



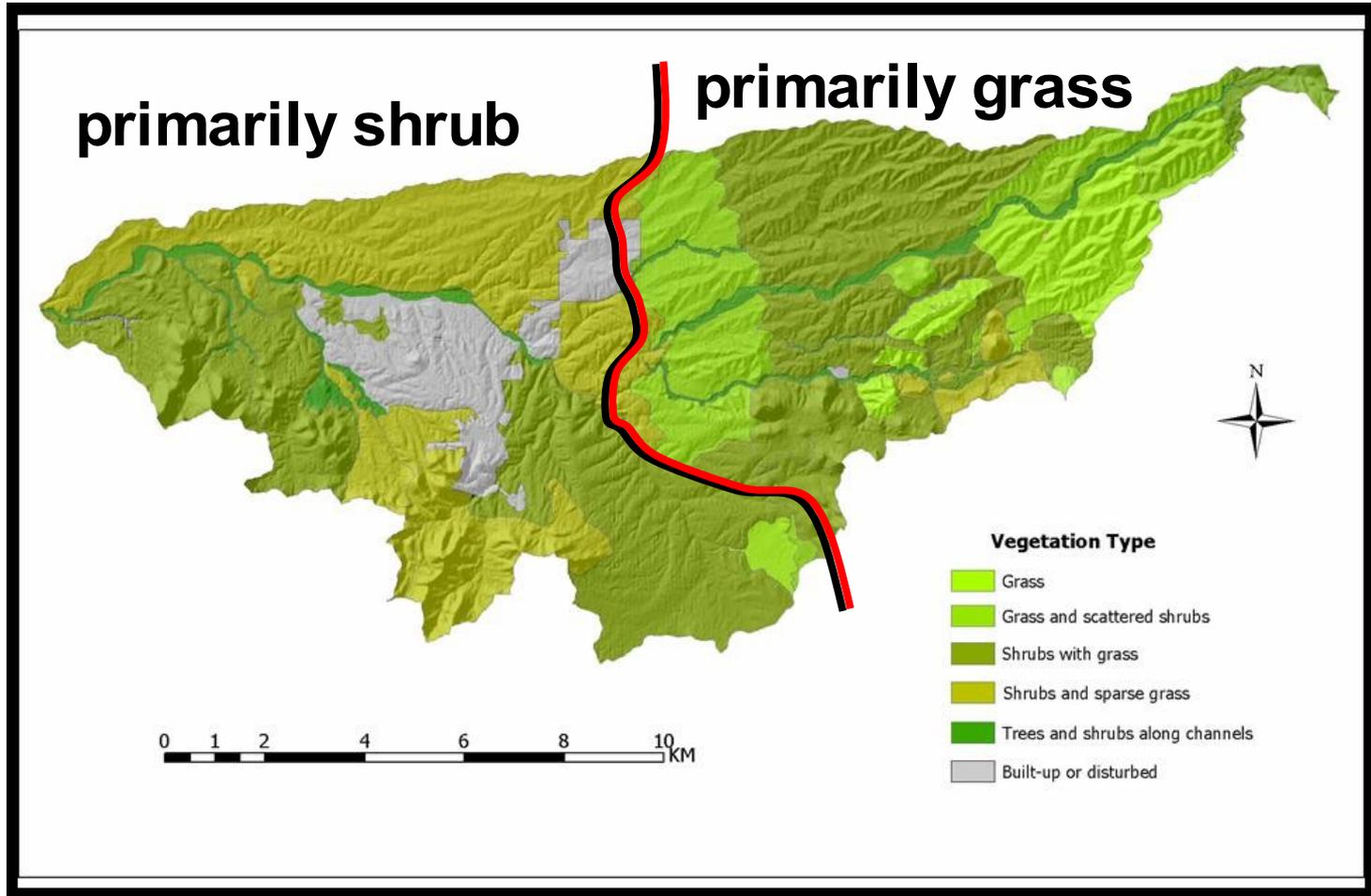
**Shrub and Grass  
Hydrology  
at a Range of Scales**

**Jeffry Stone  
SWRC-ARS-USDA**

# Introduction

- **Background of data at Walnut Gulch**
- **Small watershed data (2 ha)**
  - Runoff characteristics**
  - Controlling processes**
- **Range of scales (.25 – 14,800 ha)**
  - Controlling processes**

# Vegetation at Walnut Gulch



# Vegetation at Walnut Gulch

shrub



grass



## The Runoff Process

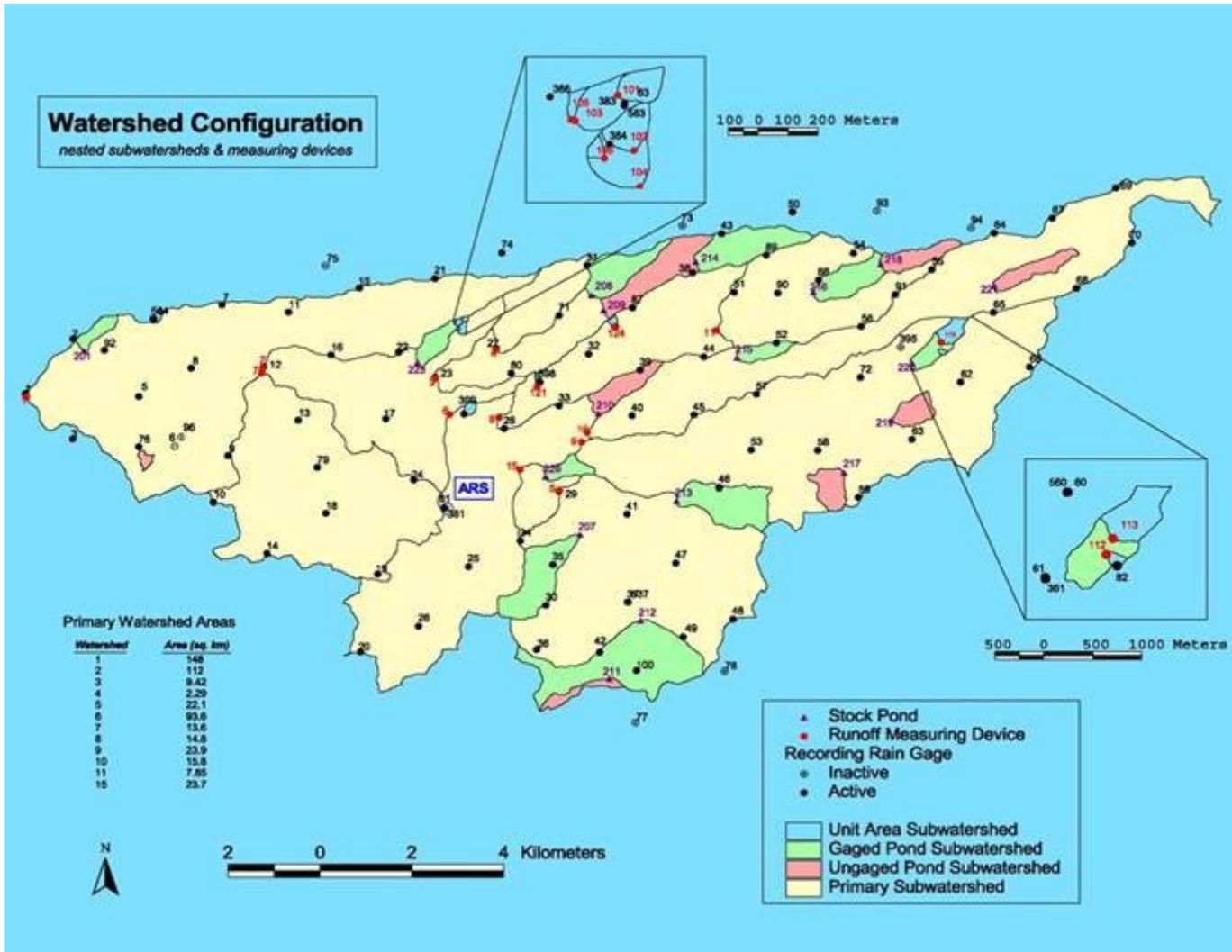
**In semi-arid regions runoff occurs when the rainfall rate  $>$  infiltration capacity of the soil**

