
Introduction to Hydrology

Part B

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Weather systems

Atmospheric parameters

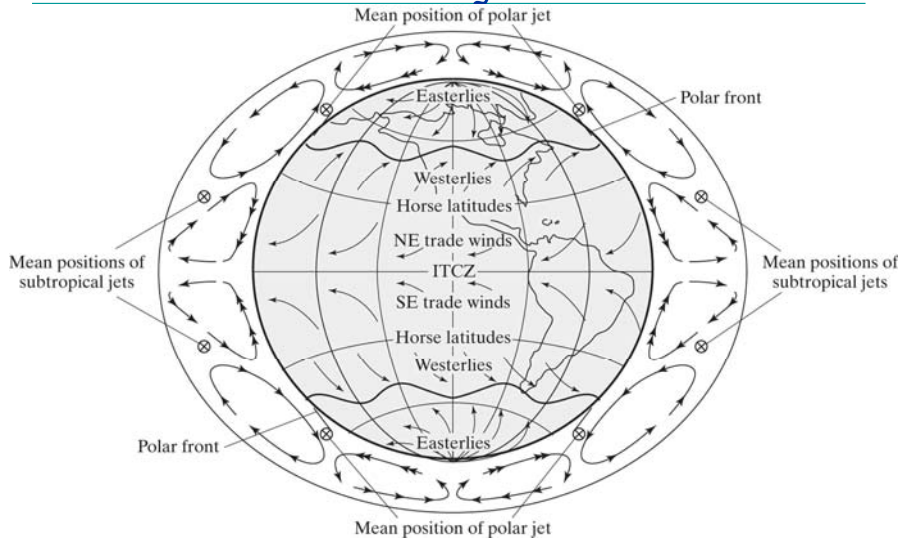
Phase change in hydrologic cycle

Latent heat and its impact on weather

Atmosphere and clouds

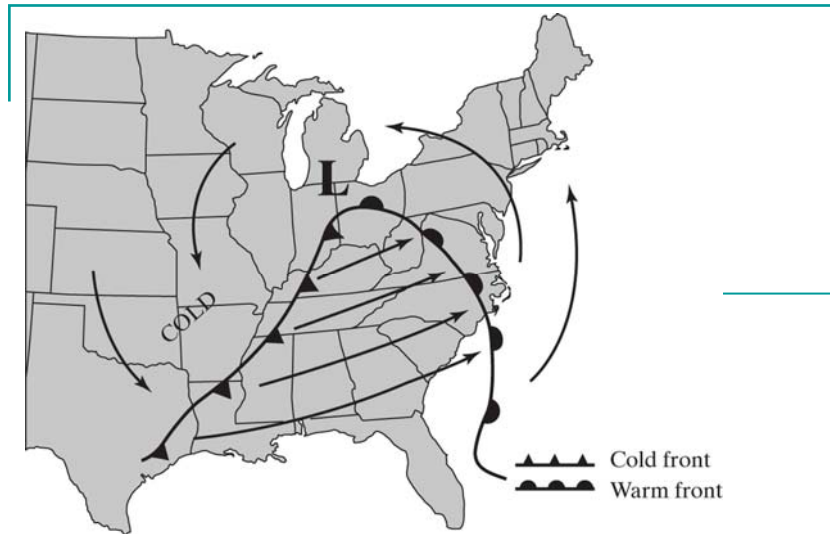
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Weather systems



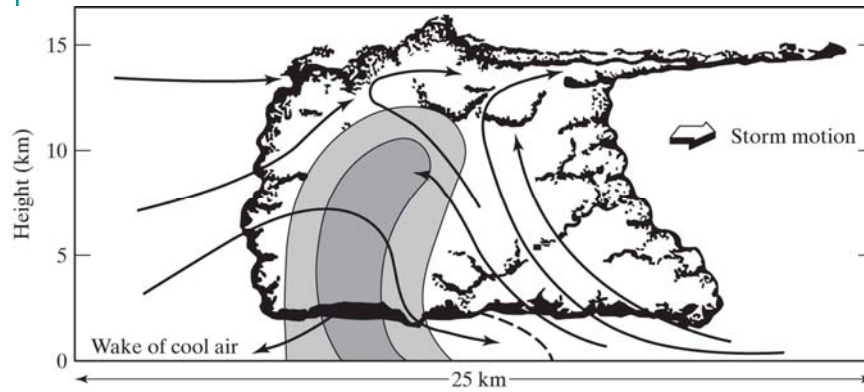
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Air masses and fronts



