

# Episodic channel hydrology:

*Long periods of boredom, brief moments of terror*



G. Matt Kondolf, University of California Berkeley

*Episodic Stream Channels, Costa Mesa 8 Nov 2010*

Northern-European/Eastern-Seaboard notions  
of how rivers behave vs episodic channels  
“Bankfull discharge” concepts  
*(How much wood could a woodcutter cut?)*

Recovery time linked to vegetation growth (range)

Episodic streams:

Runoff varies (concentrated) in time/space

Heavy rains occur over small basins

Infiltration losses downstream, esp over fans

Thus, rarely see high runoff from large basins

Smaller streams experience greater changes in  
width with cycles of floods and low-flow years

# The effective discharge/bankfull concept (1960)

## MAGNITUDE AND FREQUENCY OF FORCES IN GEOMORPHIC PROCESSES<sup>1</sup>

M. GORDON WOLMAN AND JOHN P. MILLER  
Johns Hopkins University and Harvard University

### ABSTRACT

The relative importance in geomorphic processes of extreme or catastrophic events and more frequent events of smaller magnitude can be measured in terms of (1) the relative amounts of "work" done on the landscape and (2) in terms of the formation of specific features of the landscape.

For many processes, above the level of competence, the rate of movement of material can be expressed as a power function of some stress, as for example, shear stress. Because the frequency distributions of the

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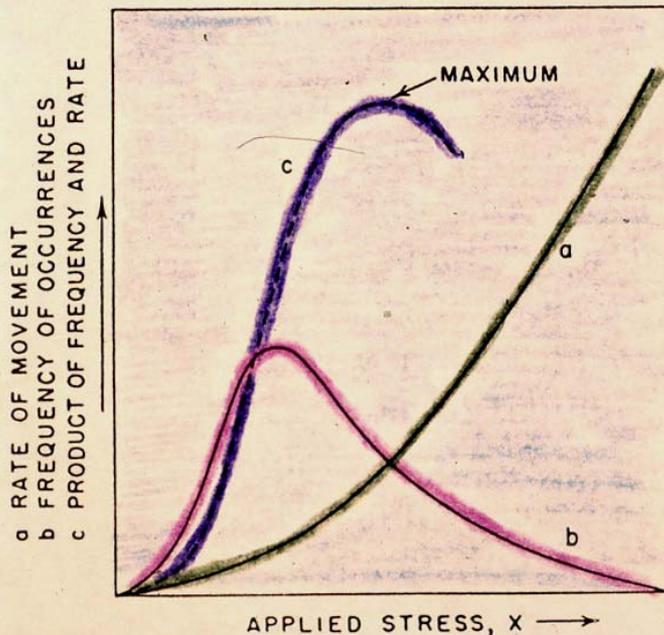
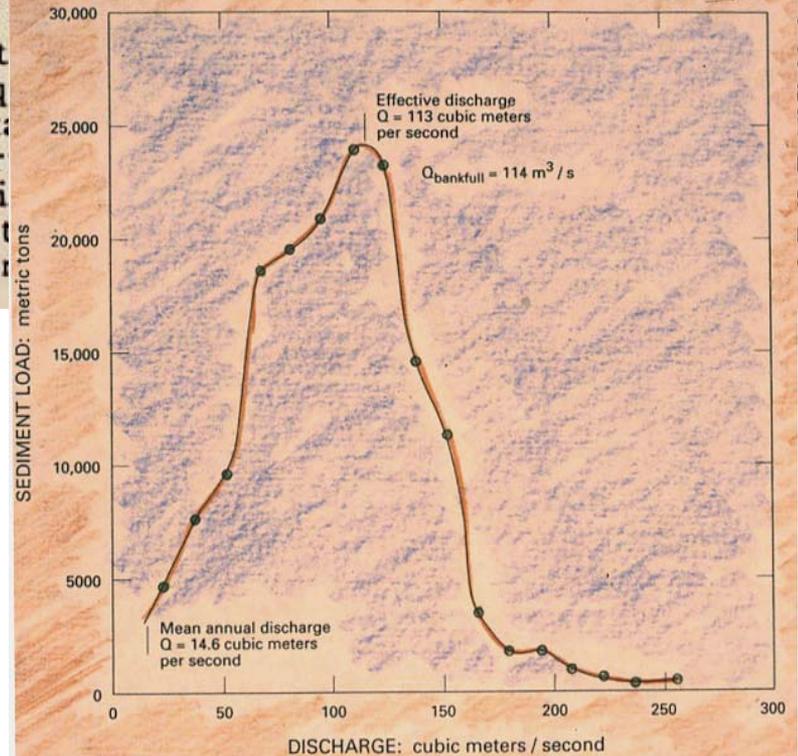


FIG. 1.—Relations between rate of transport, applied stress, and frequency of stress application.

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“...most of the work of moving sediment from a drainage basin is done by frequent flows of moderate magnitude. As used here, a “frequent” event recurs at least one each year or two and in many cases several or more times per year.”

*(Next sentence to come)*

*Wolman & Miller 1960:60*



For the Yampa R basin,  
morphological bankfull discharge  
is equivalent to effective discharge

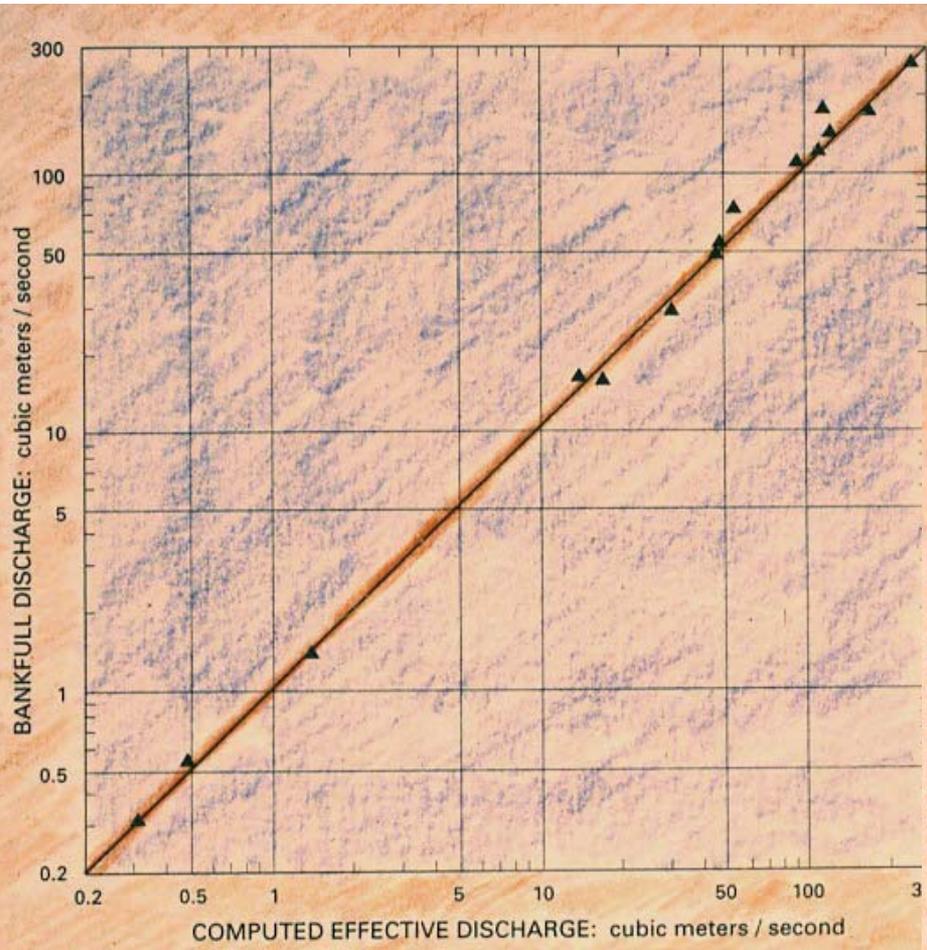


Figure 8.2 The relation of computed effective discharge to bankfull discharge for stations in the Yampa River Basin, Colorado and Wyoming. (After Andrews 1980.)