**This process is termed**

**Hortonian runoff**

**Rainfall excess runoff**

# Hydrologic Network



# Small Scale Runoff Measurement

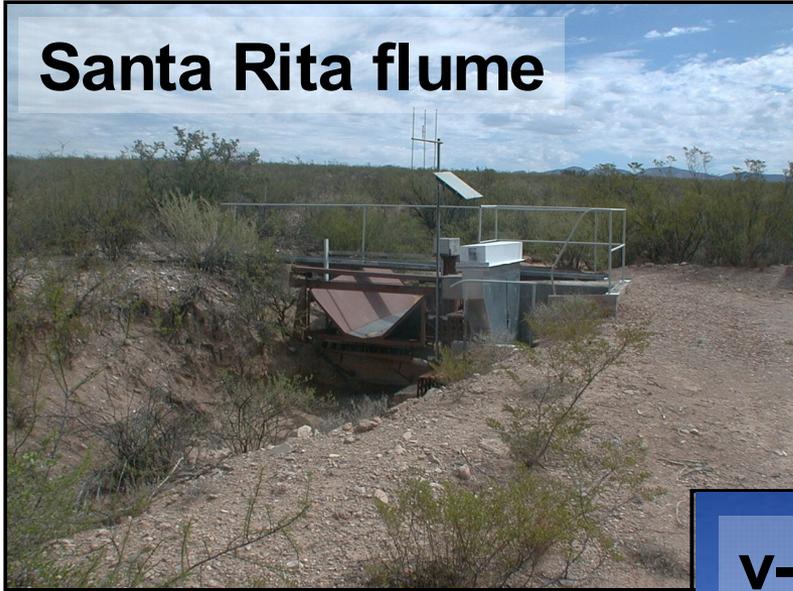
Area .25 - 6 ha

Watersheds

8 shrub

3 grass

Santa Rita flume



v-notch weir



# Medium Scale Runoff Measurement

stock tank



**Area 35 - 160 ha**

**Watersheds**

**4 shrub**

**2 grass**

**1 grass/shrub**

# Large Scale Runoff Measurement

## Walnut Gulch supercritical flume



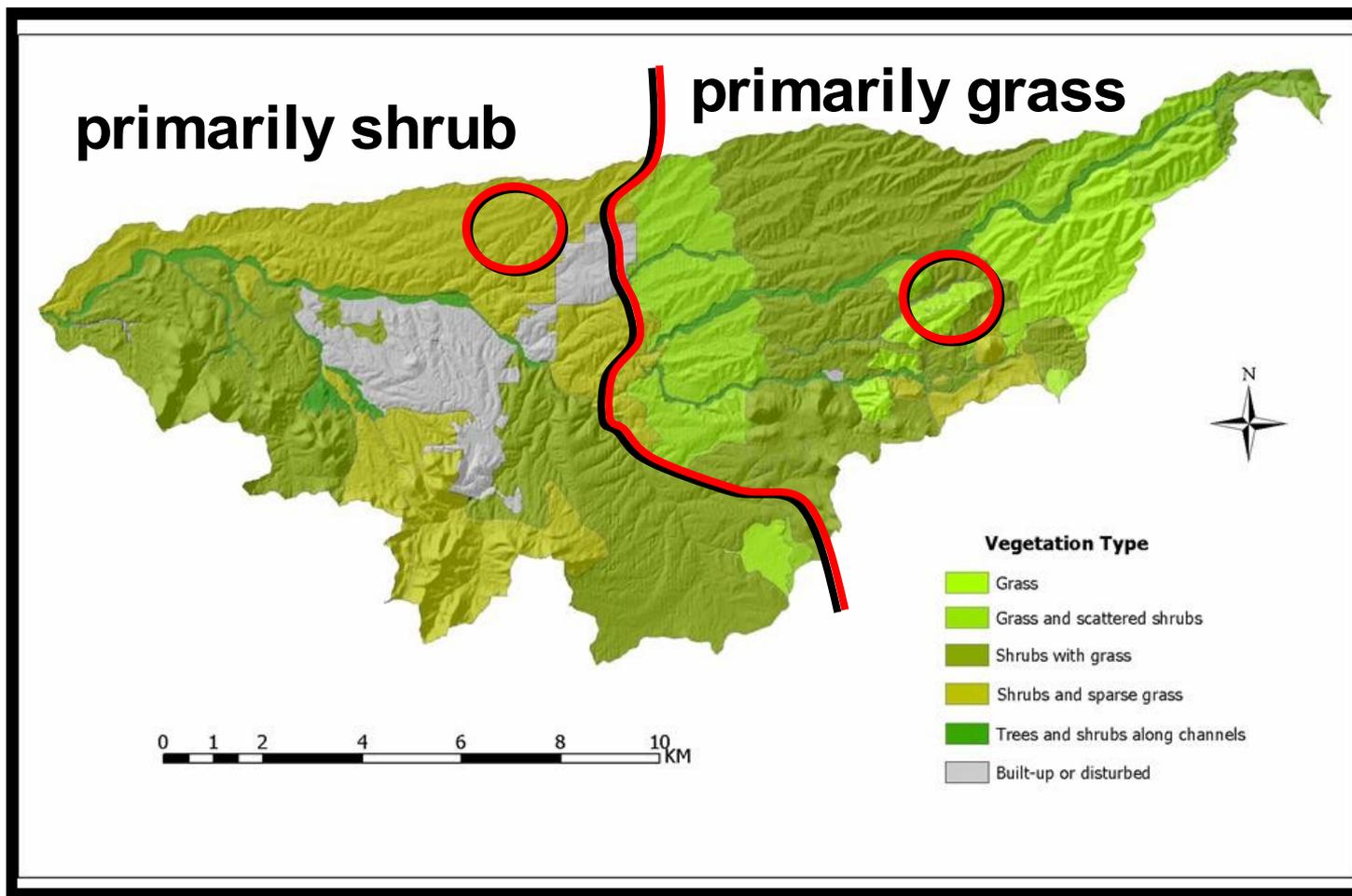
**Area 226 – 14,900 ha**

**Watersheds**

**6 shrub/grass**

**5 grass/shrub**

# Small Watershed Runoff



# Small Watershed Runoff



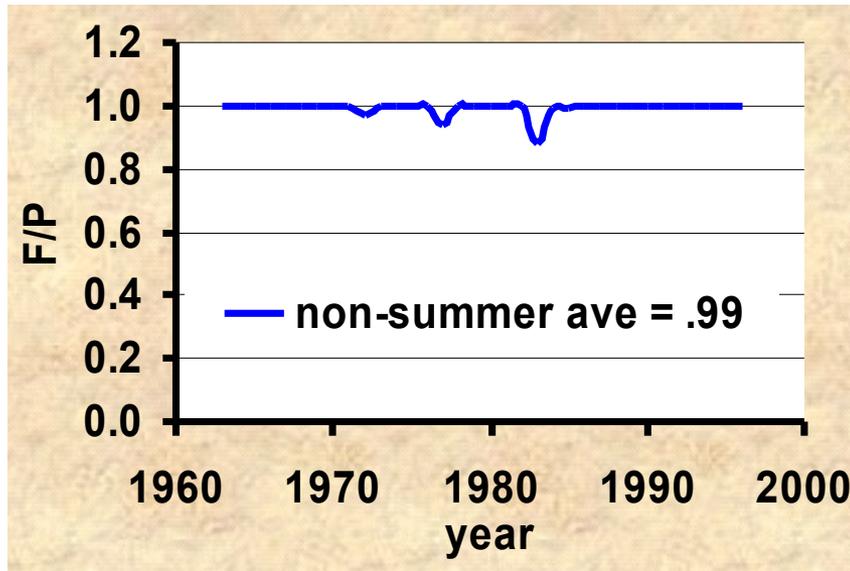
creosote  
whitethorn  
n  
tarbush

sideoats grama  
blue grama  
black grama



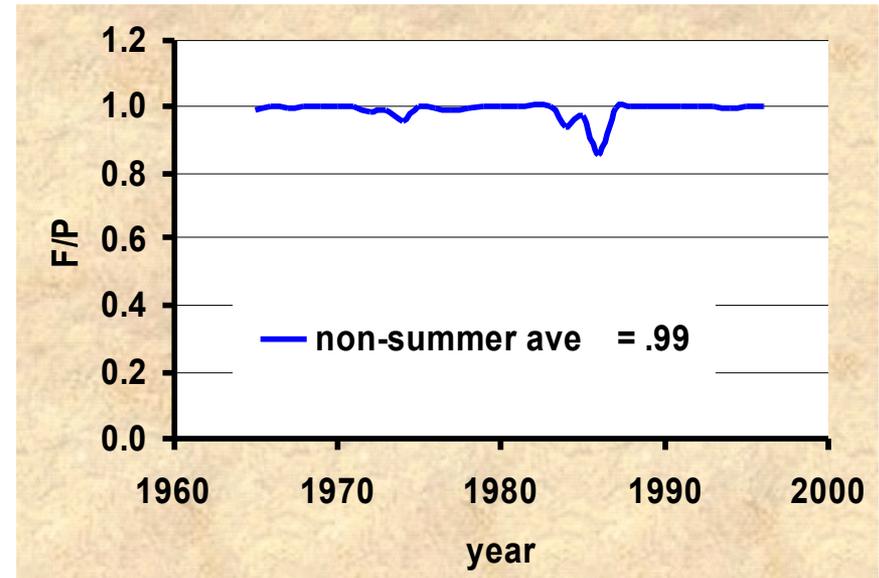
# Small Watershed Seasonal Infiltration

## Oct - June Infiltration



grass

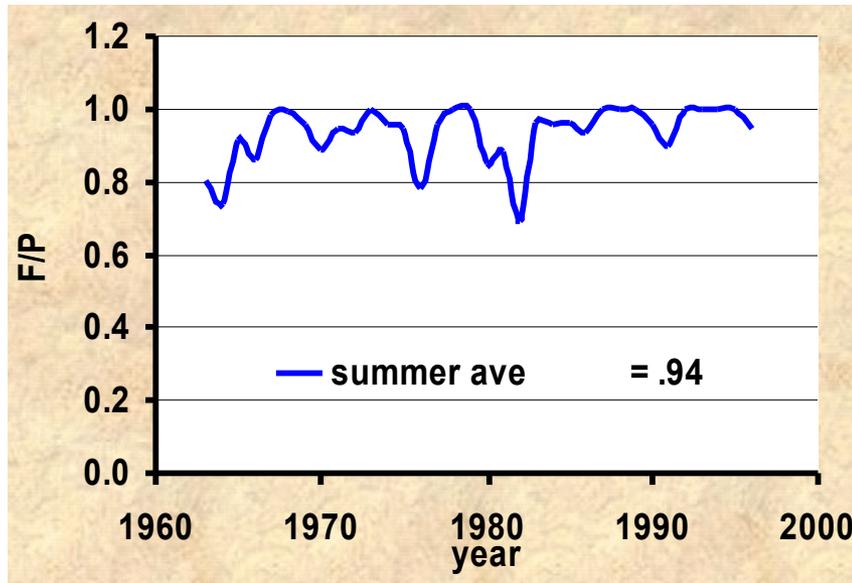
$$F/P = \frac{\text{Infiltration}}{\text{Precipitation}}$$



