Water in Environmental Planning

Calculation of Flood Hazard

Dunne and Leopold

1978

Presented by

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Flood Hazards

- Quantification of storm runoff is crucial for a variety planning and engineering projects
- Numerous investigations have sought to develop methods to calculate storm runoff
- Flood hazards have increased due to an increase in extreme weather events associated with climate change
- Understanding watershed response to storm events crucial for the development of effective management strategies

Tennessee flooding worst in decades due heavy rains (CNN, 5/4/2010).

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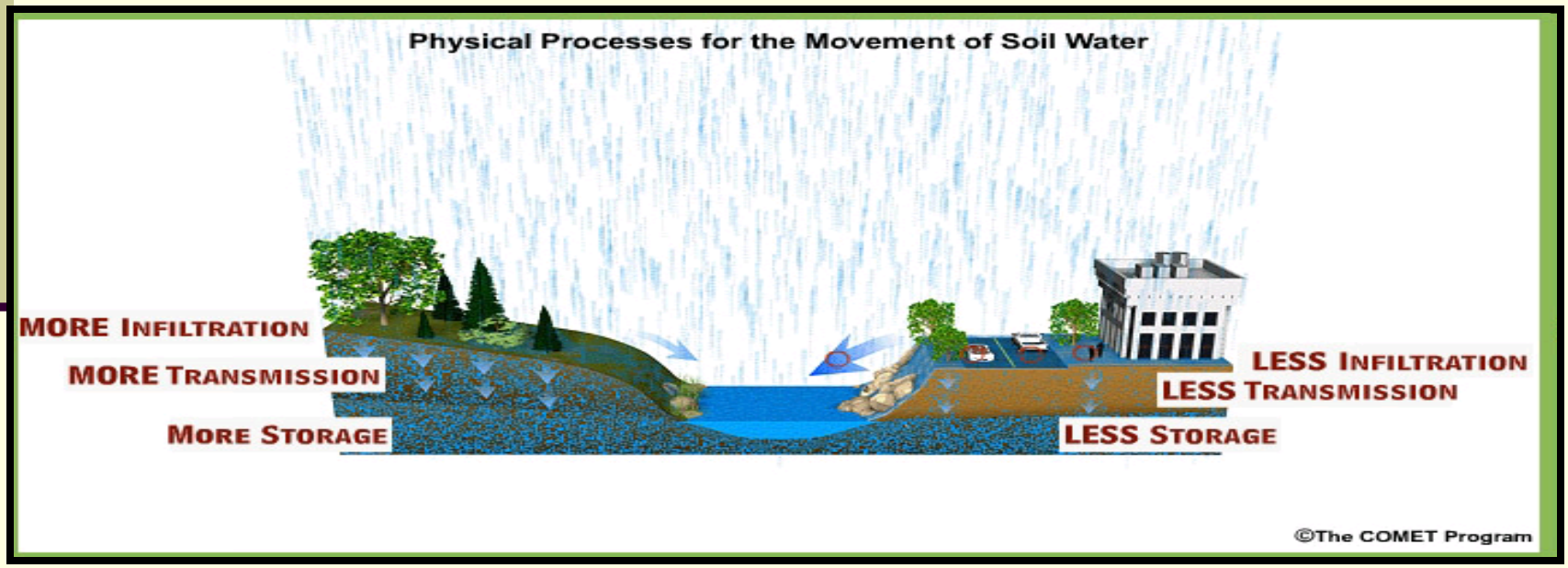
Storm Runoff

- Runoff occurs in natural catchments when soil becomes saturated due to previous rainfall or as a result of impervious surfaces in urban areas
- The amount of water in the soil prior to the rain event, also known as “antecedent soil moisture” plays a significant roll in determining runoff volume
- Runoff volumes have dramatically increased due to urbanization



