Water Balance and Precipitation
Lecture 2, 04/04/2013

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Adapted from textbook and Bedient notes
(http://doctorflood.rice.edu/bedient/handouts.html)

The Water Balance

The hydrologic continuity equation for any system is:

Governing Equation: $\Sigma I - \Sigma O = \Delta S/\Delta t$

I = Inflow, O = Outflow

$\Delta S/\Delta t$ = Change in storage per time

Δs : Δ storage

$\Delta s = A \cdot \Delta y$

Lake (Δs is significant)

River ($\Delta s \approx 0$)

3@

The Water Balance on a Lake

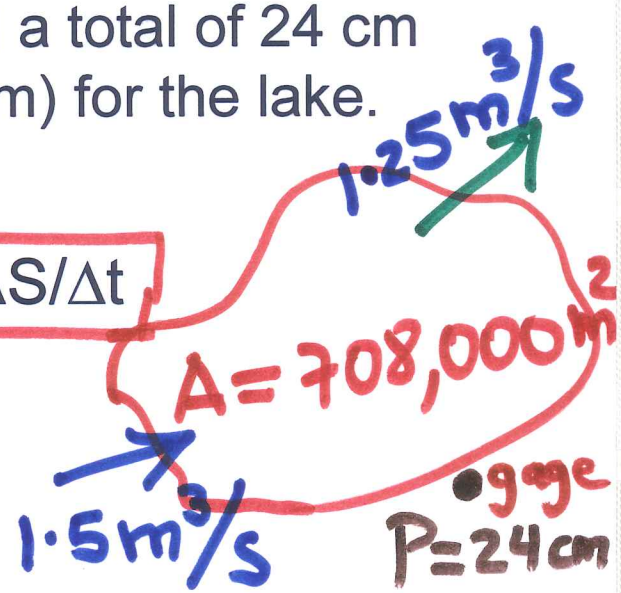
Problem 1.7. Clear Lake has a surface area of 708,000 m^2 (70.8 ha). For a given month, the lake has an inflow of 1.5 m^3/s and an outflow of 1.25 m^3/s. A +1.0 m storage change or increase in lake level was recorded. If a precipitation gage recorded a total of 24 cm for this month, determine the evaporation loss (in cm) for the lake. Assume that seepage is negligible.

infiltration

Governing Equation: Inflow - Outflow = $\Delta S/\Delta t$

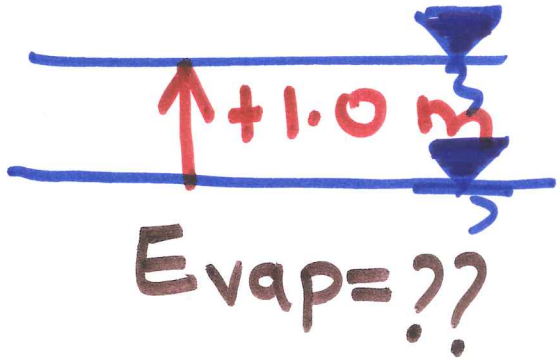
Inputs: Inflow + P

Outputs: Out + E + ~~Infiltration~~ 0



$\Delta Storage = A \cdot \Delta y$

$$\Delta y = \frac{\Delta S}{A}$$



3b

$1\ \frac{m^3}{s} \times 30 \times 24 \times 3600\ s$

$\Delta y|_{1m^3/s} = \frac{30 \times 24 \times 3600\ m^3}{708{,}000\ m^2} = 3.66\ m$

$= 366\ cm$

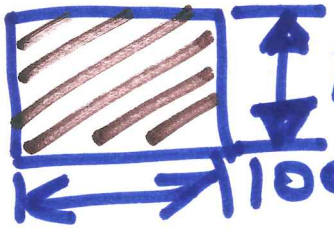
Inflow : $1.5\ \frac{m^3}{s} = 549\ cm$

Outflow : $1.25\ \frac{m^3}{s} = 457.5\ cm$

$549 + 24 - (457.5 + E) = \underbrace{100\ cm}_{+1\ m}$

$E = 15.6\ cm$

1 ha = (hectar)



$1\ ha = 10{,}000\ m^2$

$$(I - 0) = \frac{\Delta S}{\Delta t}\ )\ \Delta t$$

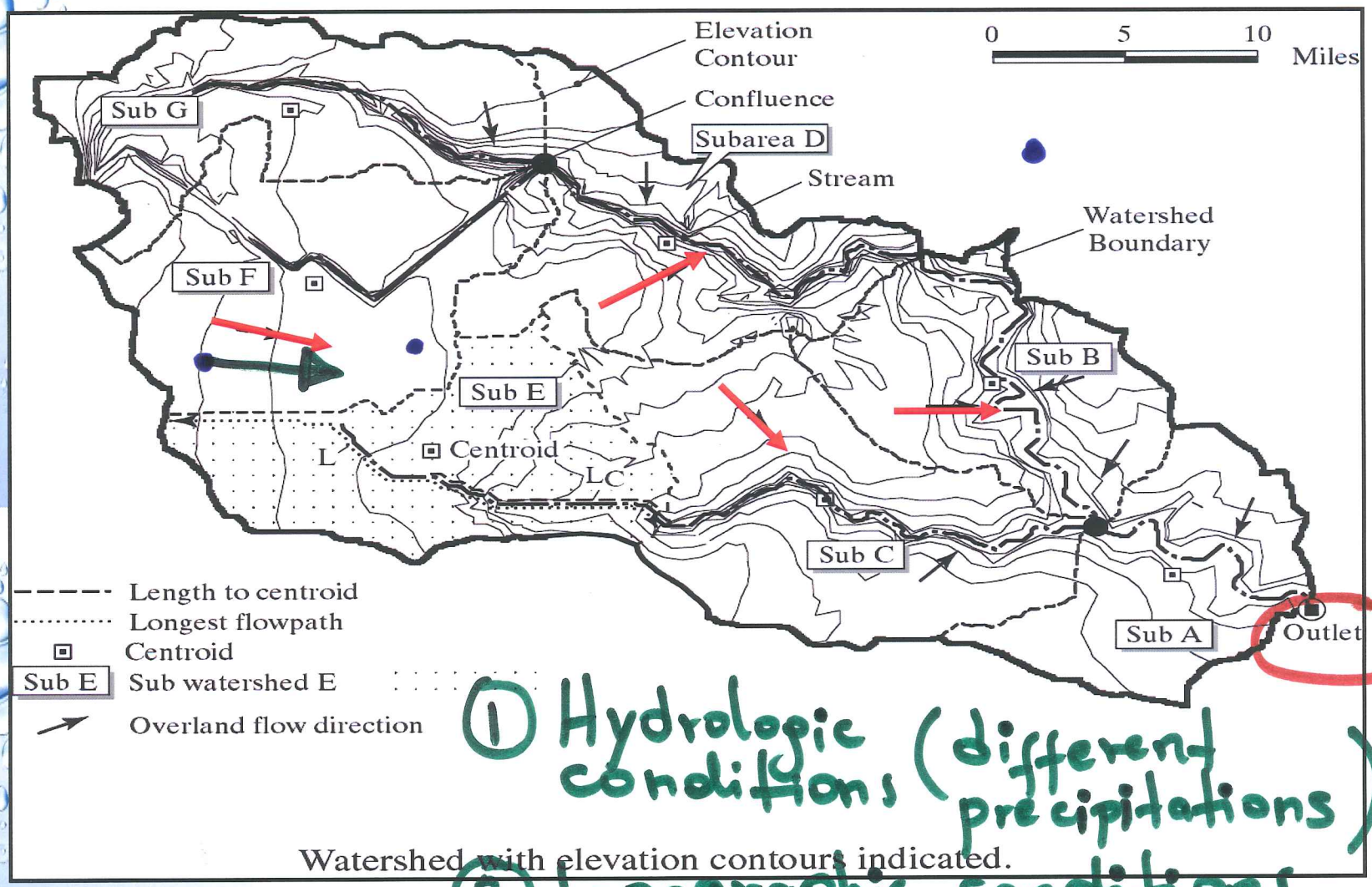
3c

units $\left(\frac{L^3}{T}\right)$

$$\frac{(I-0)\Delta t}{A} = \frac{\Delta S}{A}$$

$$(I-0)\frac{\Delta t}{A} = \Delta y$$

The Watershed



Watershed with elevation contours indicated.