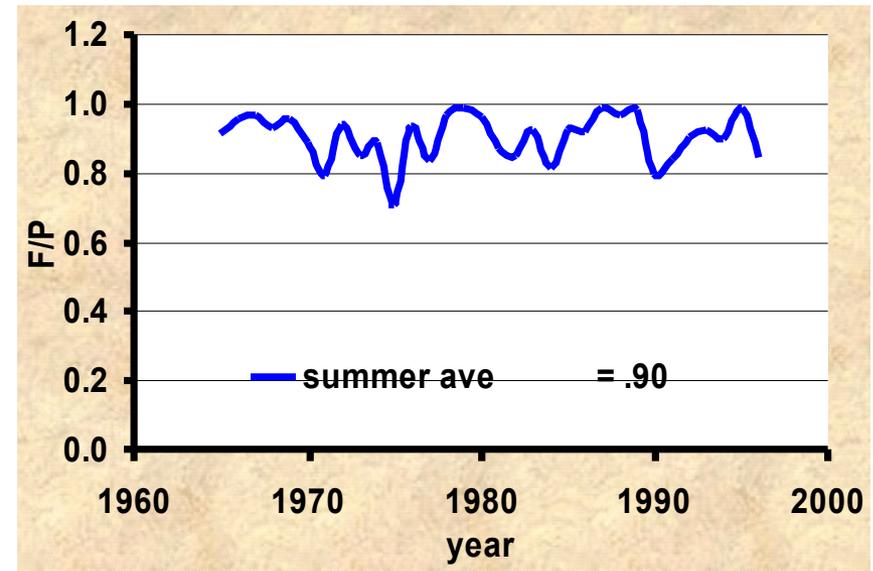
shrub

# Small Watershed Seasonal Infiltration

## July - Sept Infiltration

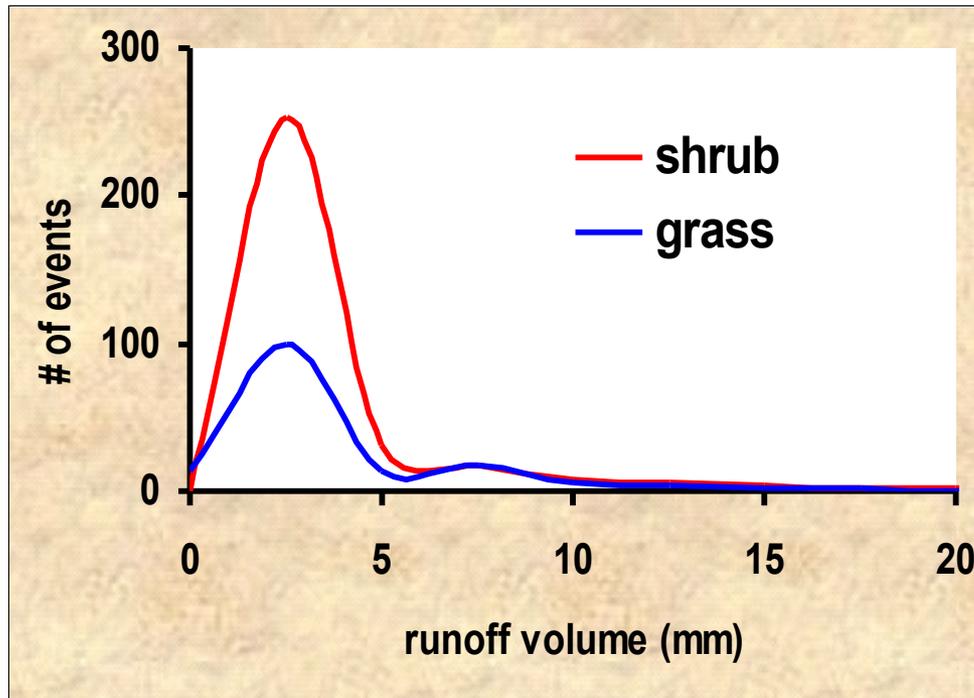


grass



shrub

# Small Watershed Runoff Volume

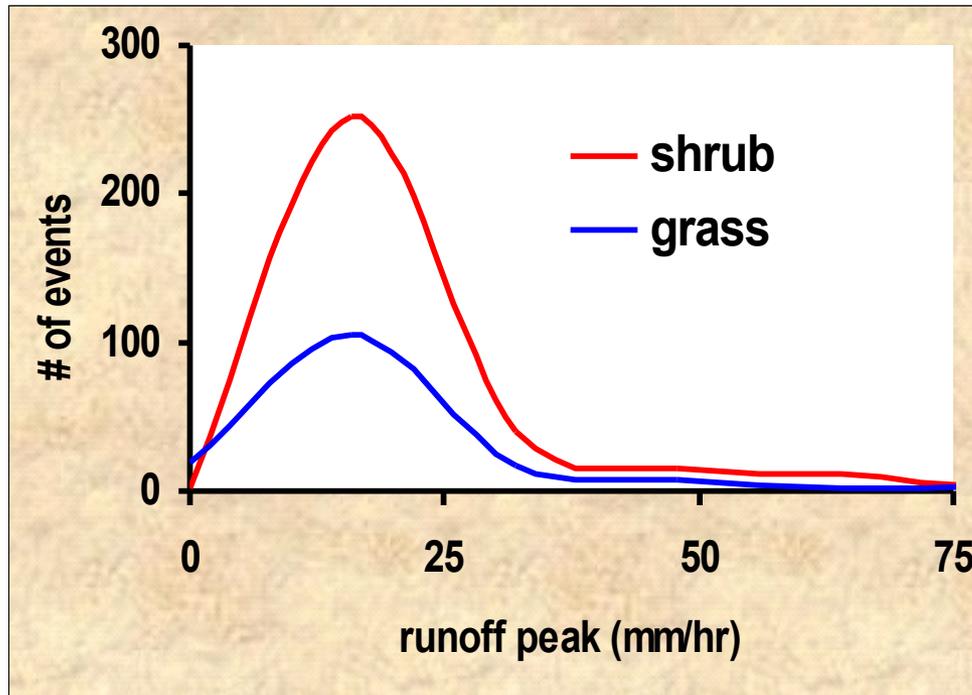


## Average Runoff Volume

**shrub: 2.2 mm, n = 328**

**grass: 2.7 mm, n = 158**

# Small Watershed Runoff Peak

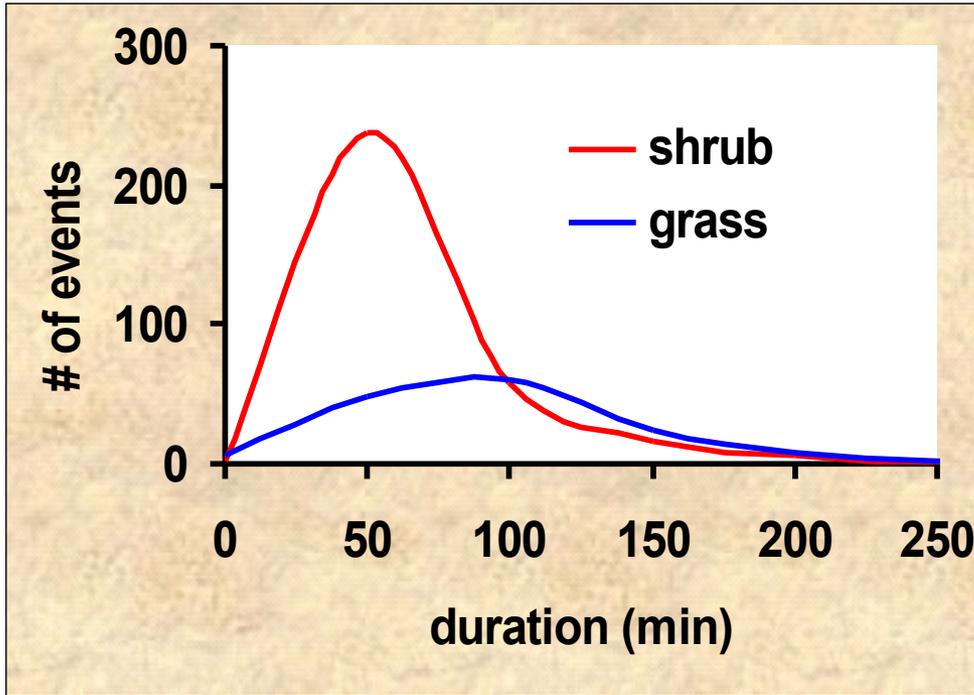


**Average  
Runoff Peak**