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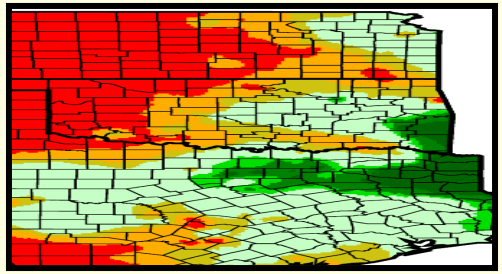
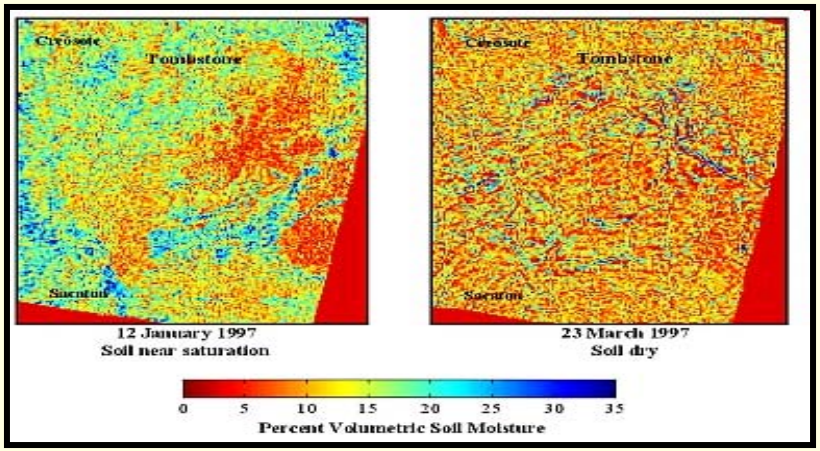


Antecedent Soil Moisture

- **Relative value that describes preceding soil moisture conditions with higher values corresponding to soil saturation**
- **These conditions are continuously changing due to environmental conditions (evapotranspiration) and weather (rain – no rain)**