① Hydrologic conditions (different precipitations)

② topographic conditions

Water flows at right angles to elevation contours and from higher to lower elevations

Video of the USDA Watershed Learning Animation

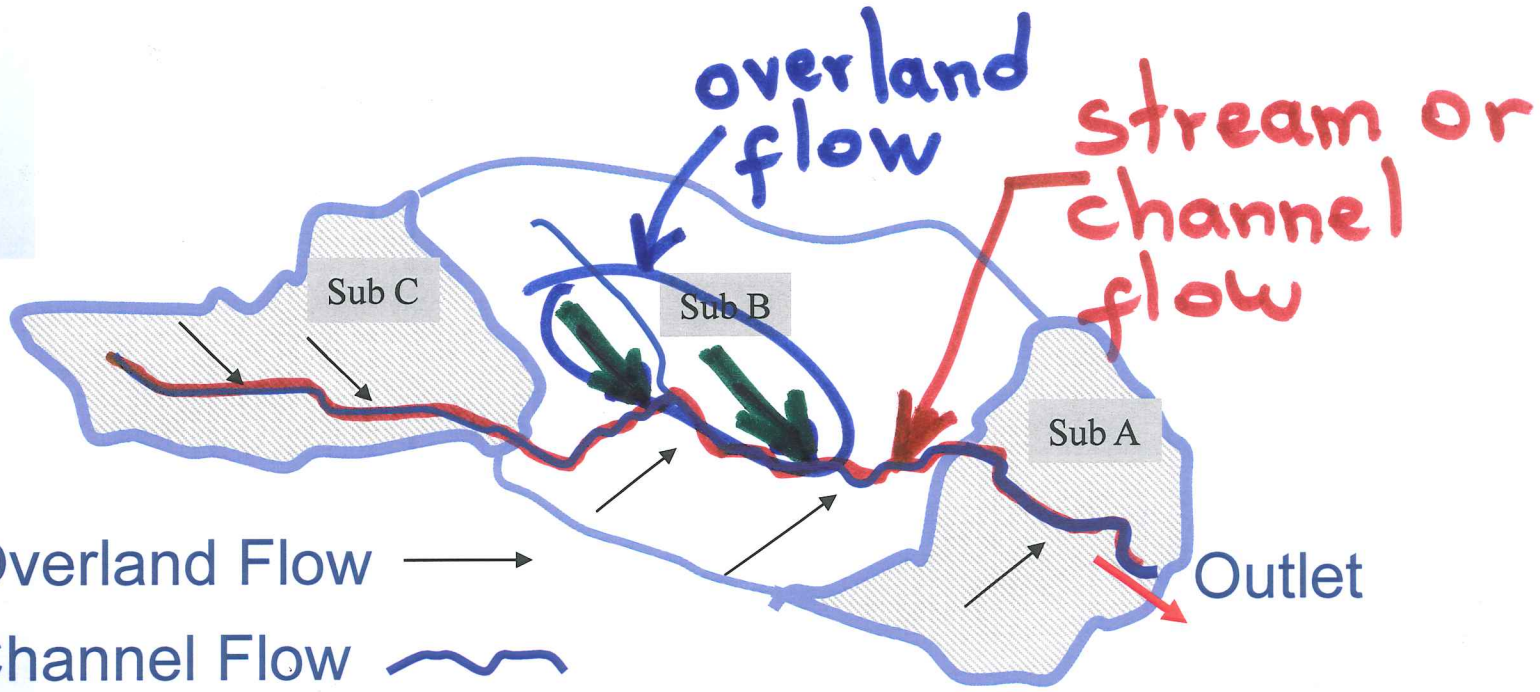
Link:

http://www.youtube.com/watch?v=dUlAANVBYHM

Watershed = Basin
Subwatershed = Subbasin

Subbasins

Divided according to topography and hydrology



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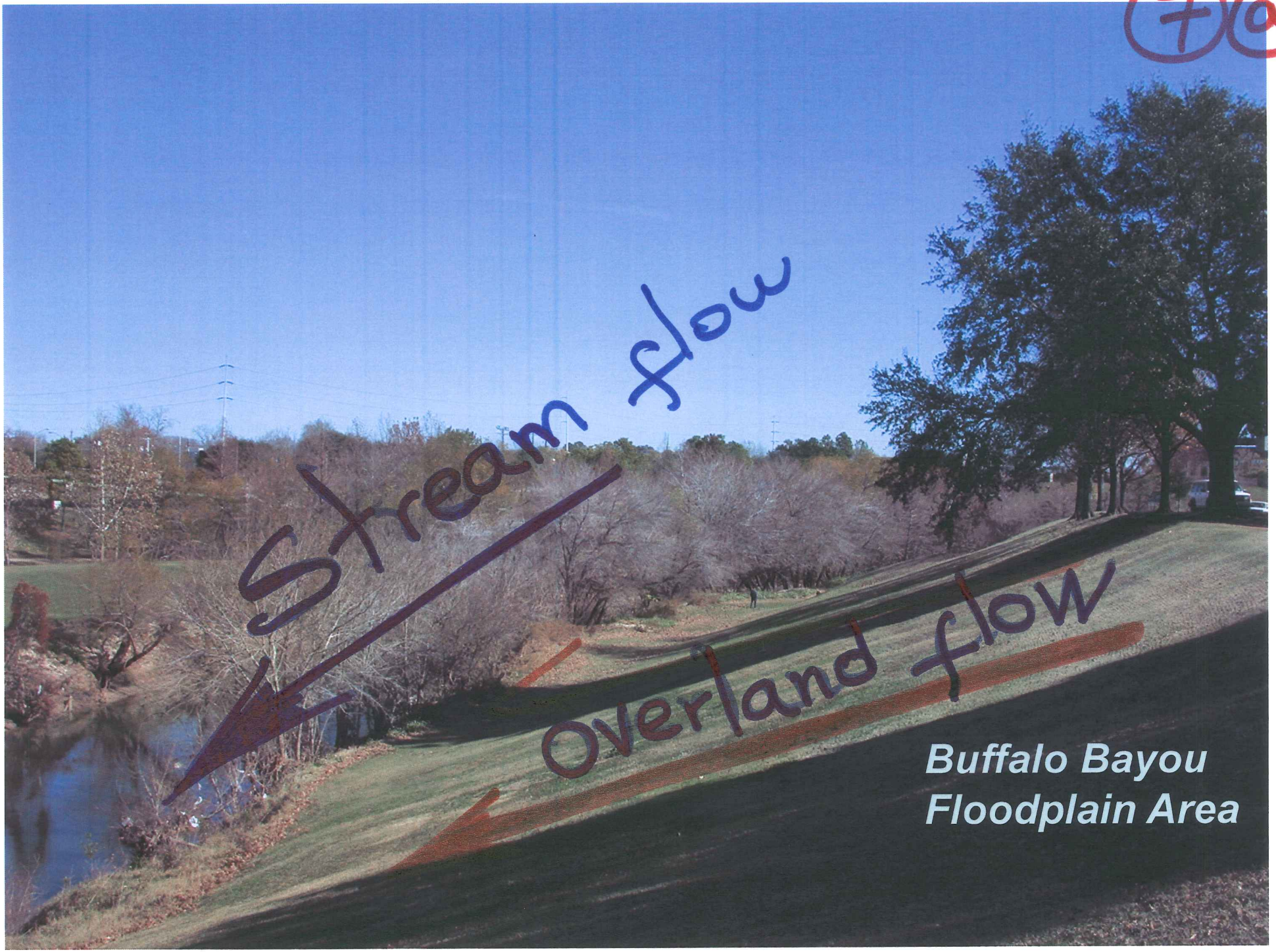