And for well-behaved channels  
(snowmelt, humid-climate)  
bankfull  $Q = Q_{1.5}$

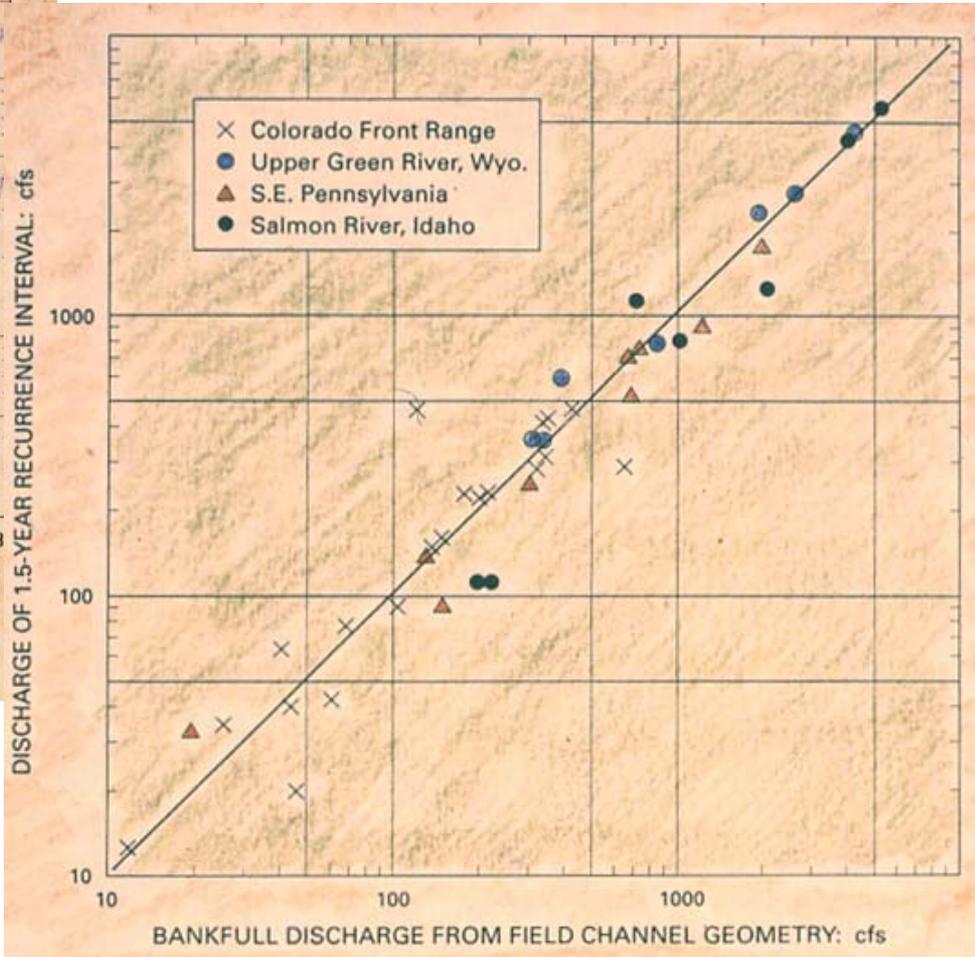


Figure 8.7 Comparison of field-determined bankfull discharge with discharge of 1.5-year recurrence interval for 4 regions in the United States.

“Perhaps the state of knowledge as well as the geomorphic effects of small and moderate versus extreme events may be best illustrated by the following analogy. A dwarf, a man, and a huge giant are having a wood-cutting contest. Because of metabolic peculiarities, individual chopping rates are roughly inverse to their size. The dwarf works steadily and is rarely seen to rest. However, his progress is slow, for even little trees take a long time, and there are many big ones which he cannot dent with his axe.

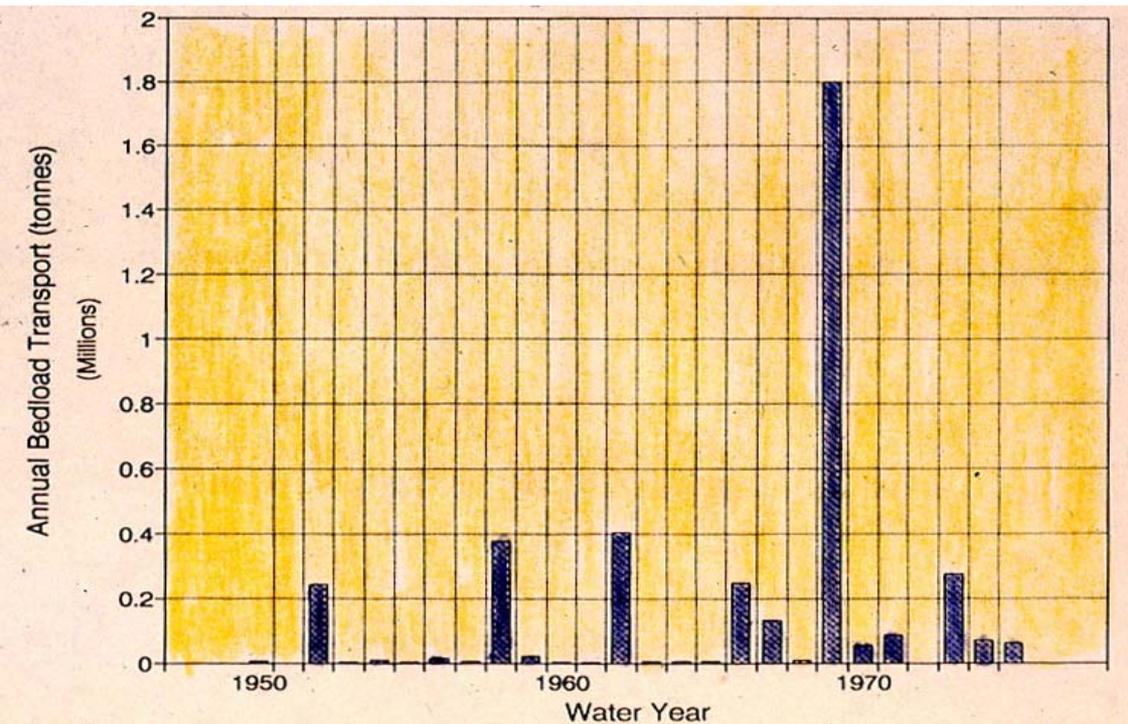
“The man is a strong fellow and a hard worker, but he takes a day off now and then. His vigorous and persistent labors are highly effective, but there are some trees that defy his best efforts. The giant is tremendously strong, but he spends most of his time sleeping. Whenever he is on the job, his actions are frequently capricious. Sometimes he throws away his axe and dashes wildly in the woods, where he break the trees or pulls them up by the roots. On the rare occasions when he encounters a tree too big for him, he ominously mentions his family of brothers – all bigger, stronger, and sleepier.”

*Wolman and Miller 1960:73*

## *What about the giant's brothers?*

“The evidence also suggests that the more variable the regimen of flow of the stream, the larger the percentage of total sediment load which is likely to be carried by infrequent flows.”

*Wolman & Miller 1960:60*



*Santa Clara River:  
Over 40-y, most sediment  
transported in one flood  
in 1969*

Balance Hydrologics

## A wide range in rivers

- From those utterly dominated by frequent events
- To those dominated by infrequent events



# RELATIVE SCALES OF TIME AND EFFECTIVENESS OF CLIMATE IN WATERSHED GEOMORPHOLOGY

M. GORDON WOLMAN

The Johns Hopkins University, Baltimore, Maryland USA

RAN GERSON

Hebrew University of Jerusalem, Jerusalem, Israel

EARTH SURFACE PROCESSES AND LANDFORMS 3:189-208 (1978)



“River channels in temperate regions widened by floods of recurrence intervals from 50 to more than 200 years may regain their original width in matters of months. In semi-arid regions, recovery of channel form depends not only upon flows but upon climatic determinants of the growth or bottomland vegetation resulting in variable rates of recovery, on the order of decades, depending upon coincidence of average flows and strengthened vegetation.

*Wolman and Gerson 1978:189*

“In truly arid regions the absence of vegetation and flow precludes recovery and the width of channels increases in drainage areas up to 100 km<sup>2</sup> but remains relatively constant at larger drainage areas.”