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Thunderstorms



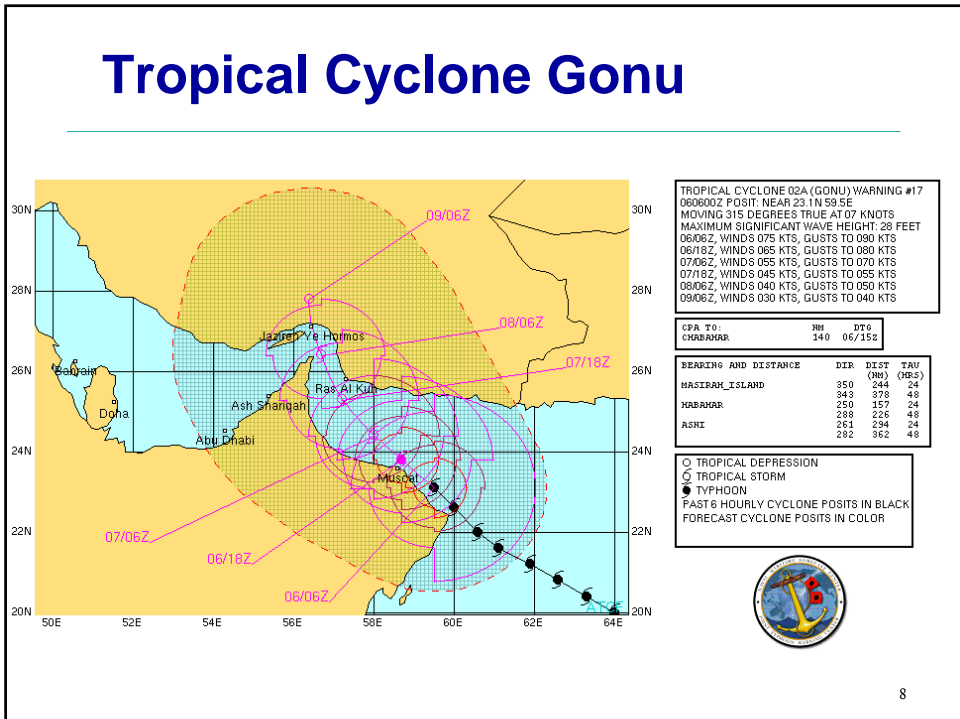
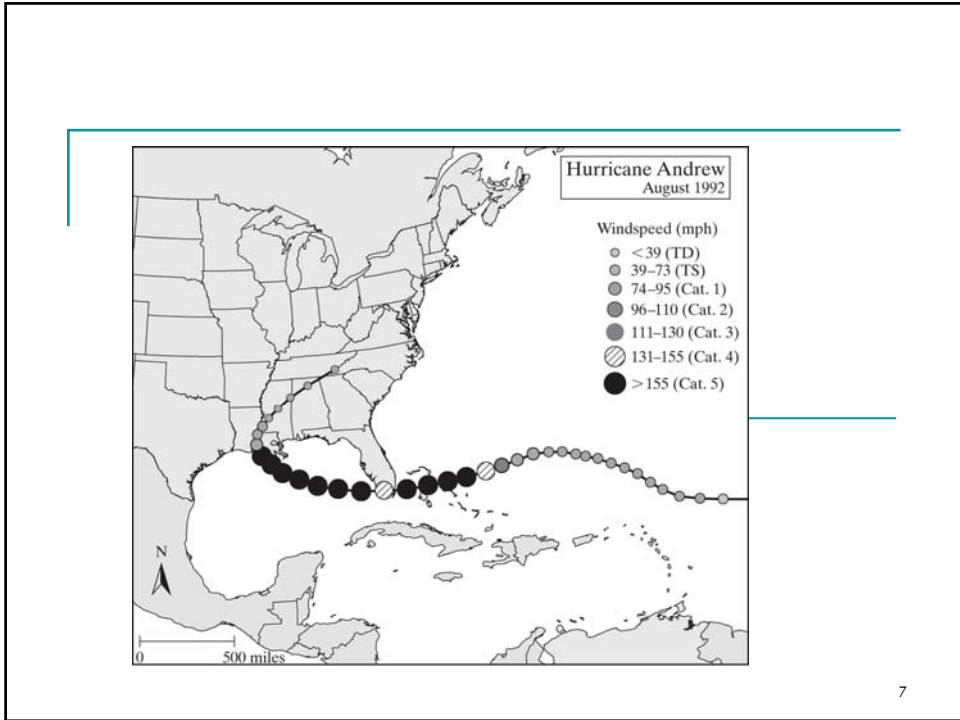
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Hurricanes

Table 1-1. Hurricane Categories

Category	Wind Speed (mph)	Extent of Damage	Damage Description
Tropical Storm	35-73	Minor	Some flooding
1	74-95	Minimal	Damage limited to unanchored mobile homes, shrubbery and trees
2	96-110	Moderate	Some roof, door and window damage to buildings, some trees blown down
3	111-130	Extensive	Some structural damage to residences and utility buildings, trees defoliated and many blown down
4	131-155	Extreme	Extensive curtainwall failures and some complete roof failures, shrubs, trees and all signs blown down
5	156+	Catastrophic	Complete roof failure and some complete building failures