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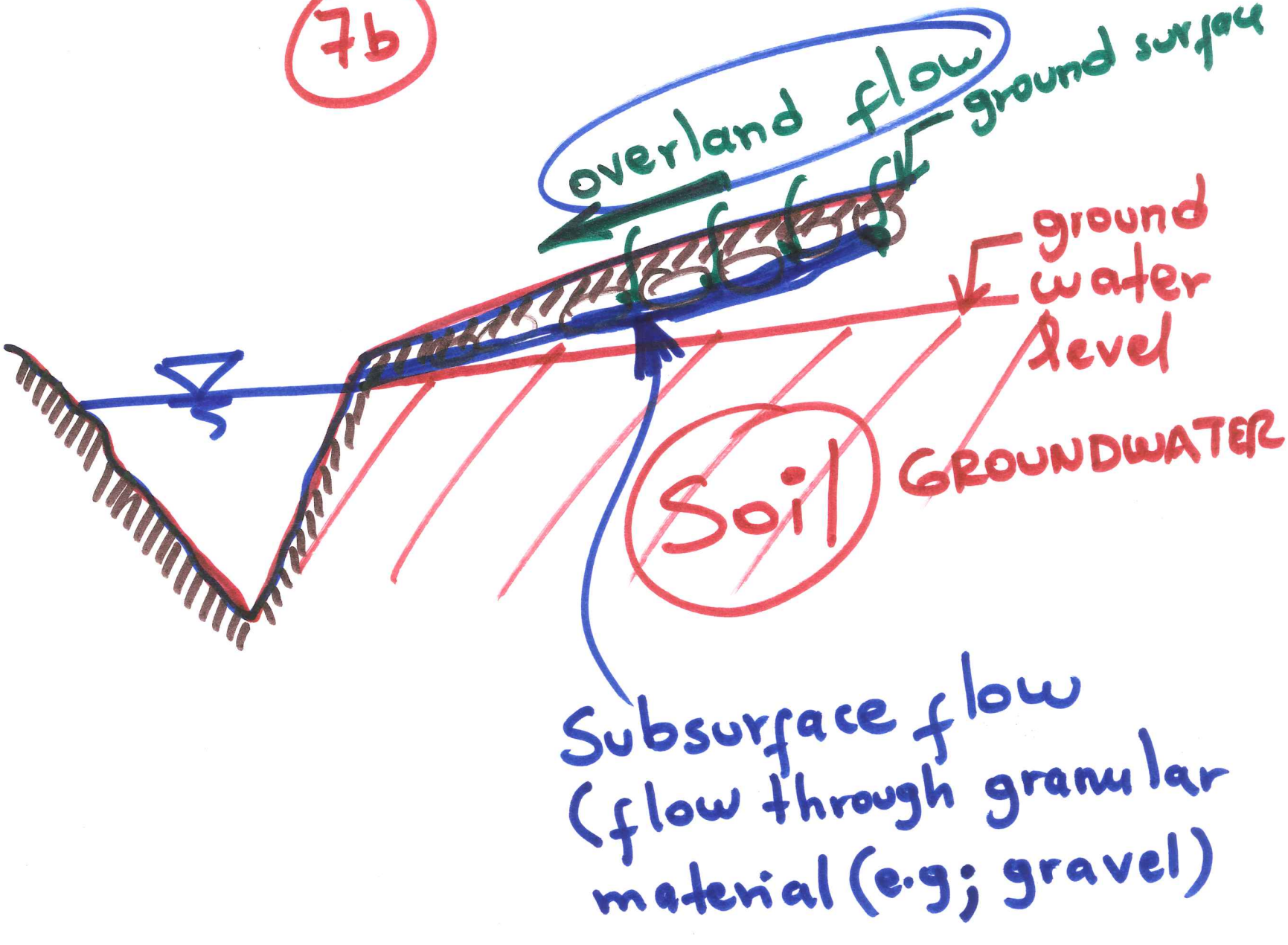
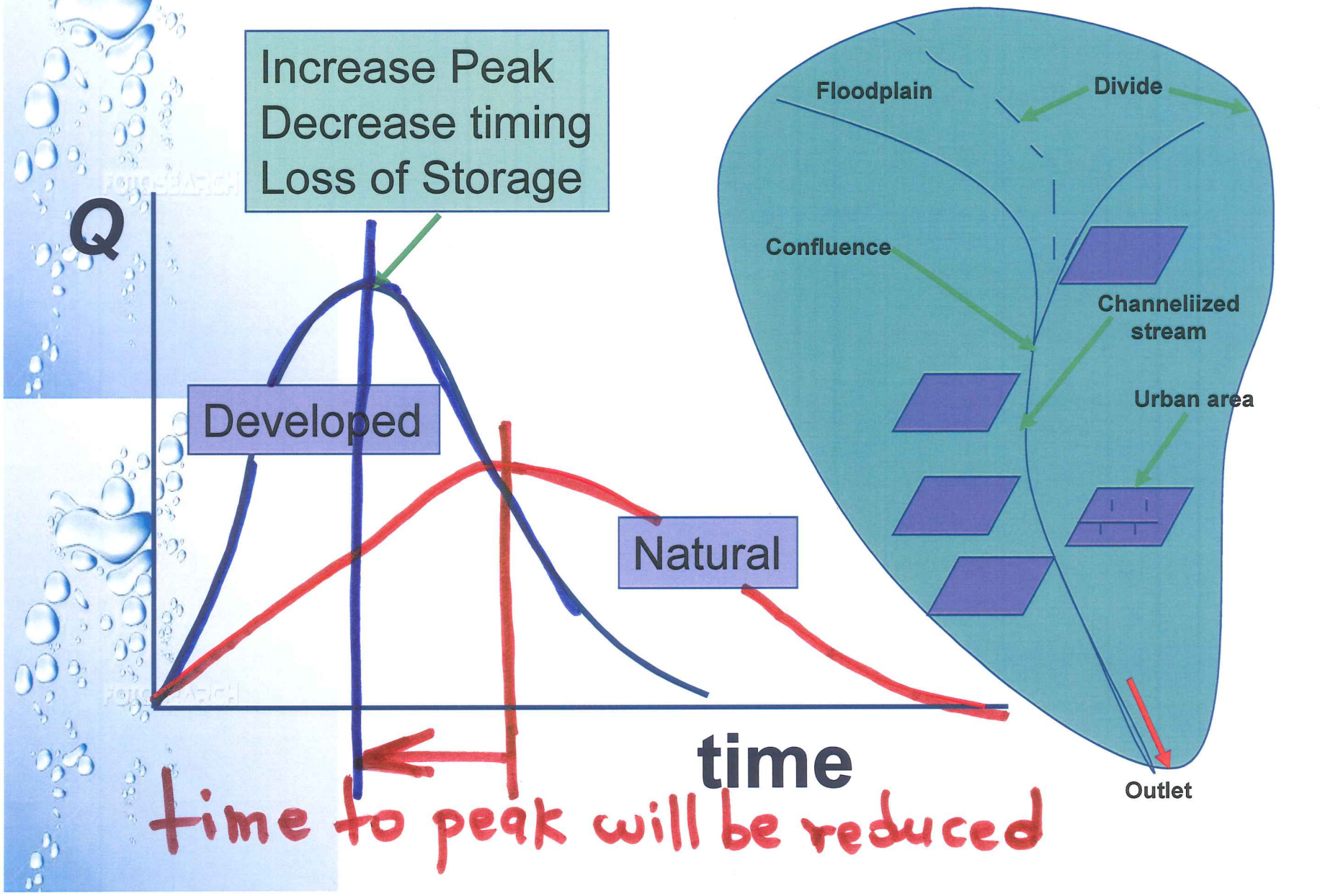
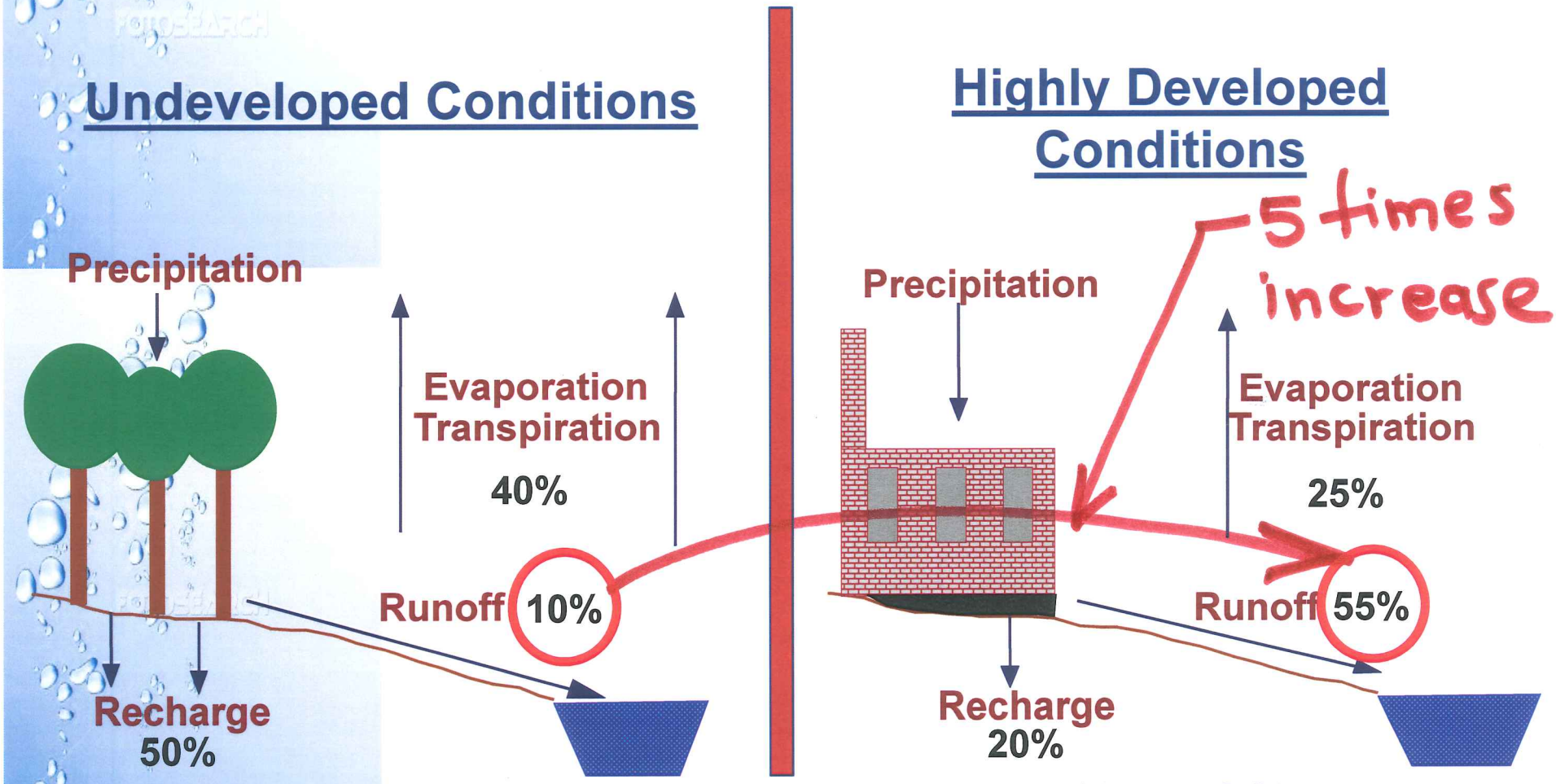