*Wolman and Gerson 1978:189*

“Long periods of boredom, brief moments of terror”

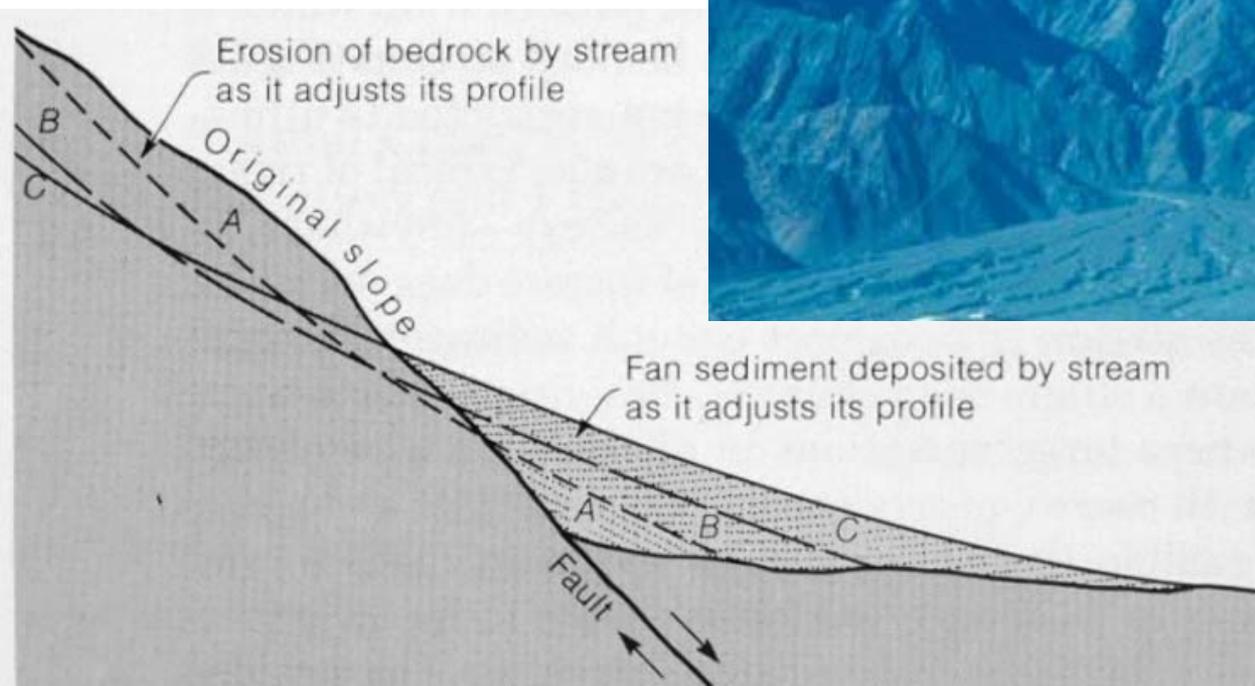
*Erich Maria Remarque, All Quiet on the Western Front*

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*Erich Maria Remarque, All Quiet on the Western Front*

Downstream Decrease in Flow-  
results for spatially concentrated precip,  
also flow over permeable units, eg alluvial fans



Alluvial Fans are ubiquitous in the landscape but often unseen  
By virtue of their characteristic stratigraphy, typically losing flow  
in a downstream direction



*Alluvial fan of Arroyo Seco, Salinas Valley*

Throughout Mediterranean and semi-arid California,  
channel processes are episodic. Alluvial fans especially  
dynamic in flow, sediment transport, and channel change

# California's climate is Mediterranean

*implications for rivers:*

***Highly variable flow:*** seasonally, and year-to-year  
Sediment transport (power function of  $Q$ ) is even more variable

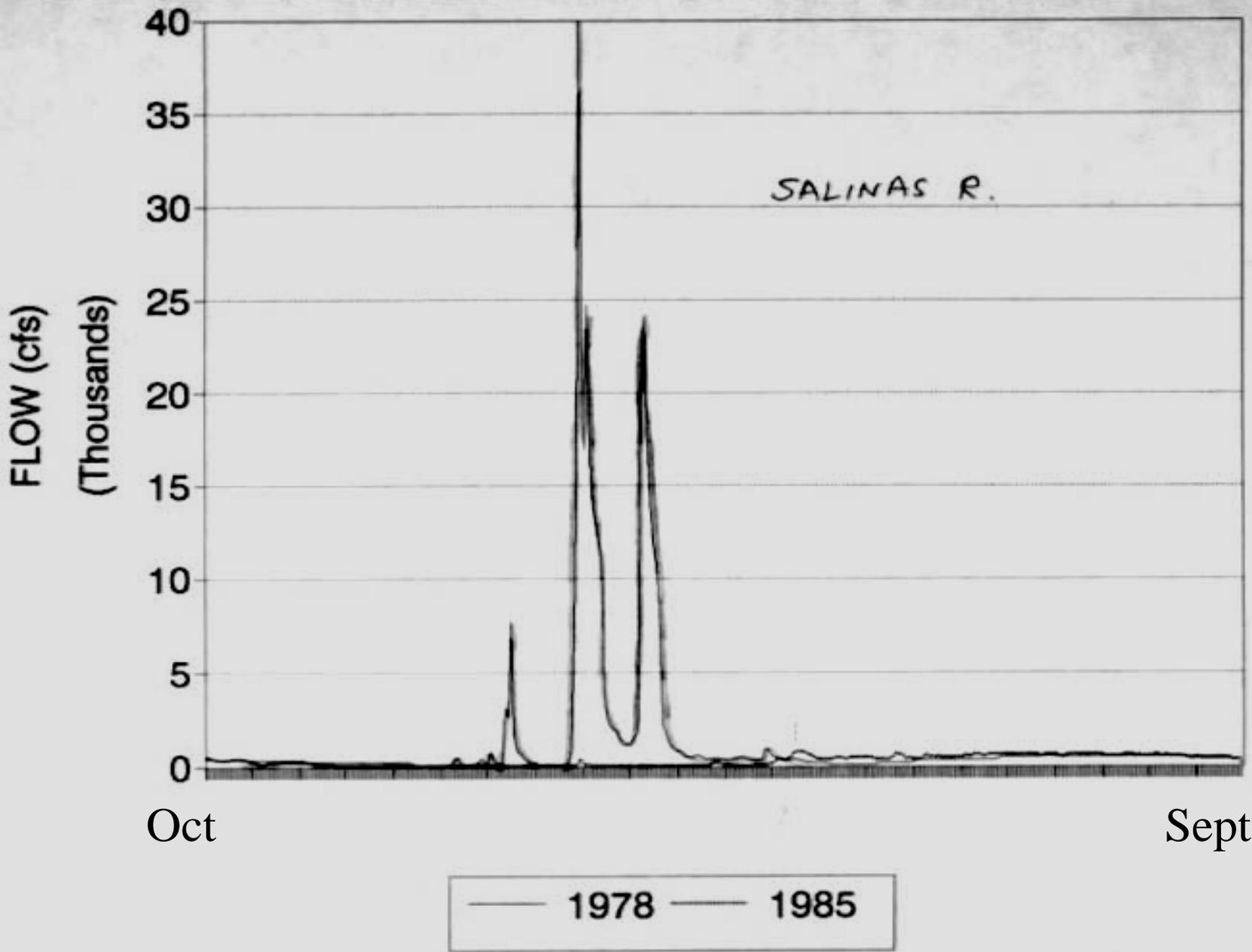
***Cyclical channel behavior:***

After floods, channel widening. Subsequent narrowing.