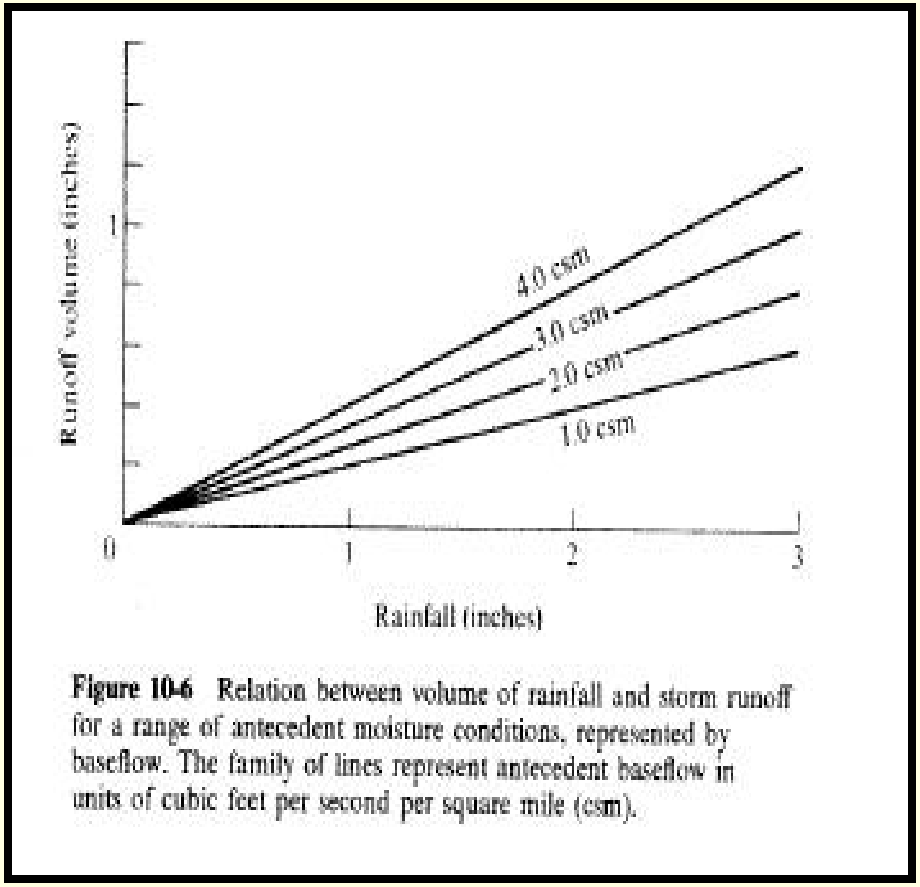


Figure 10-6 Relation between volume of rainfall and storm runoff for a range of antecedent moisture conditions, represented by baseflow. The family of lines represent antecedent baseflow in units of cubic feet per second per square mile (csm).

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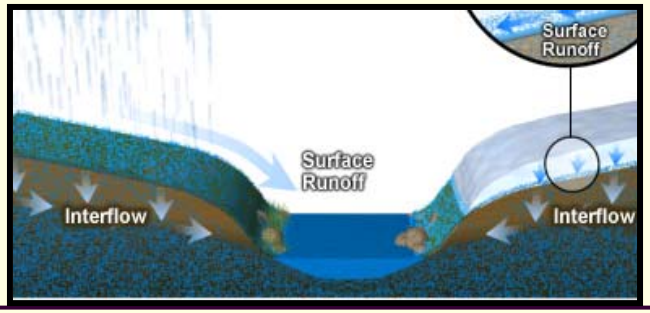

Calculation of Storm Runoff

- Simplest method is direct correlation with volume of rainfall
- Scatter of data points due to differences in intensity and duration of storm events and antecedent moisture conditions in basin
- Differentiating baseflow from storm flow crucial for calculation
- 1978 Dunne and Leopold improve methods by introducing Antecedent Precipitation Index (API)

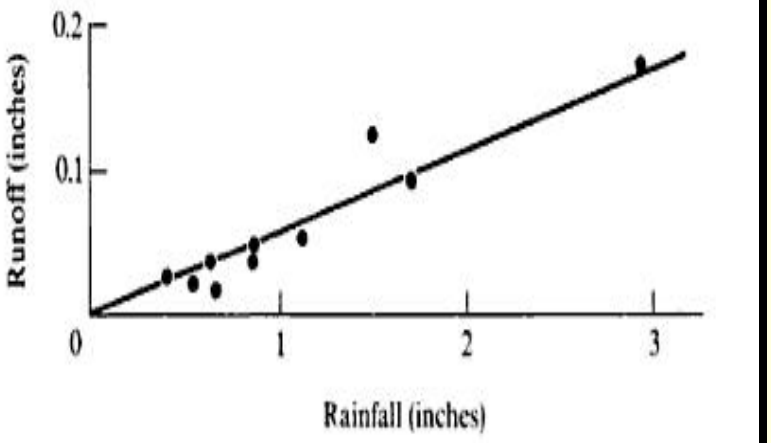

Figure 10-5 Volume of storm runoff as a function of rainfall for summer storms on a 0.23-square-mile basin at Danville, Vermont. (Data from the Agricultural Research Service, U.S. Department of Agriculture.)

Antecedent Precipitation Index (API)

- **Higher performance in runoff calculations obtained by inclusion of Antecedent Moisture Index (API) for particular catchment area**
- **The index is a weighted summation or running tally of daily precipitation amounts and there impact on soil moisture content calculated for each pixel**
- **API assumes natural drainage with evapotranspiration continuously reducing soil moisture at a logarithmically decreasing rate over time**

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Calculating the Antecedent Precipitation Index (API)

$$I_t = I_0 k^t$$

I_t	=	Antecedent Precipitation Index on day t
I_0	=	Antecedent Precipitation Index at beginning of calculation period
k	=	Decay constant between 0.85 – 0.95 indicating rate of reduction of soil wetness
t	=	time in days since last rainfall