**shrub: 11 mm/hr**

**grass: 12 mm/hr**

# Small Watershed Runoff Duration



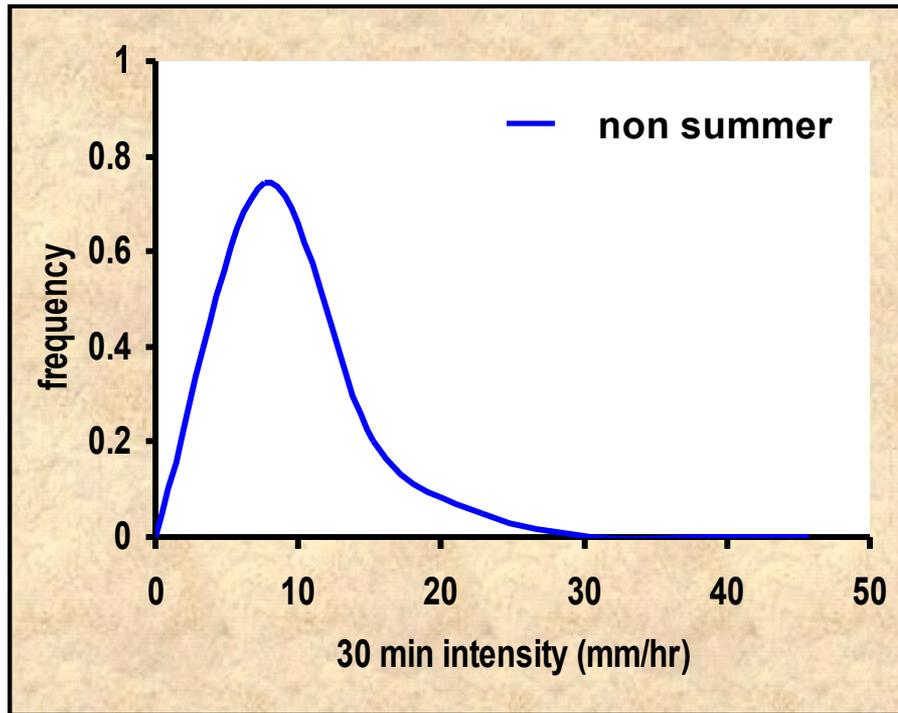
**Average  
Runoff Duration**

**shrub: 48 min**

**grass: 89 min**

# Small Watershed Runoff

## Rainfall intensity effects on runoff shrub watershed



Season

Ave

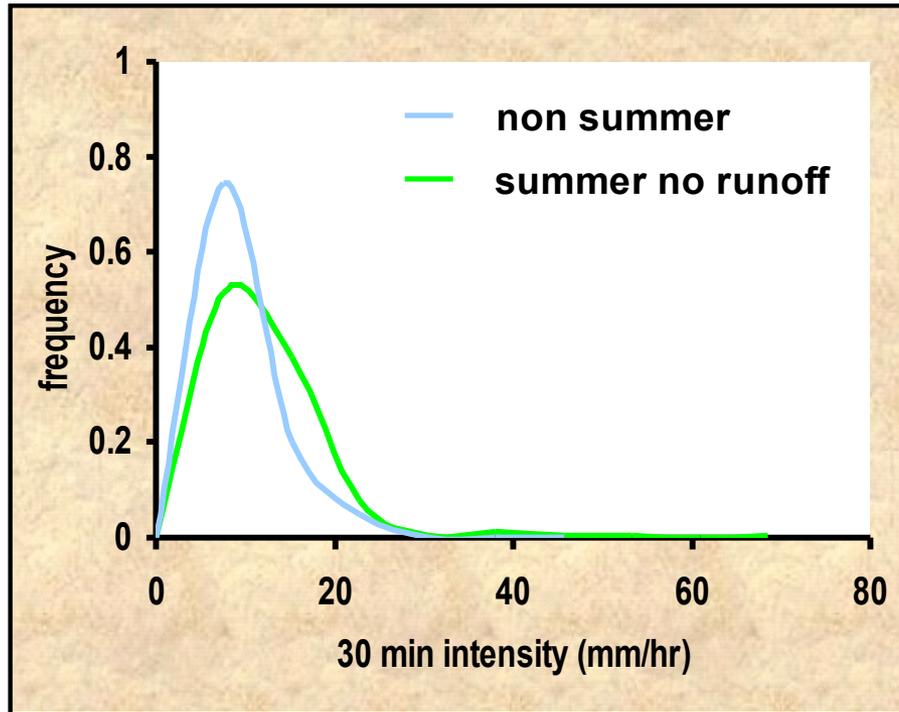
Intensity

non summer

6 mm/hr

# Small Watershed Runoff

## Rainfall intensity effects on runoff shrub watershed



Season

Ave

Intensity

non summer

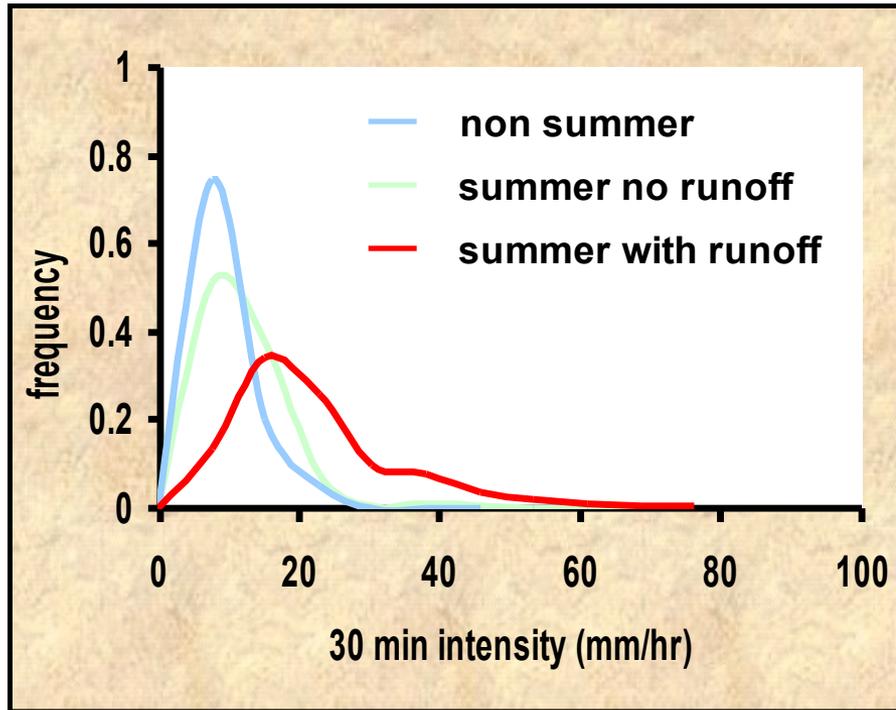