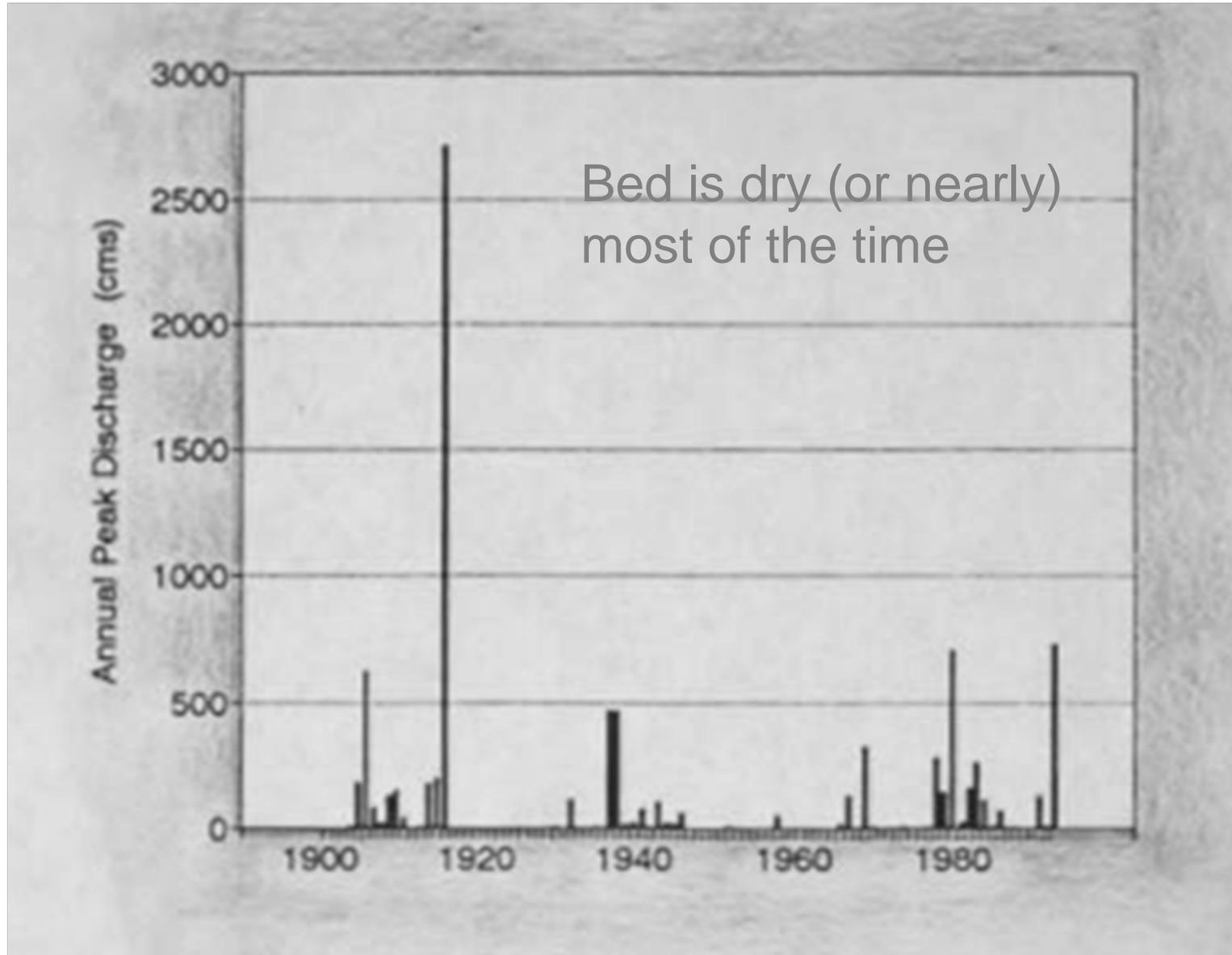


*San Luis Rey River, after the 1993 flood (RI appx 100-y)*

# Salinas R illustrating high seasonal variability (Mediterranean climate)



# High seasonal and inter-annual variability, San Luis Rey R



# An *Arizona crossing* over the San Luis Rey River



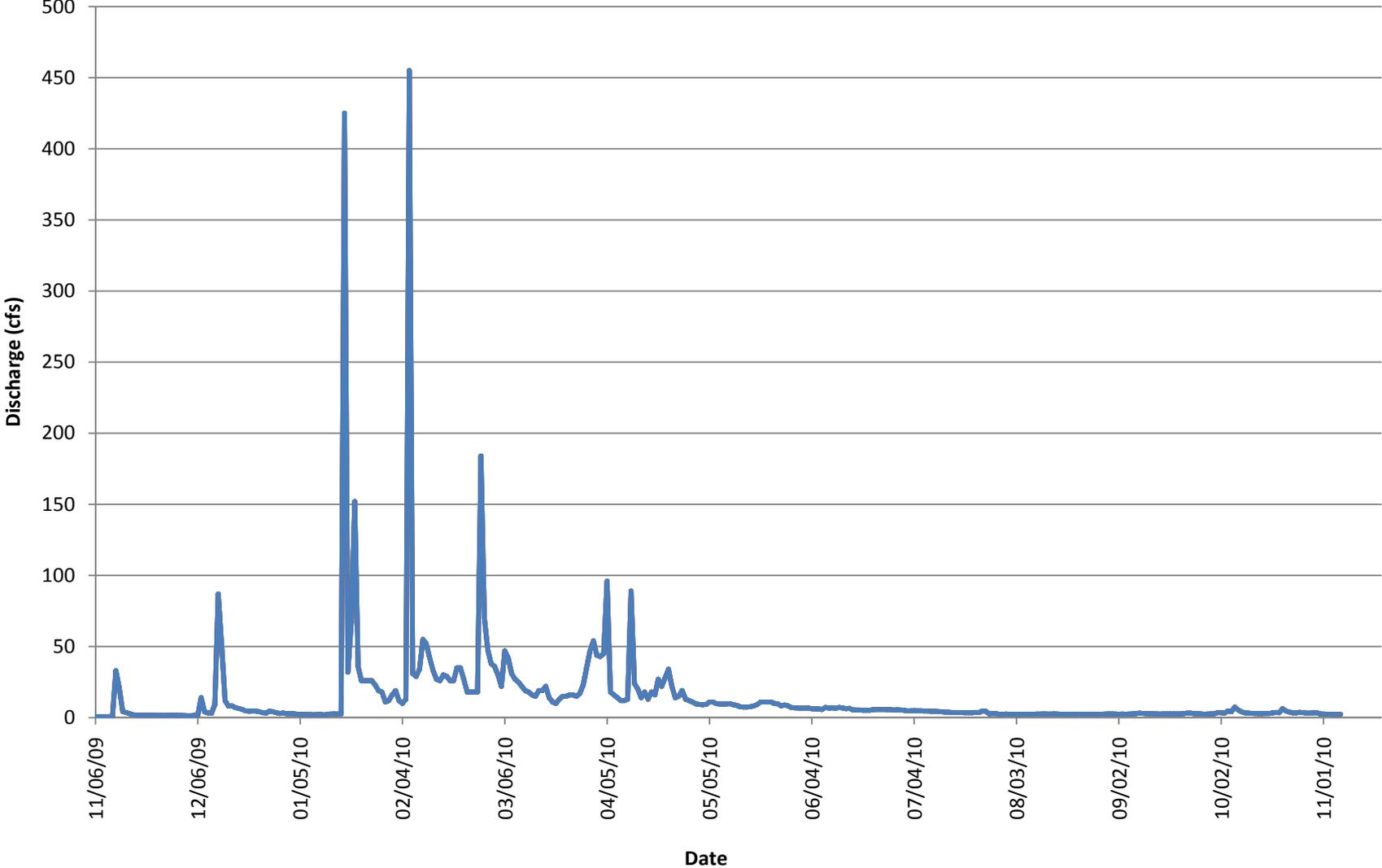
Whoops!