overland flow
ground surface
ground water level
Soil
GROUNDWATER
Subsurface flow
(flow through granular material (e.g; gravel)

Urbanization Effect in a Watershed

Urbanization Effect in a Watershed

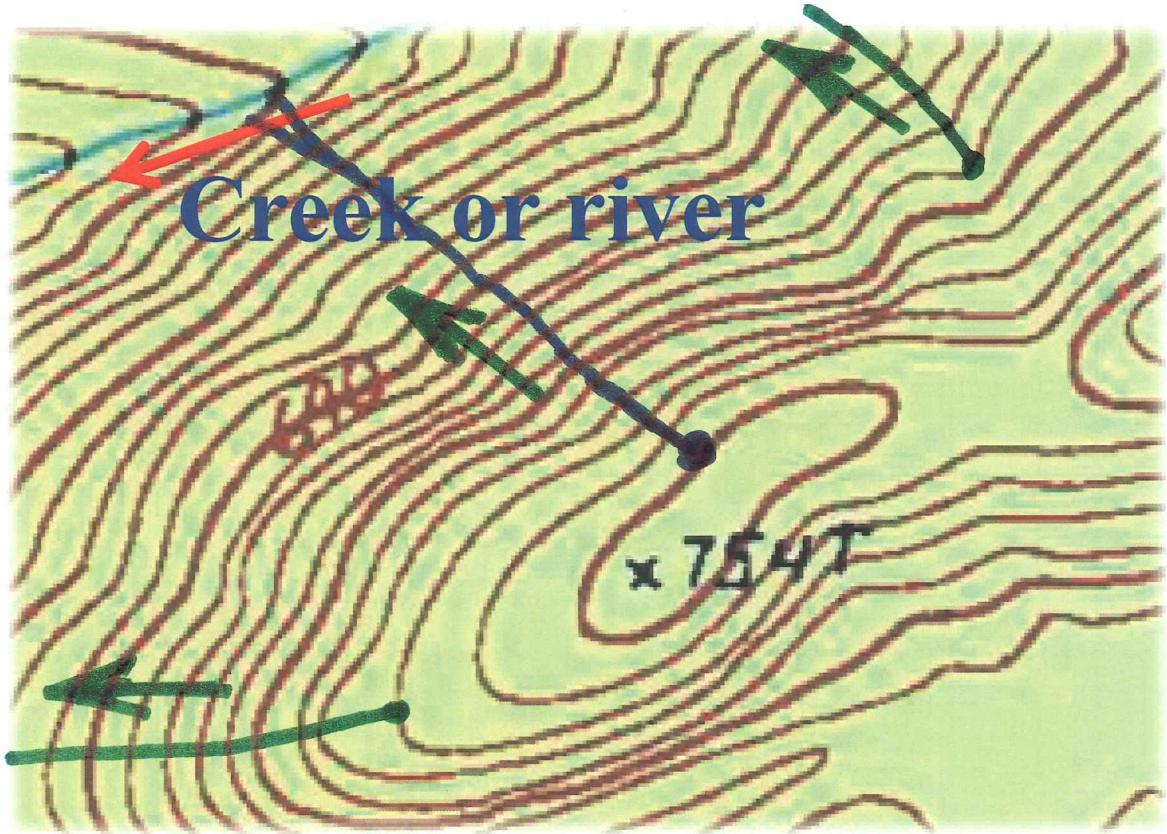


Stormwater runoff is a natural part of the hydrologic cycle … **but as land use changes, runoff can increase by 45%**, resulting in erosion, pollutant transport, sedimentation, loss of aquatic habitat, and other damages.