6 mm/hr

summer no runoff

9 mm/hr

# Small Watershed Runoff

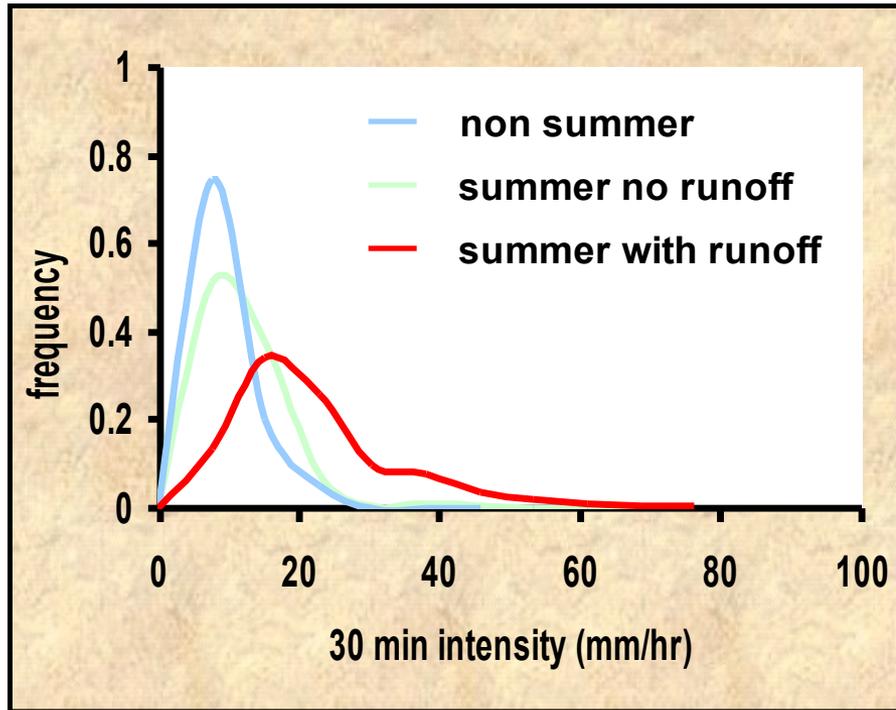
## Rainfall intensity effects on runoff shrub watershed



Season	Ave Intensity
non summer	6 mm/hr
summer no runoff	9 mm/hr
summer runoff	19 mm/hr

# Small Watershed Runoff

## Rainfall intensity effects on runoff shrub watershed

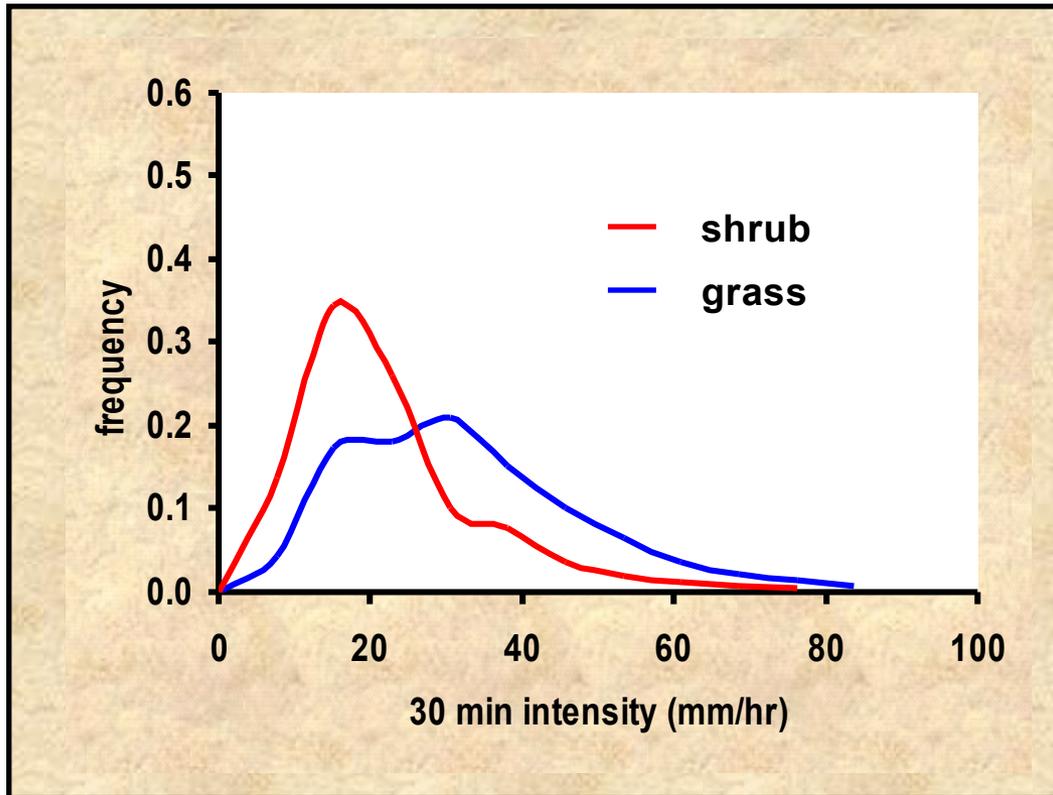


Season	Ave Intensity
non summer	6 mm/hr
summer no runoff	9 mm/hr
summer runoff	19 mm/hr