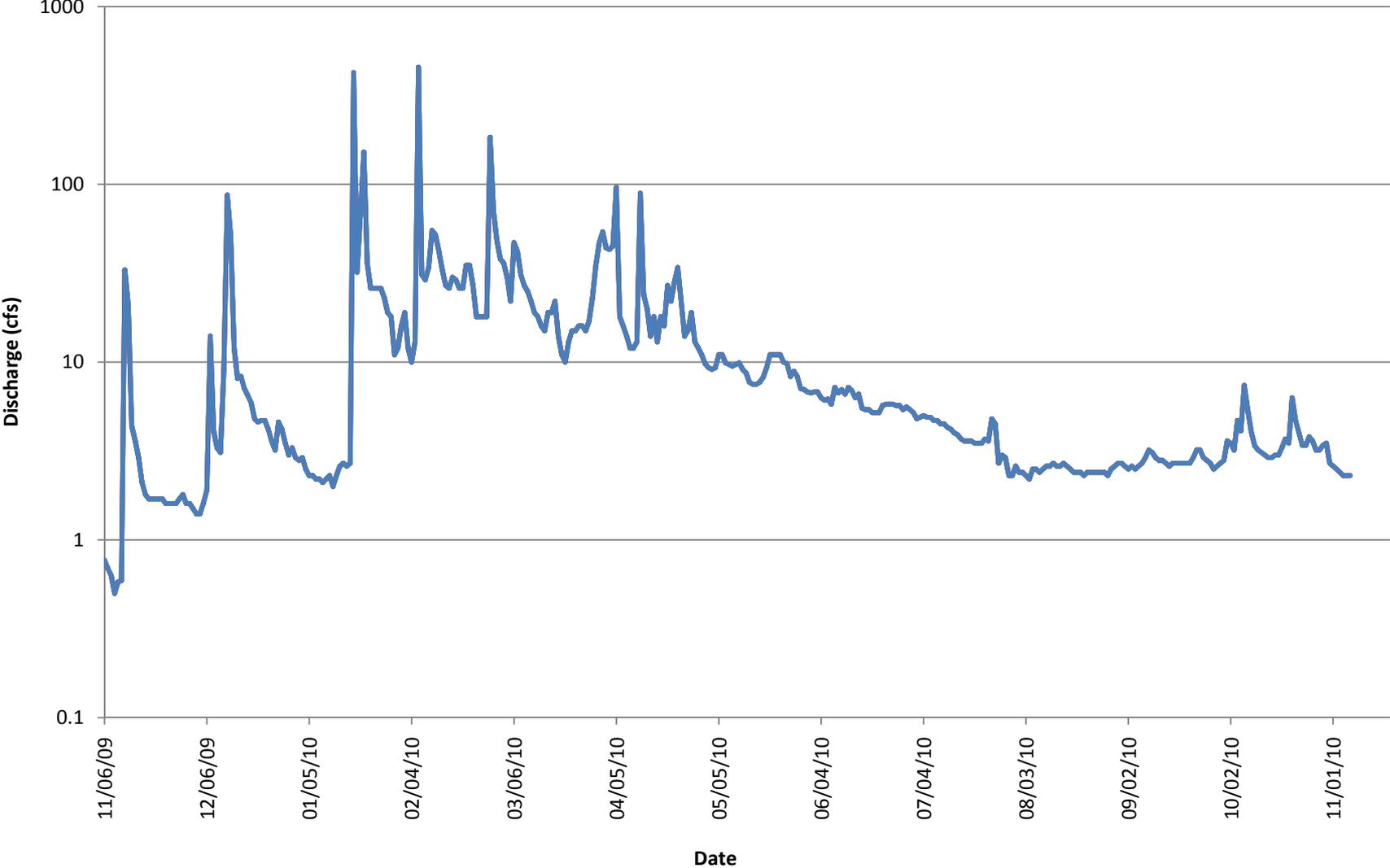


Arroyo Seco, Pasadena - July 2010 (post flood)