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$I_t = I_0 k^t$

- Generating API for any given day is obtained through keeping running calculation in which the previous day's value is multiplied by k
- The impact of a rain event on soil moisture exponentially decreases after the event:
  - Day 1 = I_0
  - Day 2 = $I_0 k^1$
  - Day 3 = $I_0 k^2$
  - Day 3 = $I_0 k^3$, and so on
- Once rain occurs again amount of rain is added to the index and t is set equal to zero again

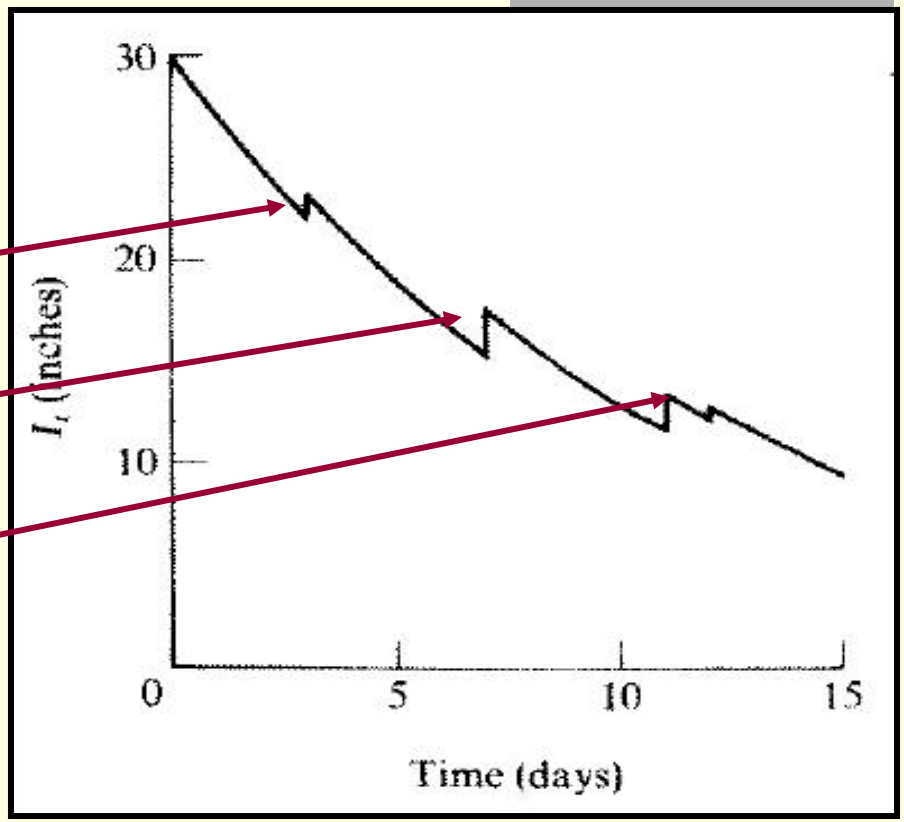
Example Calculation

$$I_t = I_0 k^t$$

Table 10-23 Calculating the antecedent precipitation index.

DAY (t)	DAILY RAINFALL (IN)	$I_0 k^t$ (IN)	ADD RAINFALL (IN)
0		30	
1		27	
2		24.3	
3	1.6	21.9	23.5
4		21.2	
5		19.1	
6		17.1	
7	2.2	15.4	17.6
8		15.8	
9		14.3	
10		12.8	
11	1.9	11.6	13.5
12	0.5	12.1	12.6
13		11.4	
14		10.2	
15		9.2	

Chart used for calculating API with 4 rain events occurring over a 15 day Period. Arrows indicate impact of rain On API.



Graphed I_t values showing exponential decrease in soil moisture over time. Values can be correlated with ratio of storm runoff volume to rainfall or with other hydrologic variables.

