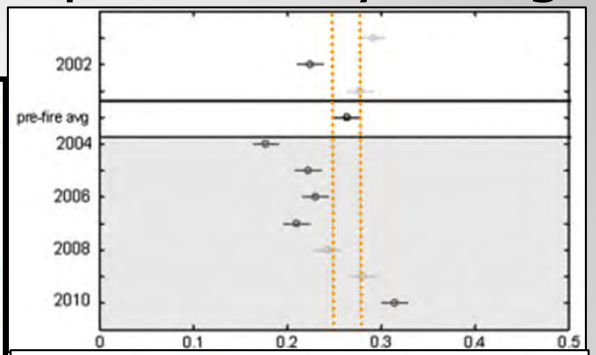
Joe Wagenbrenner and others,
USFS Rocky Mountain Research Station
(http://forest.moscowfsl.wsu.edu/)

Other Post-fire Research

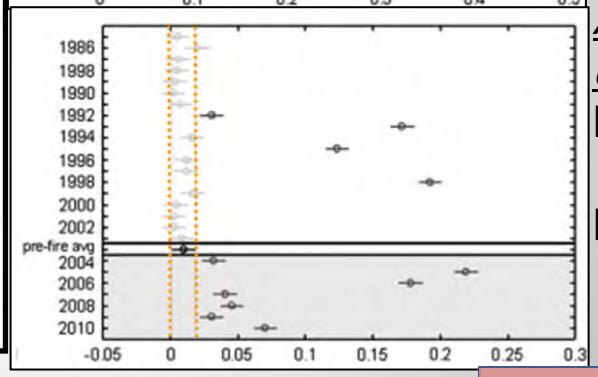
From the 2012 Southwest Wildfire Hydrology and Hazards Workshop
(to see these and other presentations go to: http://repository.azgs.az.gov/)

Spatial and temporal controls on post-fire hydrologic recovery in Southern California

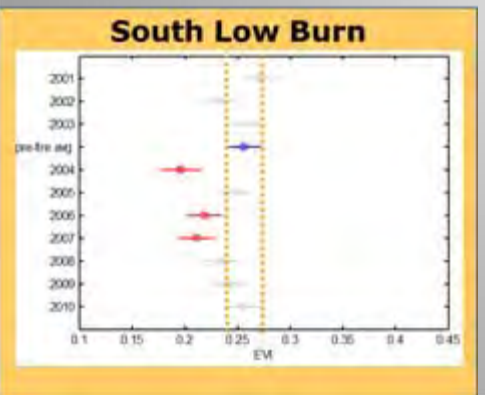




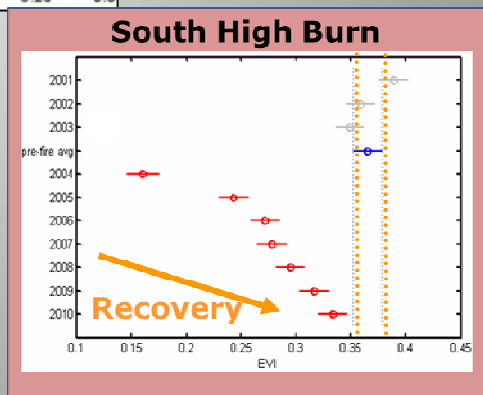
Annual basin average EVI "recovers" by 2010



Annual discharge (cms)
Pre-fire outliers = El Nino years
Discharge not similar by 2010



Burn severity, aspect, and post-fire climate affect recovery



Alicia Kinoshita, UCLA

Kinoshita, A.M., and Hogue, T.S., 2011, CATENA, v. 87, no. 2, p. 240-252.

Conclusions

- Fires trends increasing in size and severity
- Fires significantly change basin hydrology
- Different components of the watershed recover at different rates
  - Veg Recovery ≠ Hydrologic Recovery
  - Veg + Hydro Recovery ≠ Ecosystem or Riparian Recovery
  - Sediment pulses
- Reburning older burns and getting the same responses – surprising that some channels can reload so quickly

Photo: D. Greenspan, Schultz Fire from Humphrey's Peak

Acknowledgements

- Phil Pearthree, AZGS
- Dan Neary, Karen Koestner, Pete Koesnter, RMRS
- Jennifer Ruyle, Bob Lefevre, Salek Shafiqullah, Coronado National Forest
- Candace Bogart and Bart Mathews, USFS R3 GIS/Photogrammetry Program
- Susan Cannon, Debra Martin, John Moody, USGS
- Steve DeLong, UofA, Biosphere 2
- Joe Wagenbrenner and co-authors, RMRS
- Alicia Kinoshita and co-authors, UCLA
- Erica Bigio and Tom Swetnam, UofA Tree Ring Lab
- Tom and Edith Beatty

Photo: Mark Nabel, Post-Schultz Fire Debris Flow