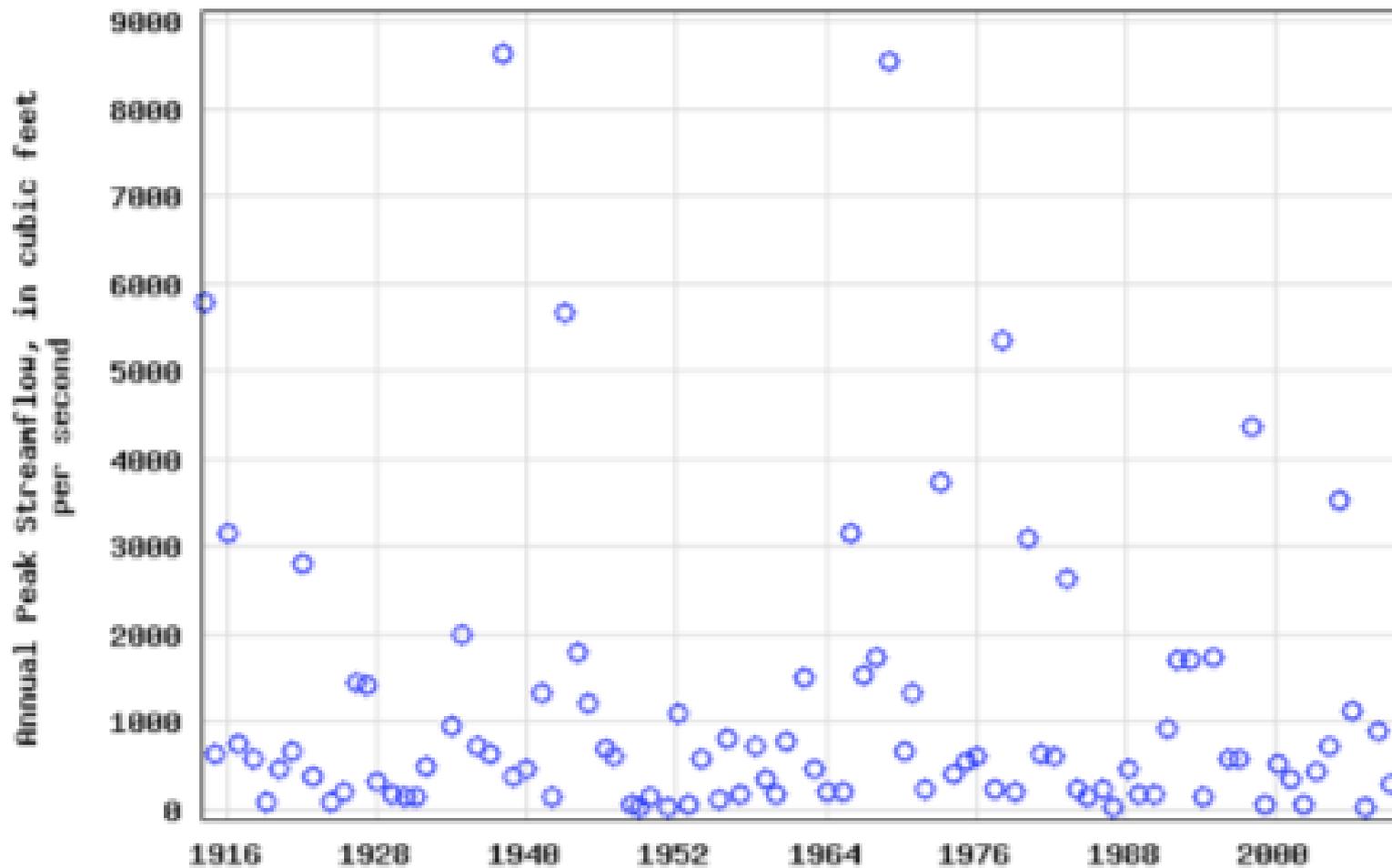
# Arroyo Seco daily peak flows WY2010



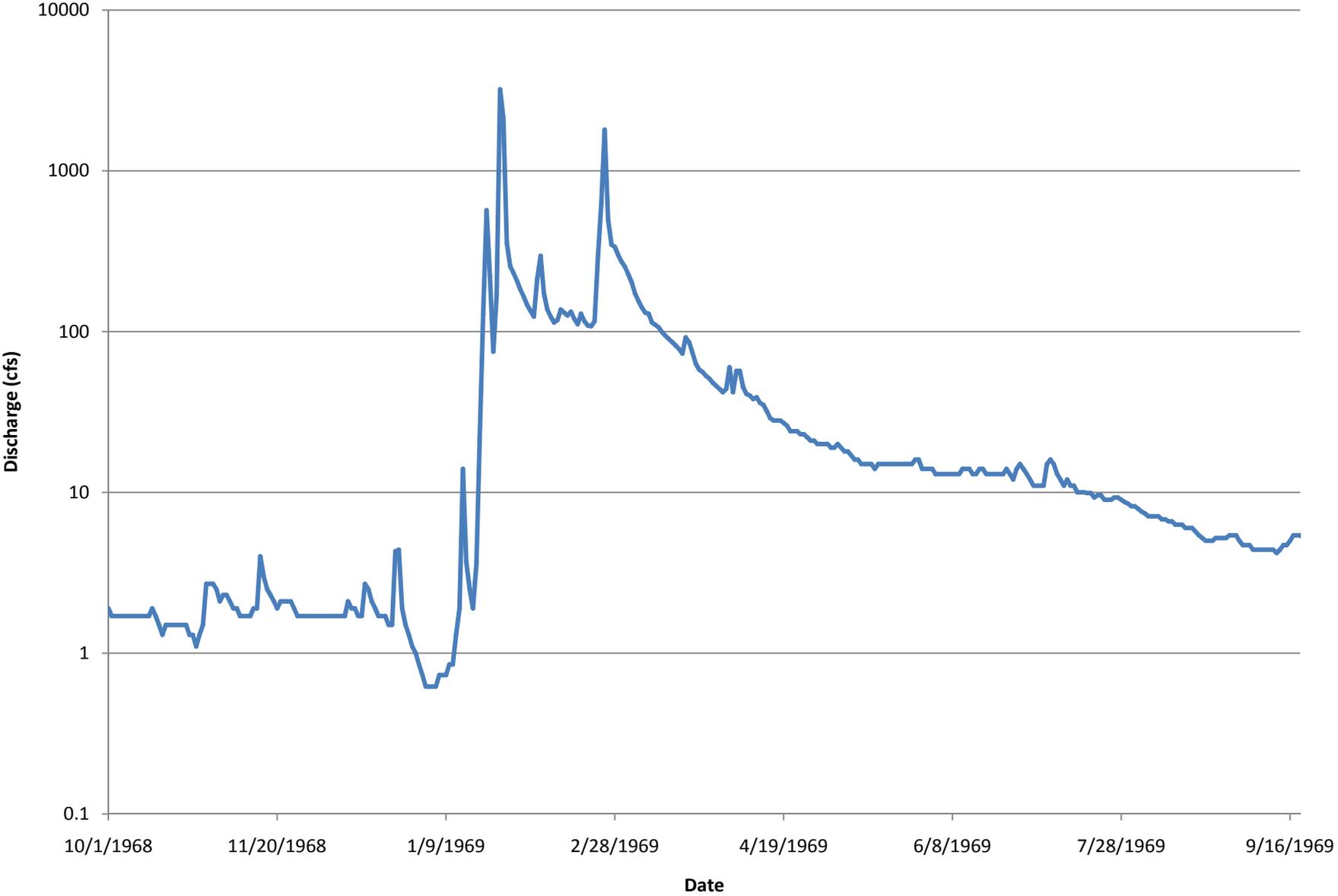
# Arroyo Seco daily peak flows WY2010



### USGS 11098000 ARROYO SECO NR PASADENA CA



# Arroyo Seco daily peak flows WY1969



*Carmel River above San Clemente Dam 1987,  
Carmel River 1987  
after high flows of early-mid 1980s*



# Carmel River 1993

*Carmel River 1993, 1993 after 6 years of drought*



# Carmel River 1995, after flood





Mediterranean climates well suited for irrigated agriculture



*Temporal/Spatial Distribution of Water Supply/Demand:*  
Water availability highly variable, out-of-phase w/ demand,  
*so need storage*

# Effects of regulation more pronounced in episodic rivers



*Impounded Runoff index IR* =  $\frac{\text{reservoir capacity}}{\text{mean annual runoff}}$

*Humid climate rivers*

Potomac, Elbe, Rhein Rivers: IR 0.05-0.20

*Mediterranean climate rivers*

Ebro, Sacramento, SanJoaquin rivers: IR = 0.57-1.20

*Thus: Dams reduce floods more than in humid climates*

# Got water?

How do humans perceive streams that don't have water most of the time? Cultural preferences for perennial streams.



Uvas Ck project 1995

And in 1997 after 6-y Q



# Case Study: Tourism Development along Red Sea Coast



Fringing reef along most of coast,  
except for wadi mouths



Behind the tourist experience up front  
*is a complex infrastructure to support luxury in the desert*





Tourist development in desert:  
Enormous infrastructure demands  
for water supply (desalination),  
wastewater treatment (reuse  
for landscape irrigation)





Less attention has been paid to the pervasive problem of solid waste disposal



To understand the problems of solid waste disposal also requires that we understand the nature of the wadis that traverse the landscape, carrying runoff from the Red Sea Range to the sea

*Wadi flows are episodic* - dry for years, the flow after intense rains, perhaps every 10-20 years.

But the landscape expression is subtle to the untrained eye, and offers flat, easily worked ground for building



The normally dry wadis experience periodic flash floods  
Return periods around 10-20 years.

The last big floods in the region were in 1996.

*(view: Marsa Tondoba, 12 km south Marsa Alam)*



But the flash floods are so infrequent that developers have built hotels on the wadi floods  
Most people in the region are recent immigrants and thus have no direct memory of flooding



Garbage dump in wadi south of Qussair (official dumpsite)  
Typical practice: in flood, garbage will be transported to reef



This water tank was transported 40 km from Sheikh Salem to Marsa Alam in November 1996. The forces that moved a large water tank could easily scour solid waste dumps and transport contaminants to the fringing reef

## **Wadi flooding: infrequent, but may be catastrophic**

### *Wadi floods observed/photographed recently in*

1992 – affected appx 3 wadis south of Qussair

1994 – affected appx 3 wadis south of Qussair

1996 – affected almost all wadis along Eastern  
Desert Red Sea coast and Southern Sinai

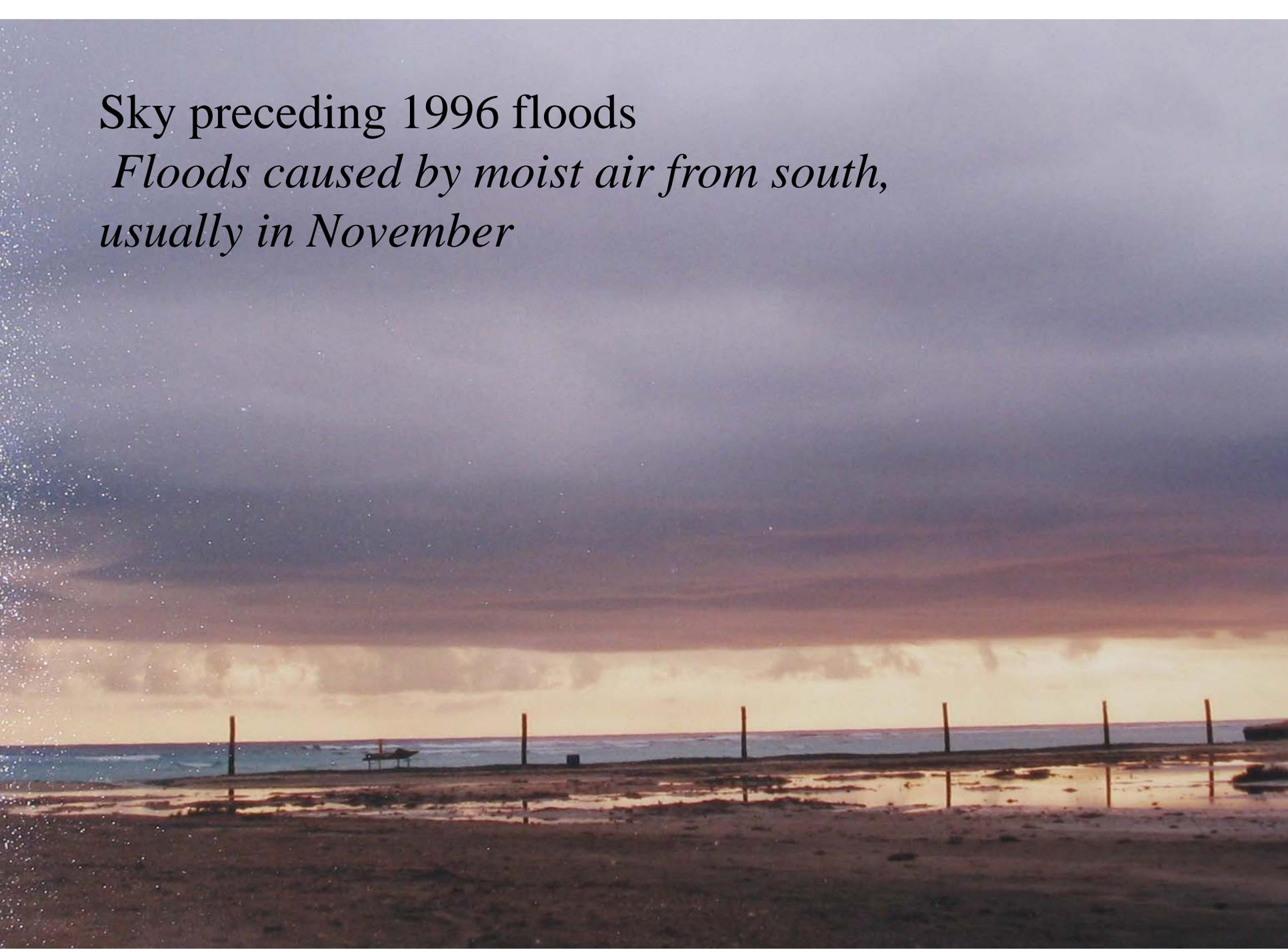
No floods since – thus most recent arrivals have  
no experience with flooding in wadis.