Adapted from T. R. Hersey Jr., G. A. Palumbo, Mary C. Rossi, Richard R. Rutkowski, The Western New York Stormwater Coalition

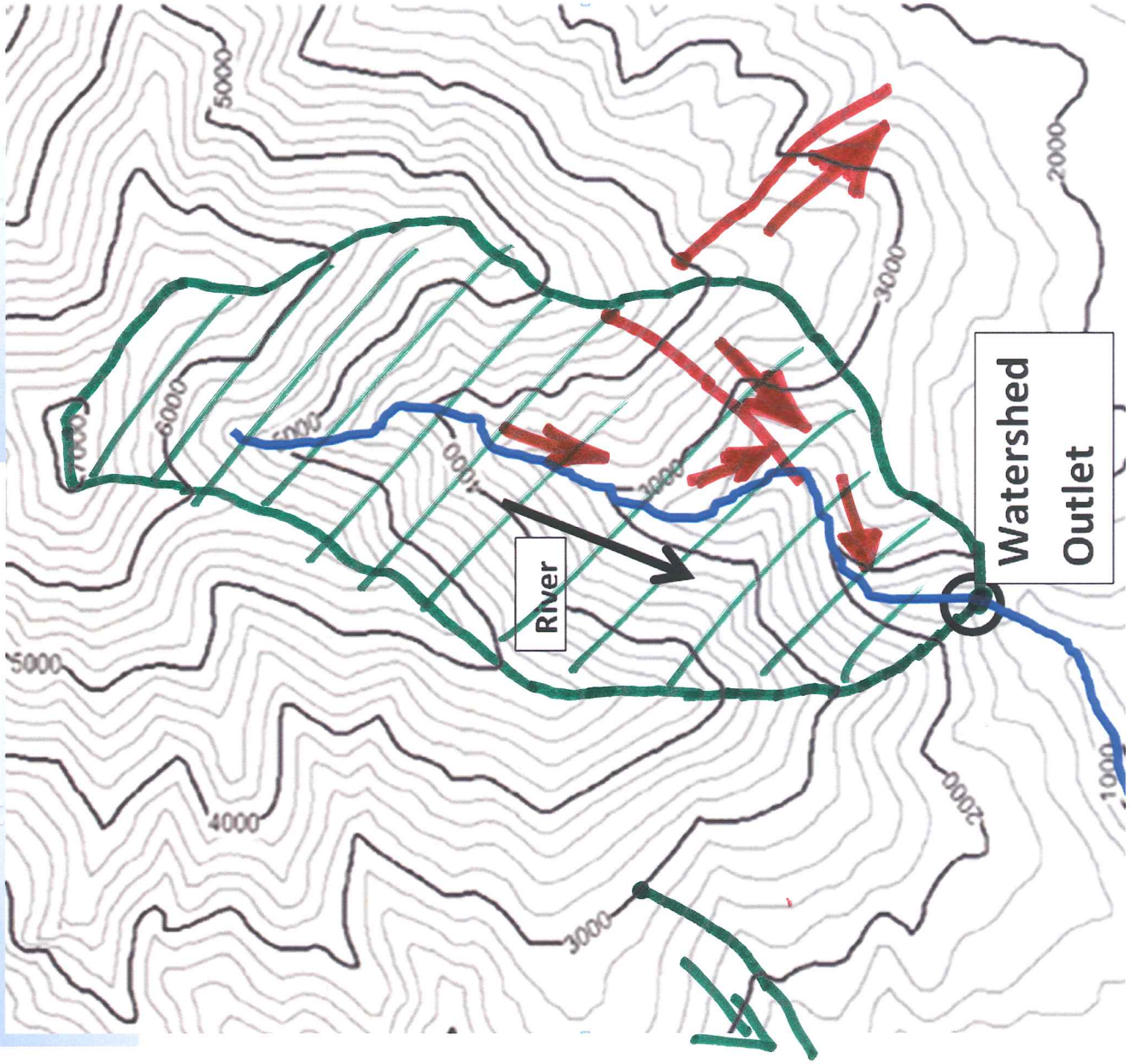
Elevation Contours



Water flows at right angles to elevation contours and from higher to lower elevations

In-class Assignment 1: Practice on Watershed Delineation

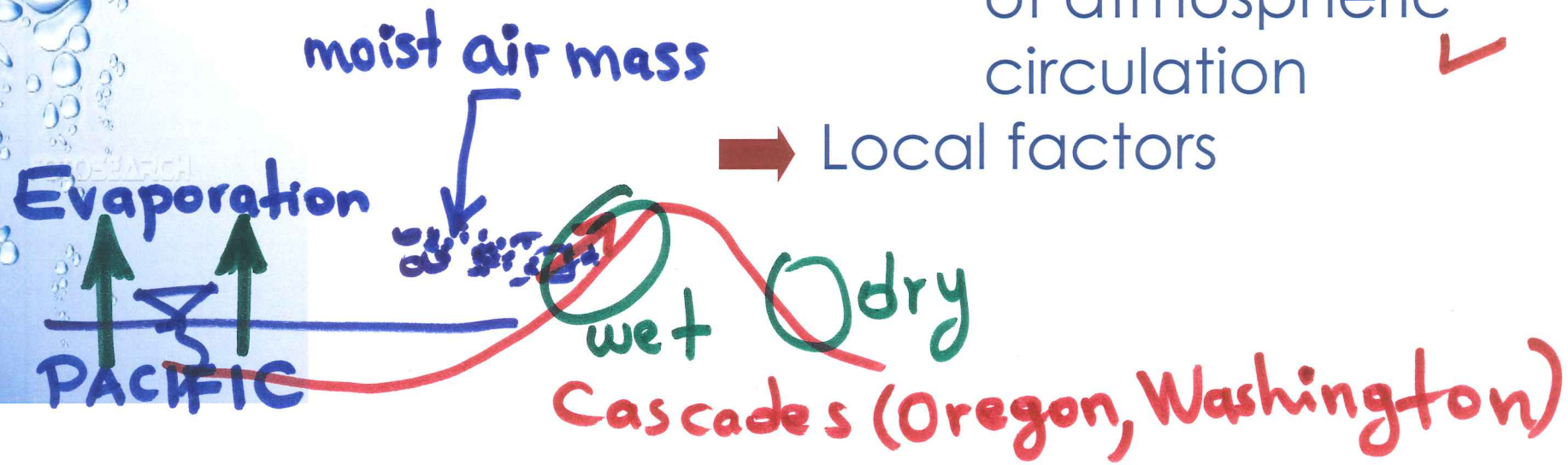
Student Name:



Precipitation

Precipitation varies in
- Space
- Time

According to
- The general pattern of atmospheric circulation
- Local factors



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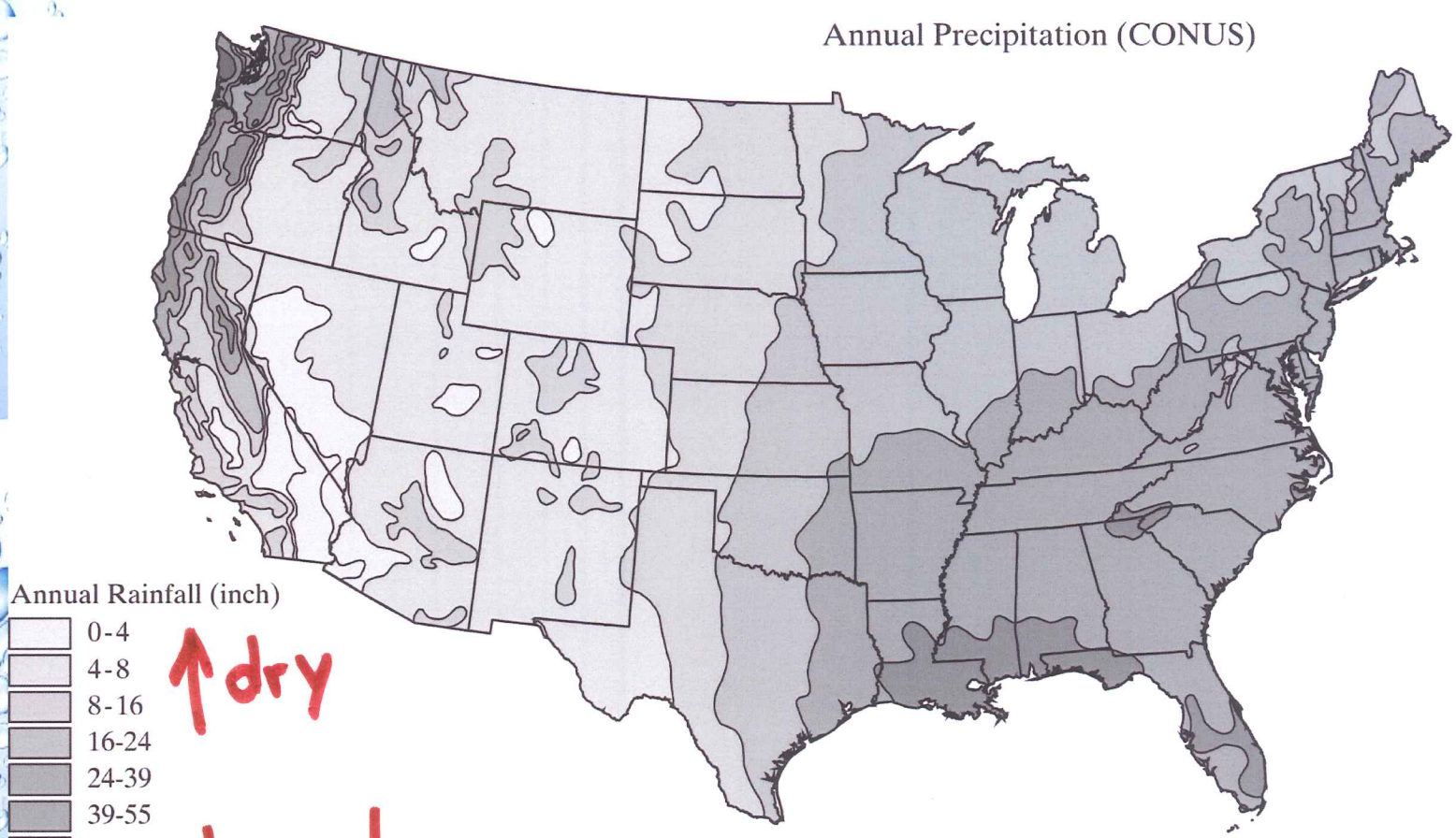
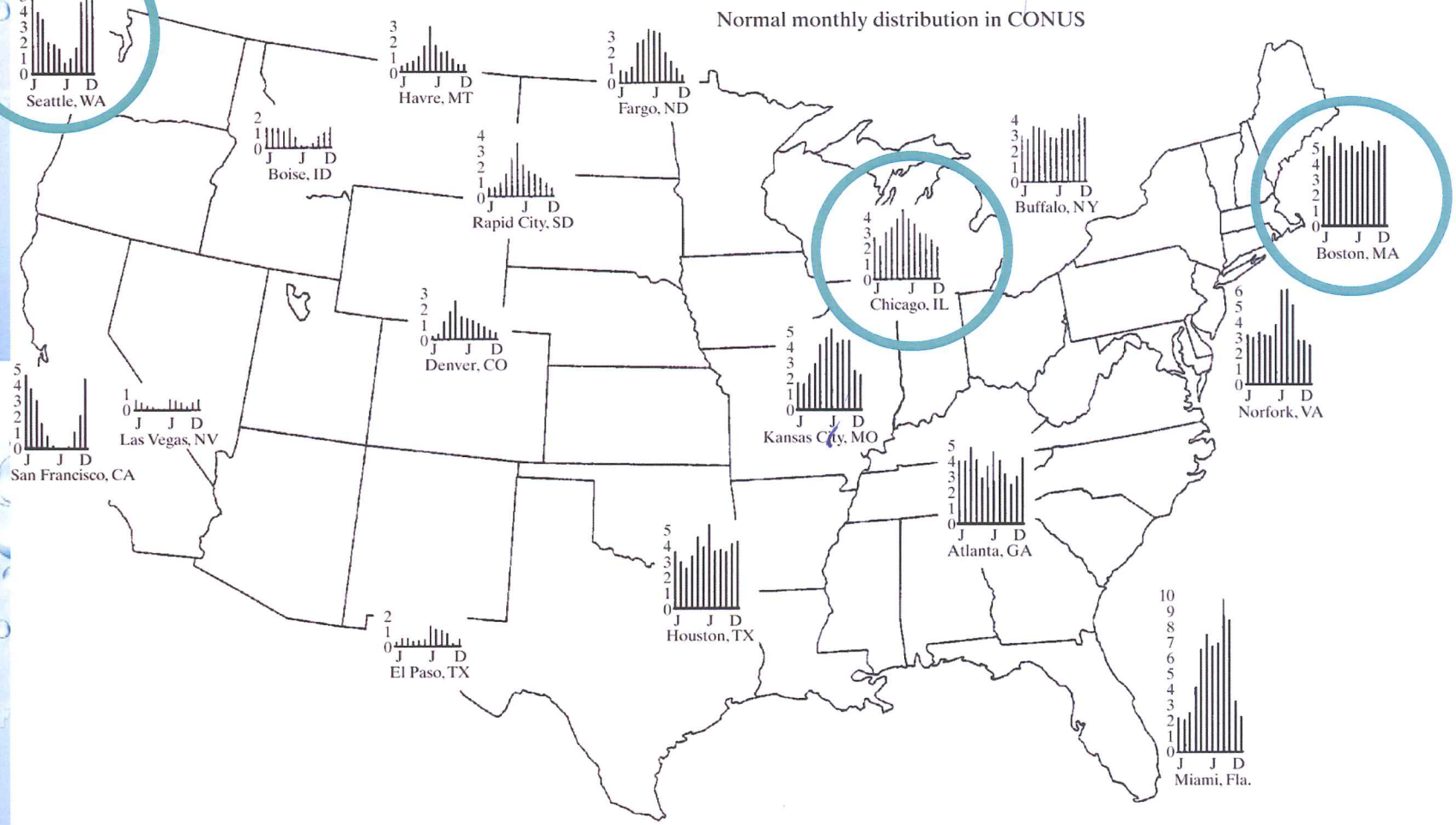
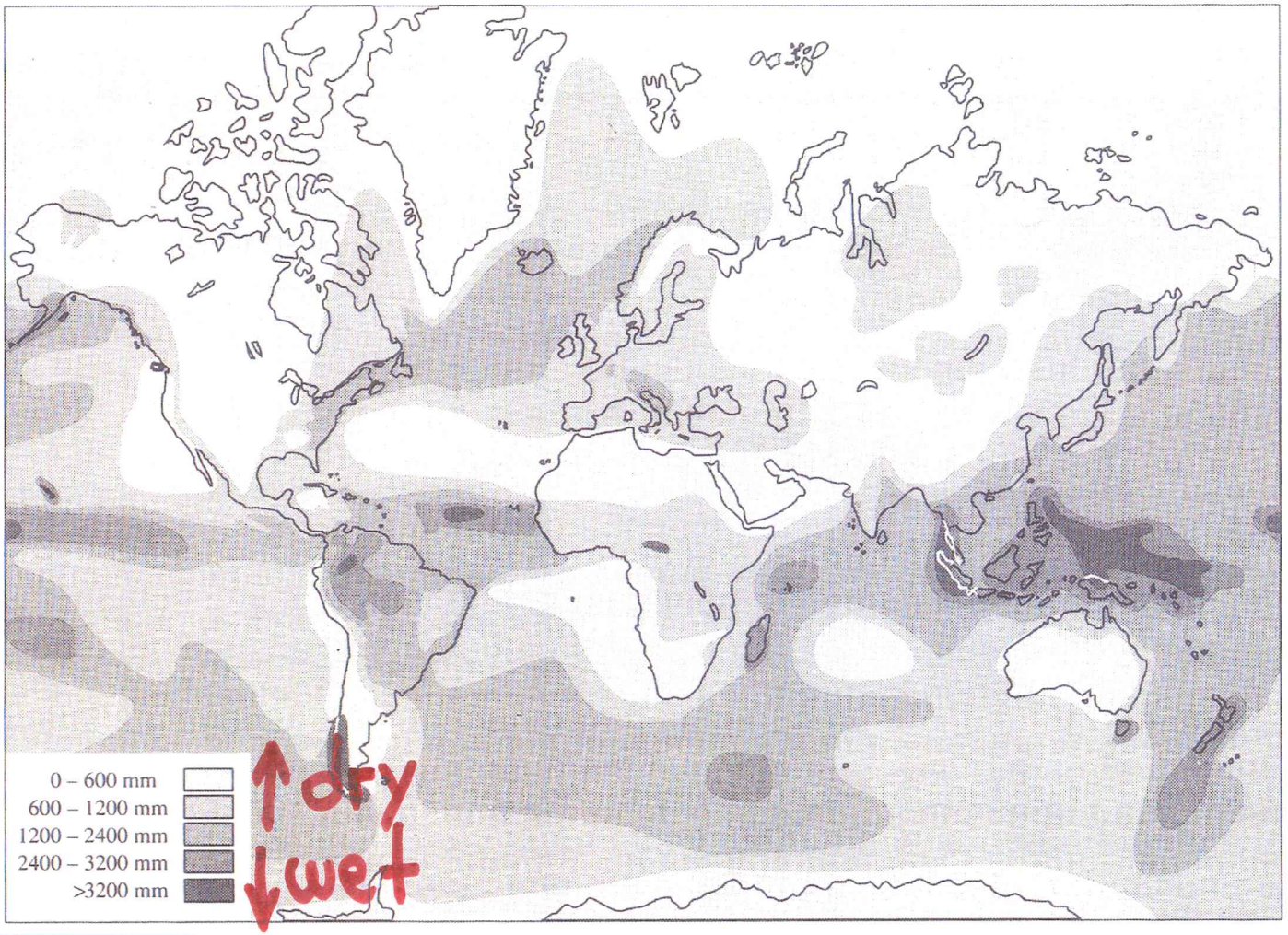
Distribution of average annual precipitation across the United States