**Rainfall which causes runoff has a higher intensity than rainfall which has no runoff**

# Small Watershed Runoff

## Summer rainfall with runoff shrub vs grass



Season	Ave Intensity
shrub	19 mm/hr
grass	29 mm/hr

It takes higher intensities to generate runoff from the grass watershed

# Small Watershed Runoff

## Shrub vs Grass Runoff

1. Average volume and peak are similar
2. For grass watershed
  - less number of events (primarily small)
  - longer duration
  - higher rainfall intensity to initiate runoff

# Small Watershed Runoff

## Shrub vs Grass Runoff

These differences could be explained by

1. higher infiltration rate on grass
  - however, this would mean shorter durations
2. microtopographic differences
  - higher depression storage
  - reduce runoff velocity
  - higher infiltration opportunity time

# Small Watershed Runoff

## Walnut Gulch Rainfall Simulator Variable intensity - 25-180 mm/hr



# Small Watershed Runoff

## Grassland Sites



# Small Watershed Runoff

## Grassland Sites

- Flow is sinuous
- Many obstructions to flow
- High amount of depression and detention storage
- Lower flow velocities



# Small Watershed Runoff

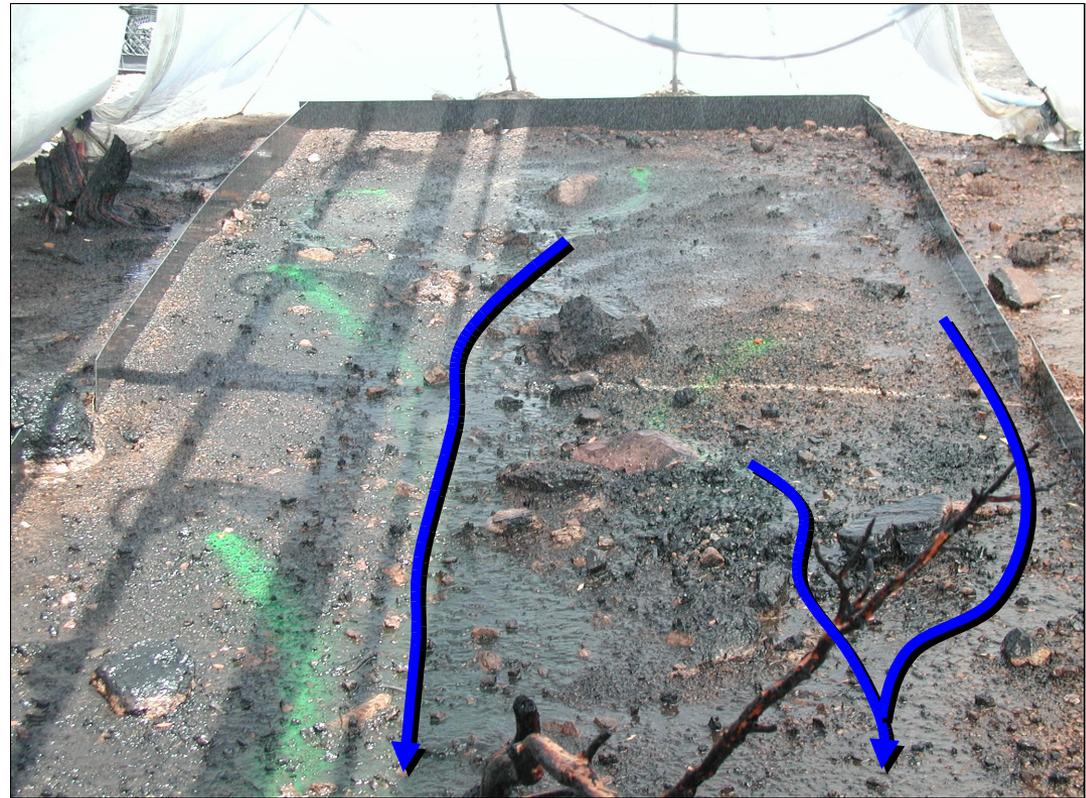
## Oak Woodland Sites



# Small Watershed Runoff

## Oak Woodland Sites

- Flow paths are continuous
- Few obstructions to flow
- Lower amount of storage
- Higher flow velocities