Tourist development and garbage dumps in wadis

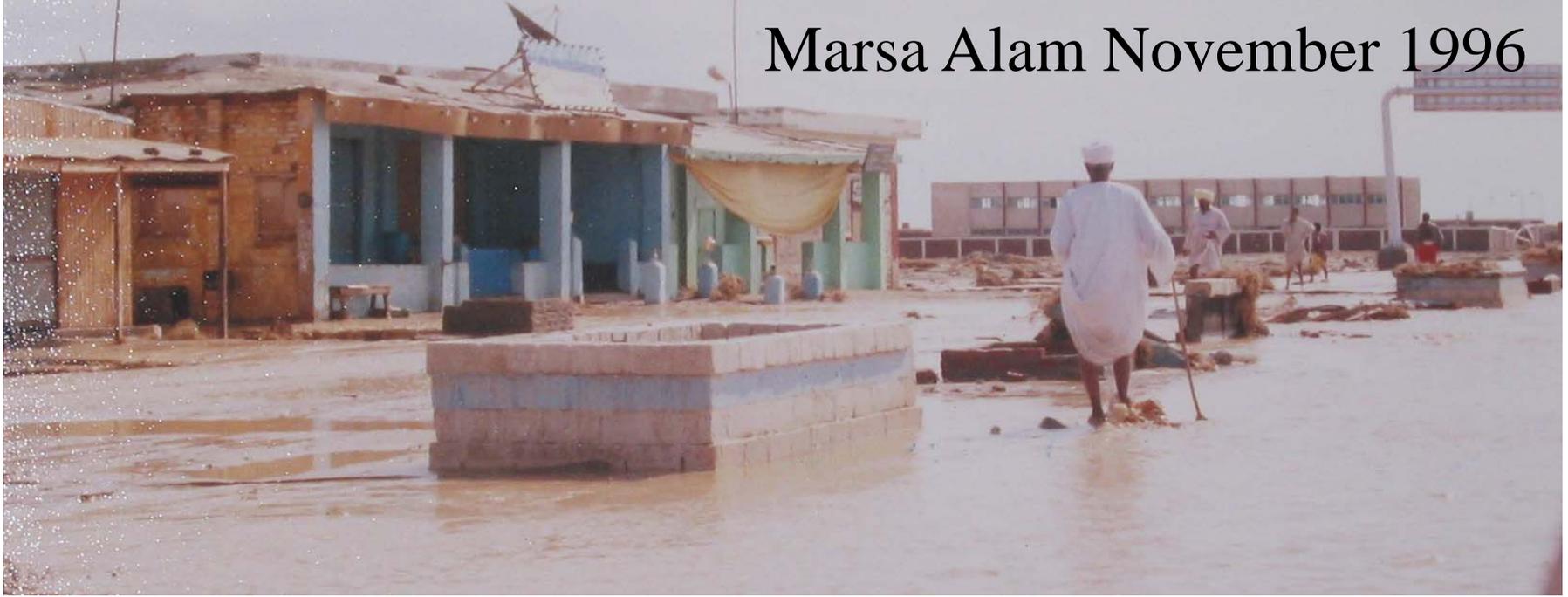
- developments at risk from flood damage
- fringing reef at risk from transport of garbage

Sky preceding 1996 floods

*Floods caused by moist air from south,  
usually in November*

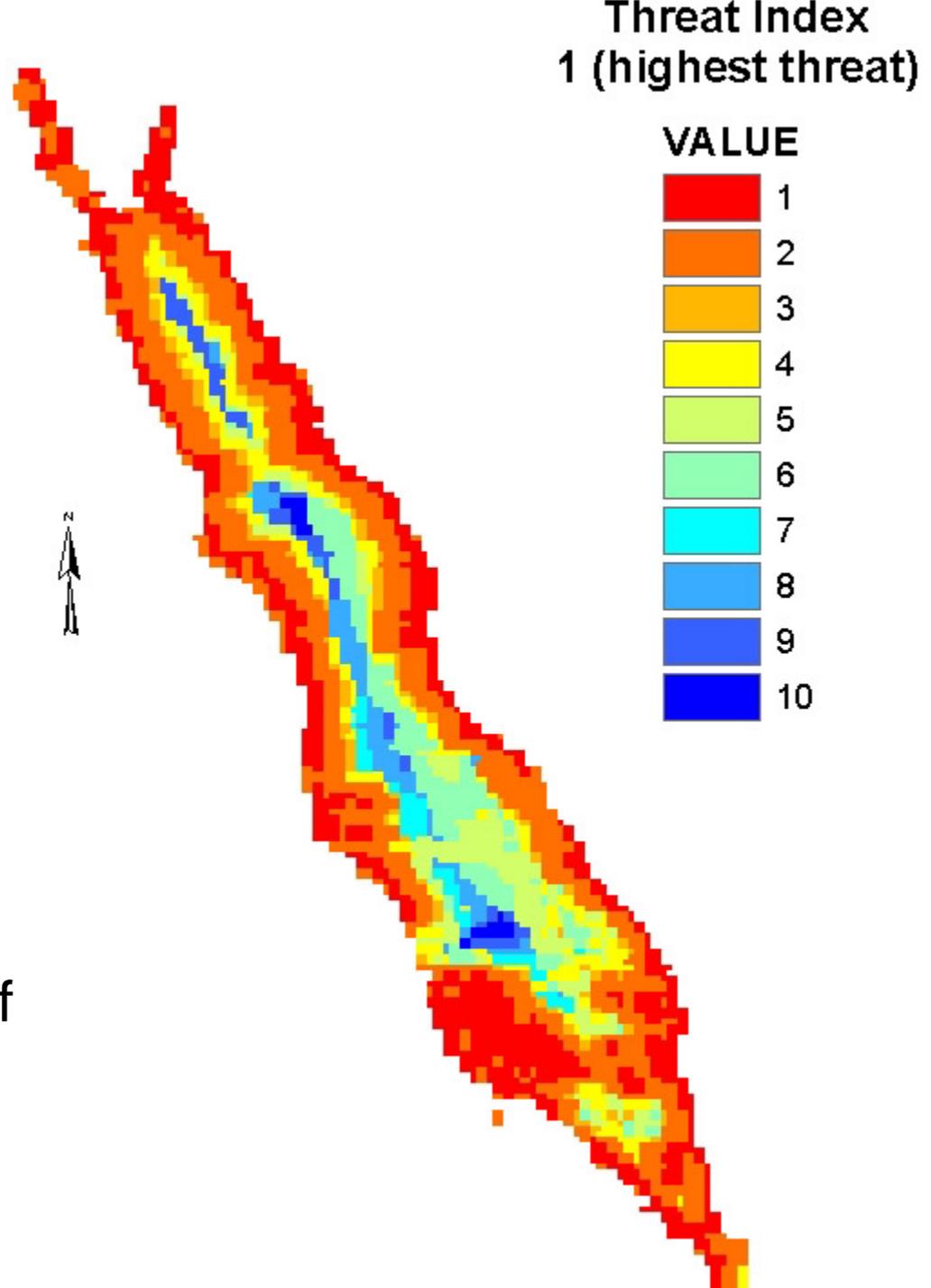


# Marsa Alam November 1996



Based on location of wadi mouths and currents in the Red Sea, Inas Ismael modelled dispersion and transport of contaminants from a flash flood eroding solid waste dumps.