Normal monthly distribution of precipitation in different U.S. cities (inches)



Mean annual precipitation of the world in mm (1977)



Maximum Recorded Rainfall across the United States (in.)

Table 1–2 Maximum Recorded Rainfall across the United States (in.)

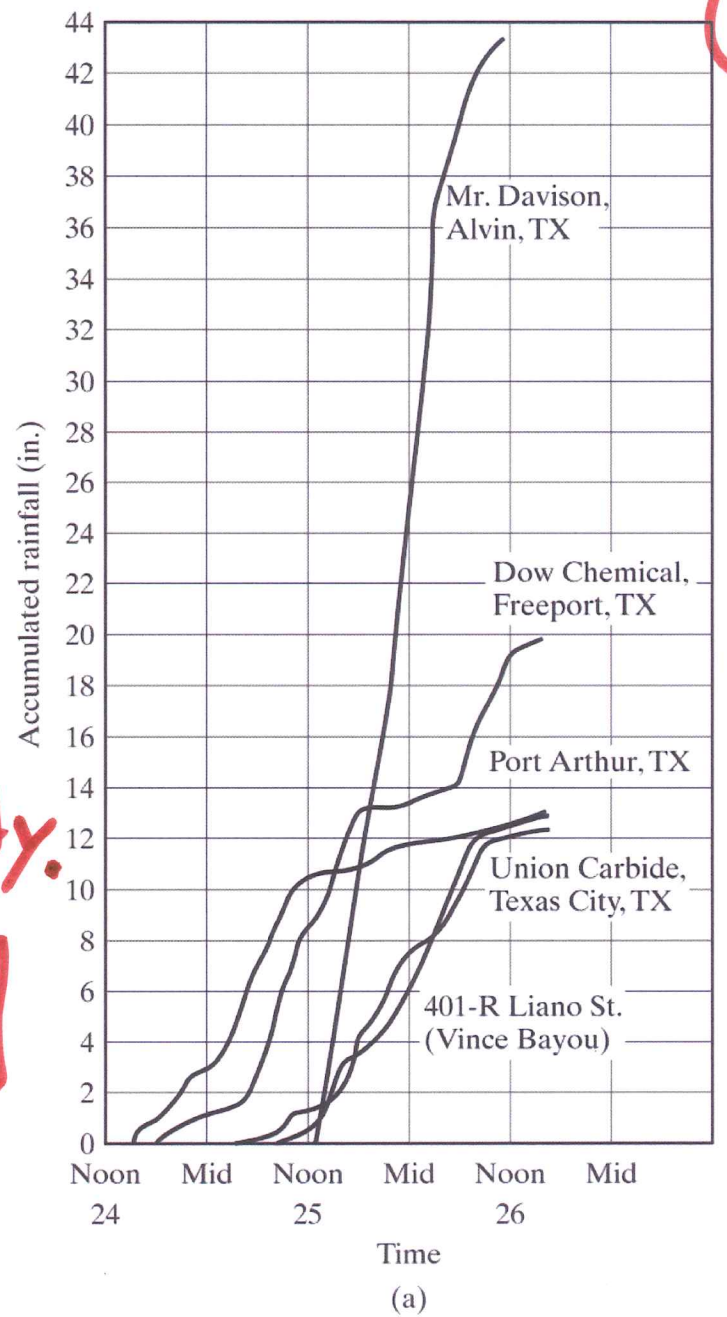
	Duration		
	1 hr	6 hr	24 hr
San Francisco, CA	1.07	2.34	4.67
Portland, OR	1.31	—	7.66
Denver, CO	2.20	2.91	6.53
St. Louis, MO	3.47	5.82	8.78
New Orleans, LA	4.71	8.62	14.01
Alvin, TX (near Houston)	4.00	15.67	43.00
New York, NY	2.97	4.44	9.55
Miami, FL	4.53	10.64	15.10

World Record Rainfalls

Table 1–3 World Record Rainfalls

Duration	in.	mm	Location
1 min	1.50	38	Barot, Guadeloupe
15 min	7.80	198	Plumb Point, Jamaica
1 hr	15.80	401	Shangdi, China
12 hr	52.76	1,340	Belouve, Reunion
24 hr	72.40	1,840	Cherrapunji, India
2 days	98.42	2,500	Ciliaos, Reunion
15 days	253.60	6,443	Commerson, La Reunion
1 mo	366.14	9,300	Cherrapunji, India
1 yr	1041.78	26,461	Cherrapunji, India

Accumulated rainfall for the July 1979 storm event near Houston, TX.