# Range of Scales



**.25 - 6 ha**



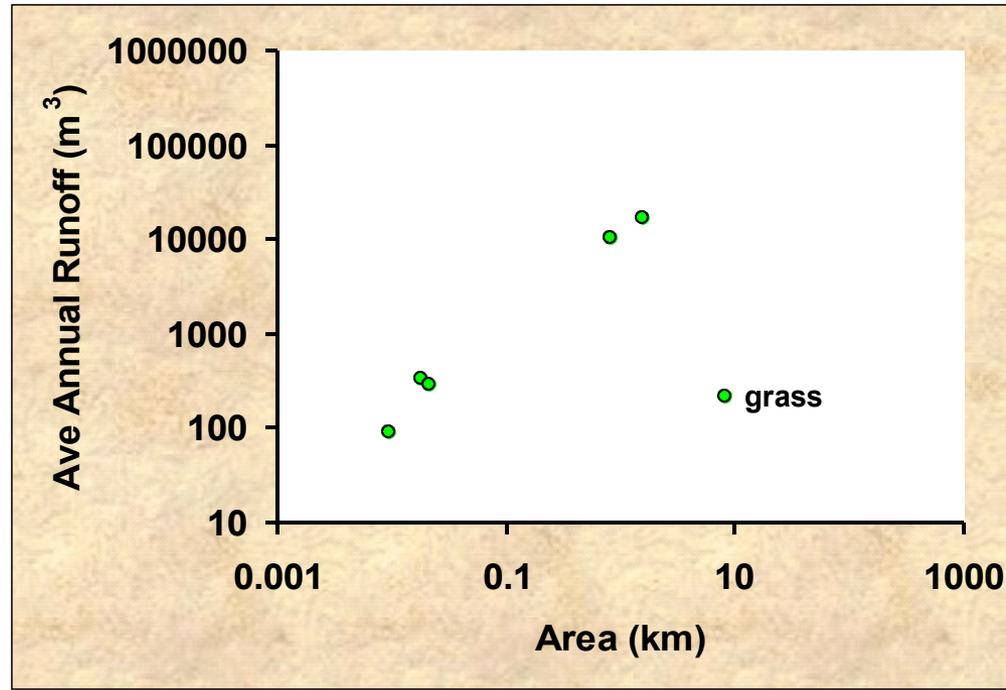
**35 - 160 ha**



**226 - 14,900 ha**

# Range of Scales

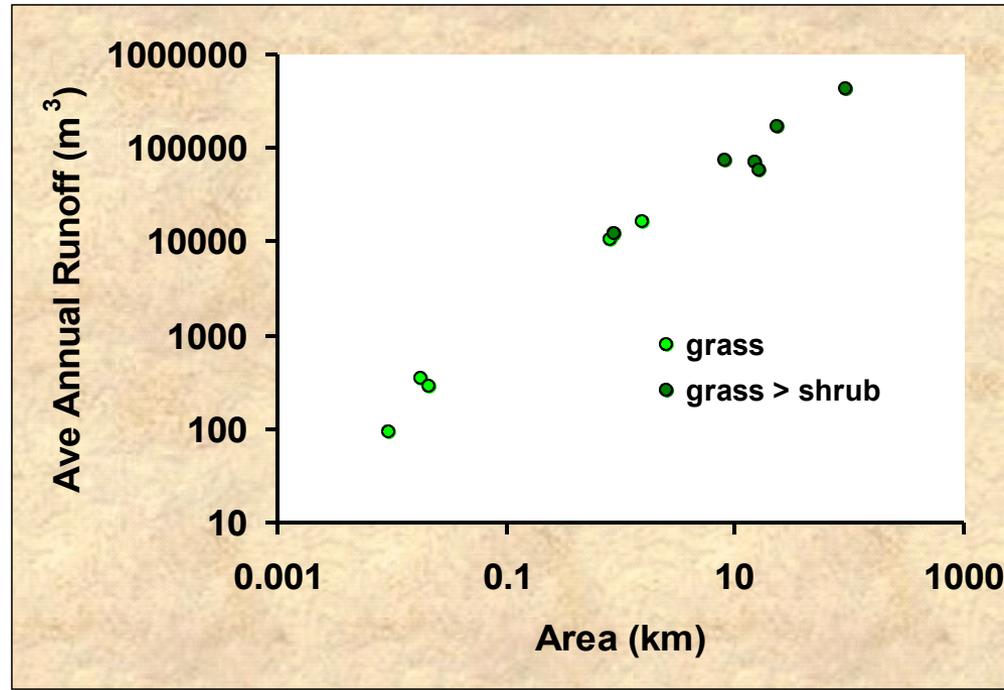
## Small – medium scale GRASS watersheds



Average annual runoff vs drainage area

# Range of Scales

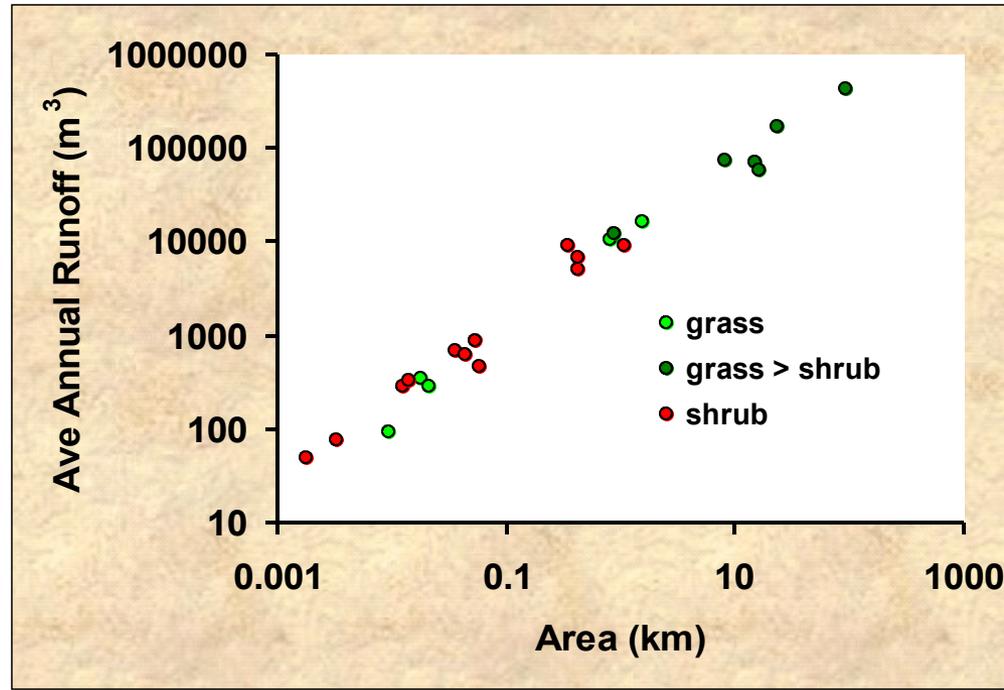
## Medium - large scale GRASS/SHRUB watersheds



## Average annual runoff vs drainage area

# Range of Scales

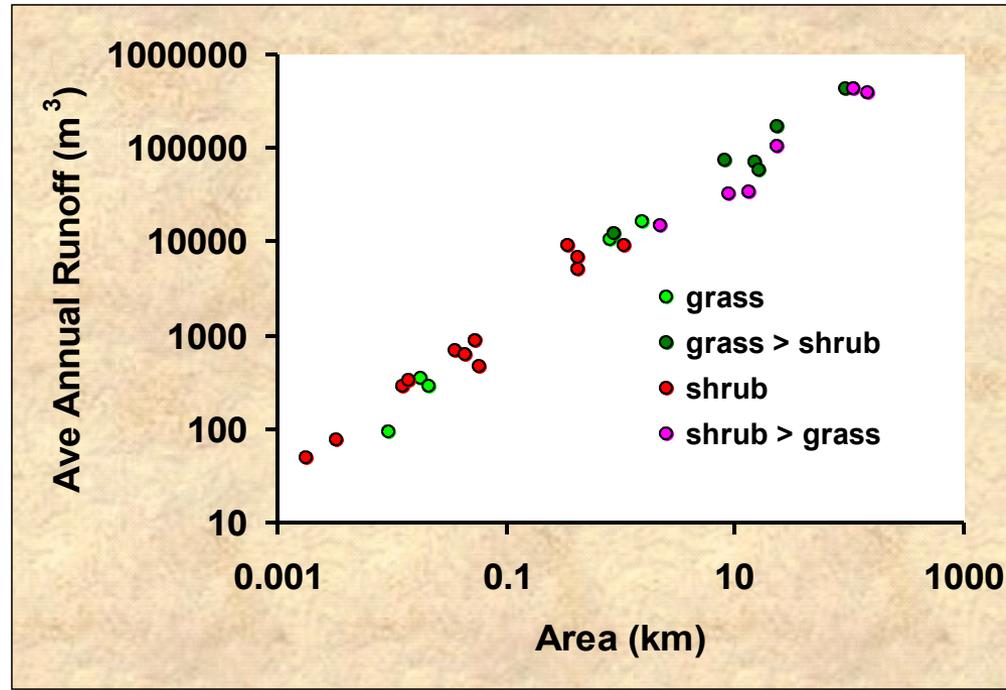
## Small – medium scale SHRUB watersheds