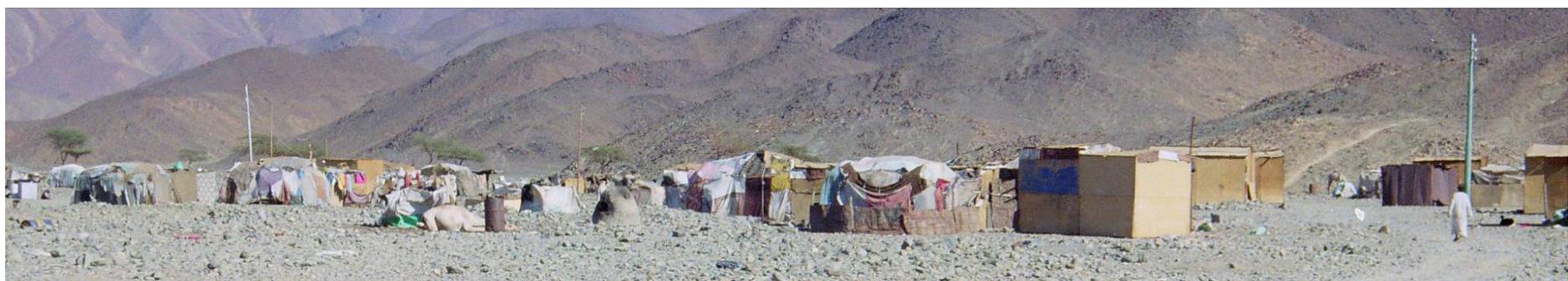
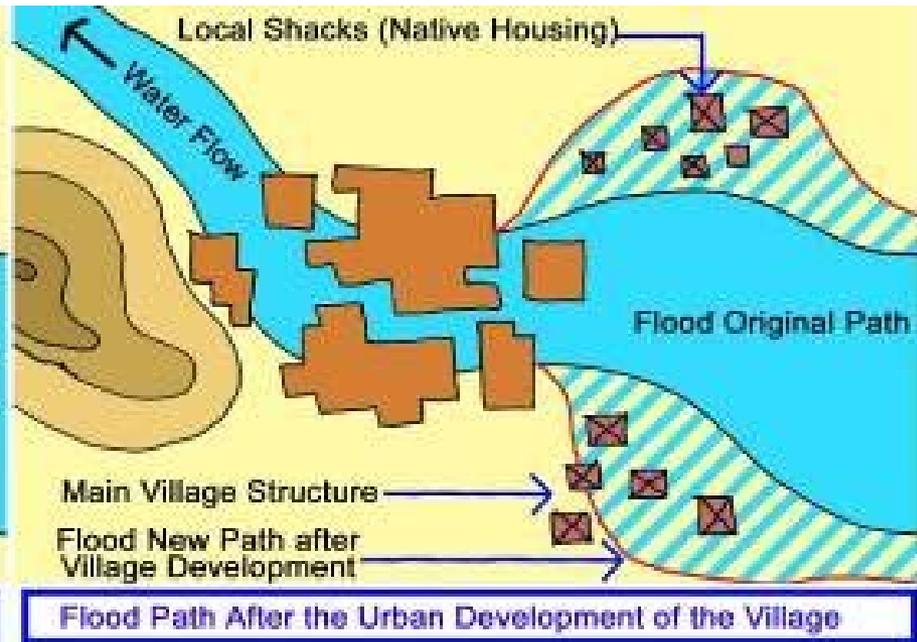
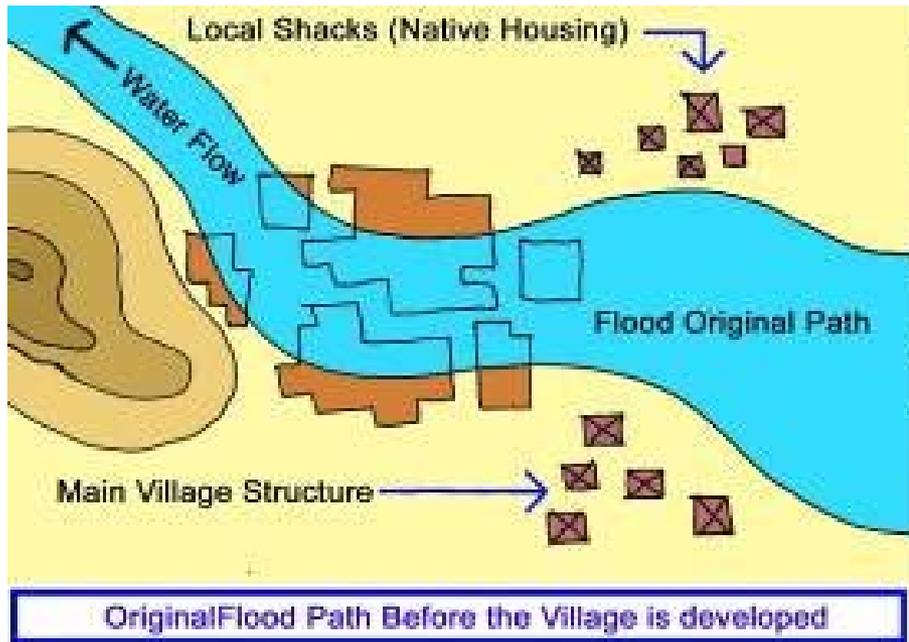
Her results showed that impacts on the fringing reef would be extensive.



# El-sheikh el-shazli village, Red Sea Range

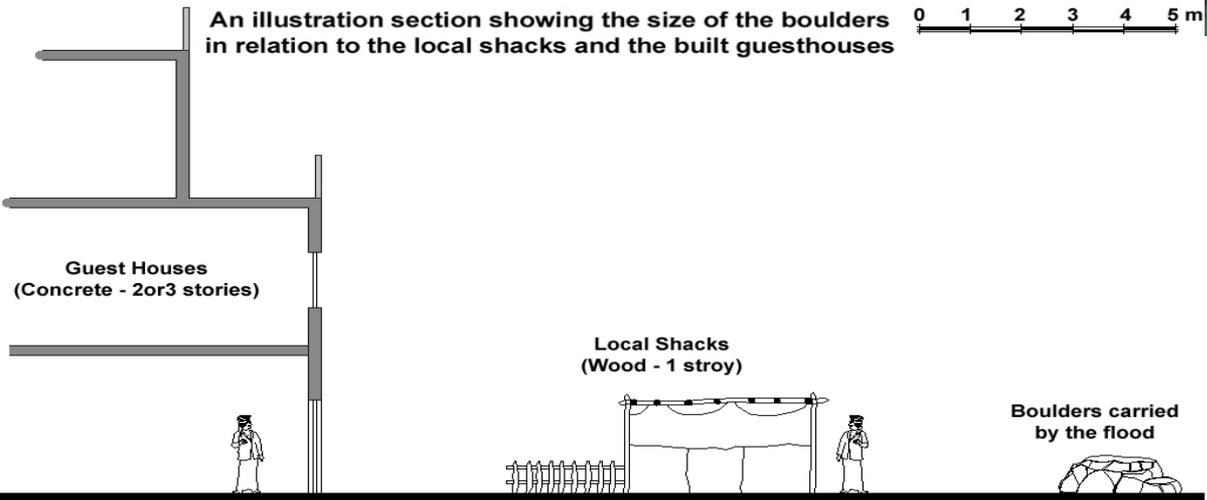


Aerial view of El-sheikh el-shazli village, located at the confluence of four wadis. The largest come from the north and northeast: Wadi Um Samrah and Wadi Um Hiraynah.





An illustration section showing the size of the boulders in relation to the local shacks and the built guesthouses





El-Sheikh El-Shazli illustrates the problem of human perception of natural hazards. Although clearly in the path of future flash flood and debris flows, the settlement has been expanded and the flow constriction exacerbated. Most people here arrived recently and have not experienced a large flash flood.



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processor  
e this picture.



QuickTime  
decomp  
are needed to see