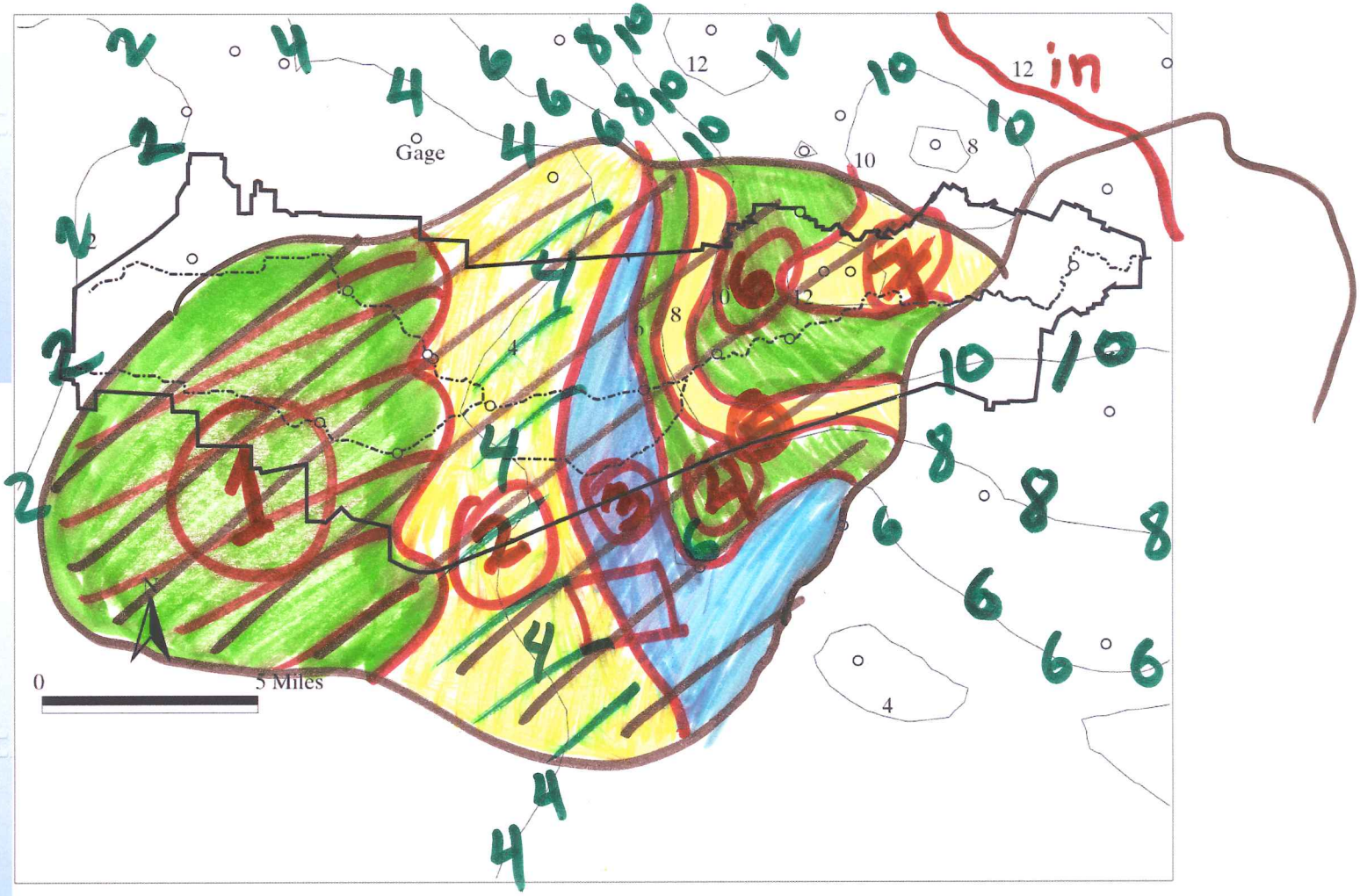
We are interested not only in the cumulative rainfall but also the intensity.

Reservoirs: [volume]

Pipes: [intensity of rain]

Spillways:

T.S. Allison 9-hr rainfall gage contours (in) from Brays Bayou watershed in Houston, TX.



(b)

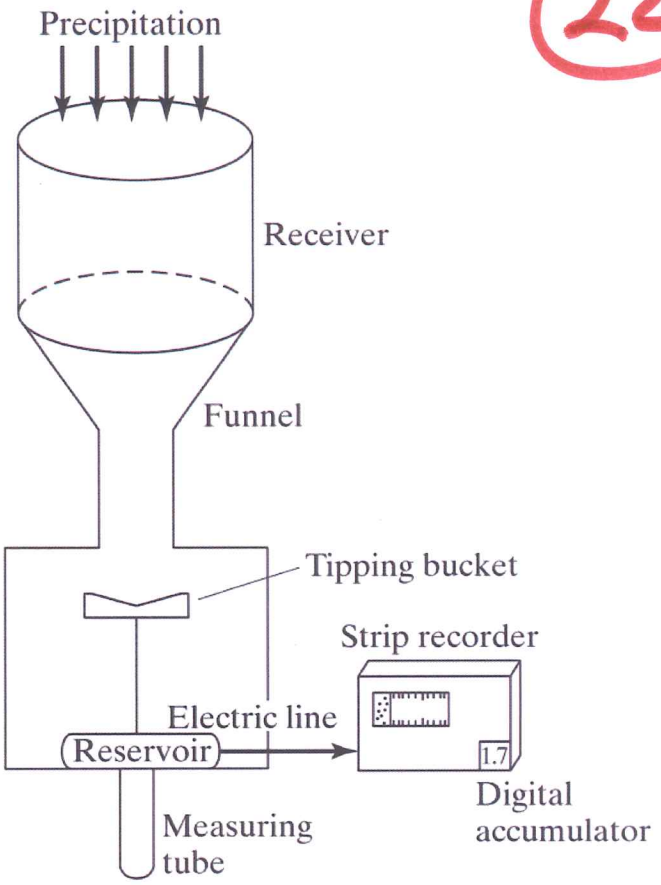
Rainfall Measurement

Tipping bucket rain gauge

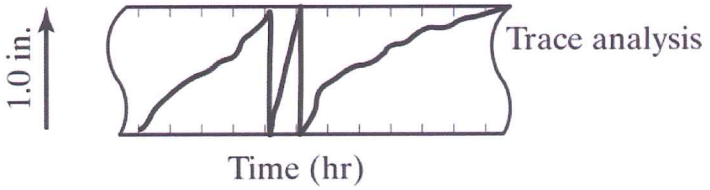
Recording tipping bucket gage.

Tipping bucket video

http://www.youtube.com/watch?v=C6eMMGVF5Wg



(a)



(b)