Average annual runoff vs drainage area

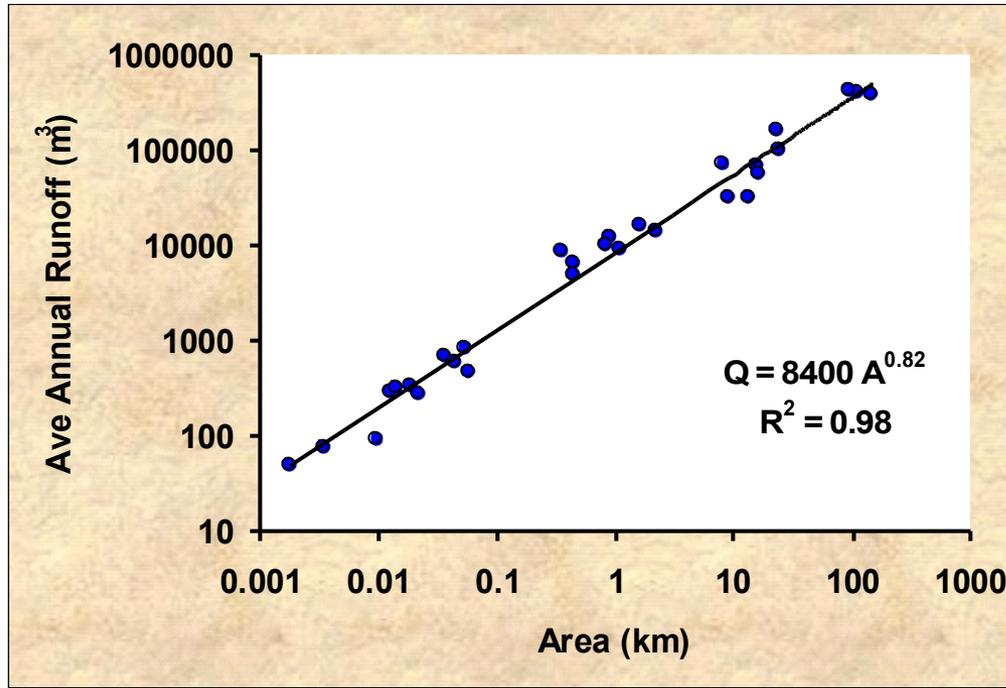
# Range of Scales

## Medium - large scale SHRUB/GRASS watersheds



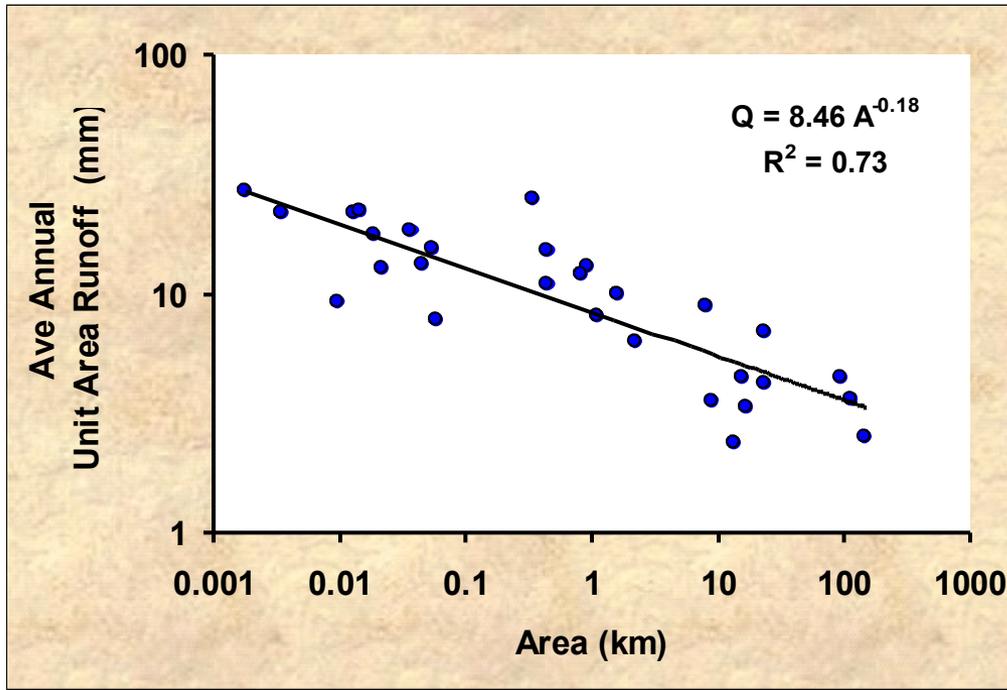
Average annual runoff vs drainage area

# Range of Scales



**At the range of scales at Walnut Gulch, runoff is more related to AREA than VEGETATION**

# Range of Scales



A plot of runoff per unit area vs area shows that runoff **DECREASES** with **AREA**

**WHY?**

# Range of Scales



**Transmission Losses**  
**infiltration of the flood wave**  
**into the dry channel**  
**alluvium**

# Range of Scales

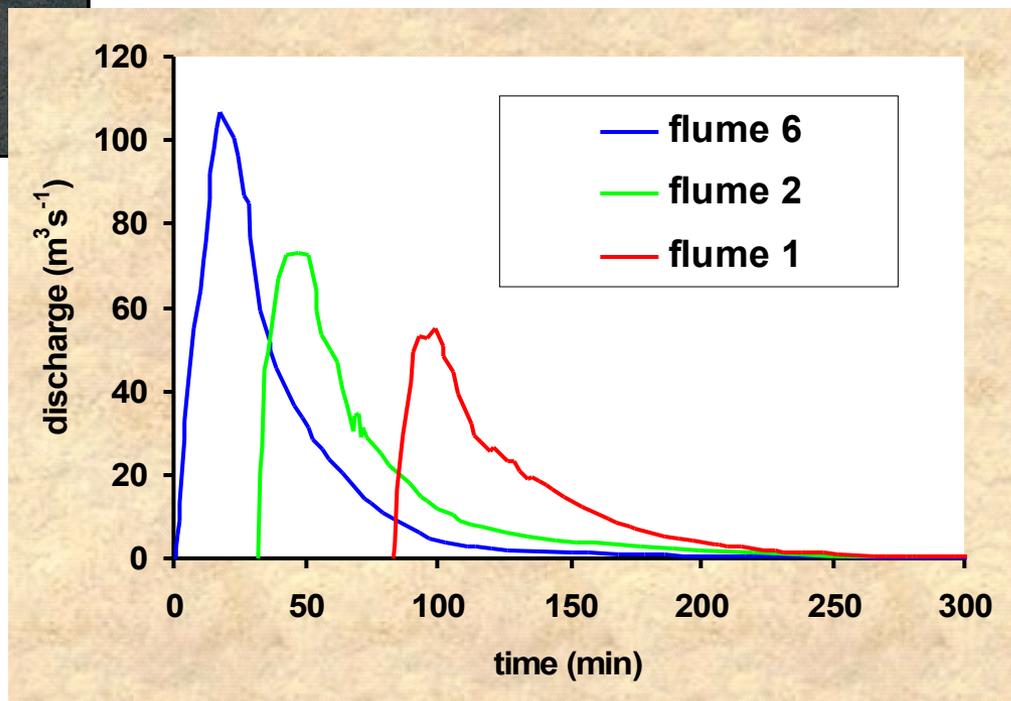


**Transmission Losses**

**flume 6:  $Q = 246,000 \text{ m}^3$**

**flume 2:  $Q = 197,000 \text{ m}^3$**

**flume 1:  $Q = 155,000 \text{ m}^3$**

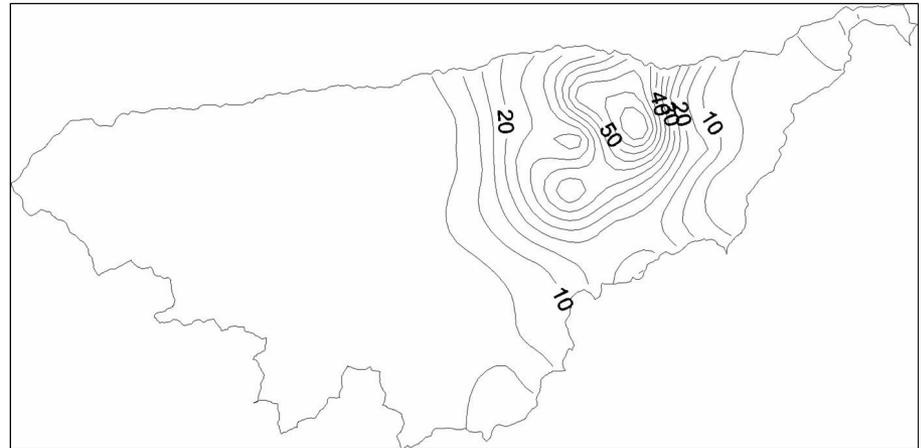


# Range of Scales



**Transmission Losses**

**Limited areal extent of  
thunderstorm rainfall**



# Summary

## Small Scale

- **Similar runoff amount and peak per event**
- **Grass**
  - **higher rainfall intensity for runoff**
  - **longer duration**
  - **smaller number of events**
  - **microtopography vs infiltration**

## Range of Scales

- **No vegetation effects**
- **Transmission losses and spatial rainfall**



*Southwest Watershed Research Center*

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