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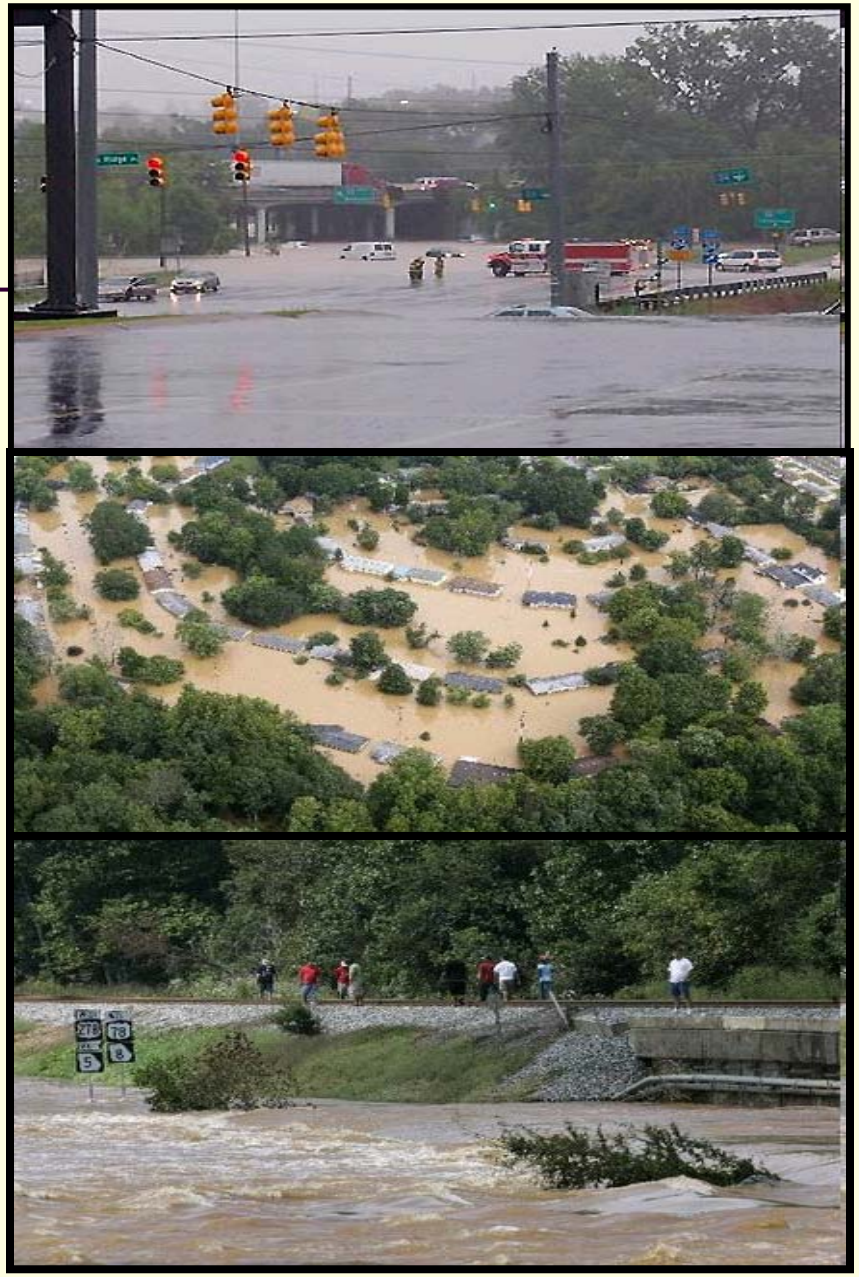
Conclusions

- The calculation of storm runoff volume is crucial to effective flood hazard management
- The volume of storm runoff is correlated to the antecedent moisture content within the soil prior to the rainfall event
- Including an Antecedent Precipitation Index (API) in runoff models dramatically improve performance
- The API formula, $I_t = I_0 k^t$ is daily running tally of soil moisture content which exponentially decays after the initial rain event



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QUESTIONS?