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Moisture relationships

$$e = \frac{\rho_w RT}{0.622}$$

e = vapor pressure (mb)

ρ_w = vapor density or absolute humidity (g/cm^3)

R = dry air gas constant = $2870 \text{ mb}\cdot\text{cm}^3/\text{g } ^\circ\text{K}$

T = absolute temperature ($^\circ\text{K}$)

$$RH = 100e / e_s$$

e_s = saturation vapor pressure (mb)

RH = Relative humidity (%)

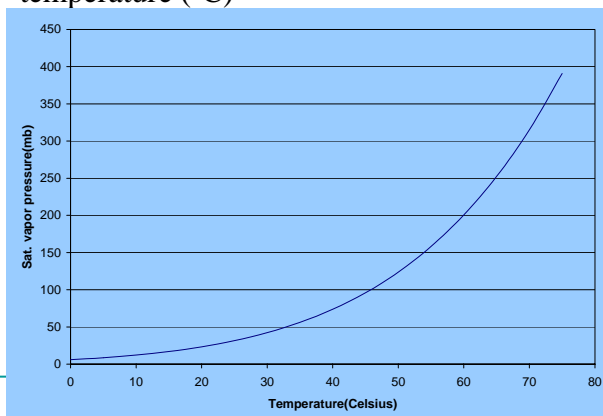
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Moisture relationships

$$e_s = 2.7489 \times 10^8 \exp\left(-\frac{4278.6}{T + 242.79}\right)$$

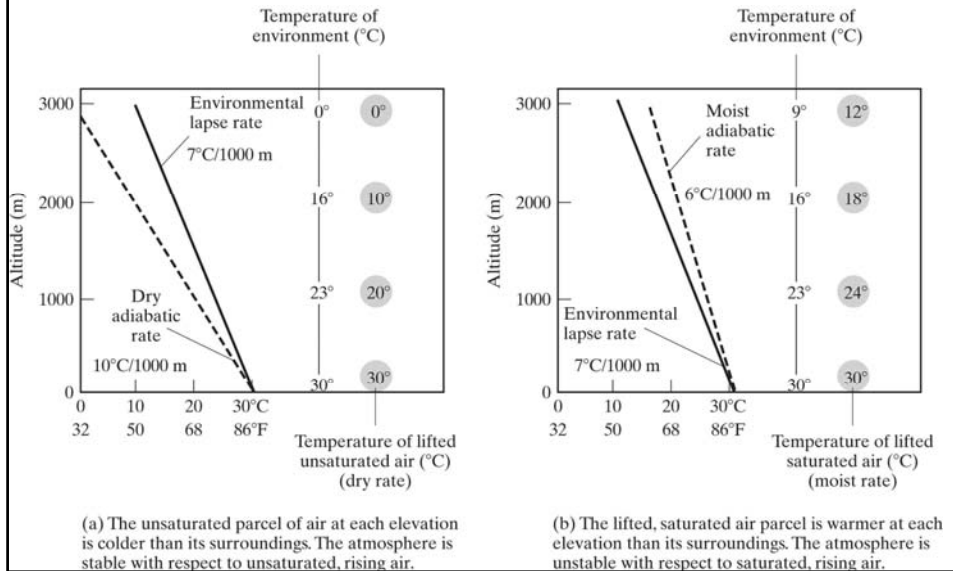
e_s = saturation vapor pressure (mb)

T = temperature ($^\circ\text{C}$)



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- Dew point temperature
- Dry adiabatic lapse rate

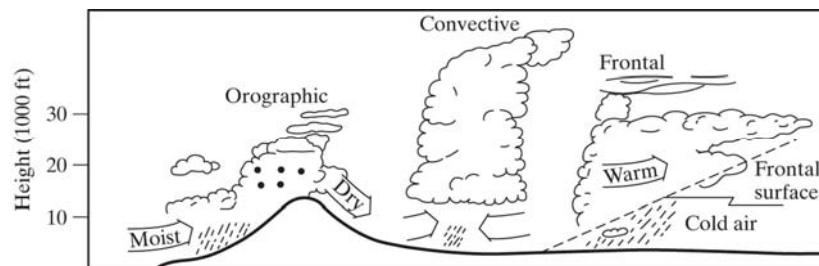


Mechanisms of precipitation formation

1. A moisture sources must be available
2. Moist air must be lifted and cooled
3. Nuclei must be present in the air
4. Droplets must grow larger to reach the ground

Classification of precipitation

1. Convective: due to intense heating of air at the ground, which leads to expansion and vertical rise
2. Cyclonic: associated with the movement of large air-mass systems
3. Orographic: due to mechanical lifting of moist air over the windward side of mountain ranges



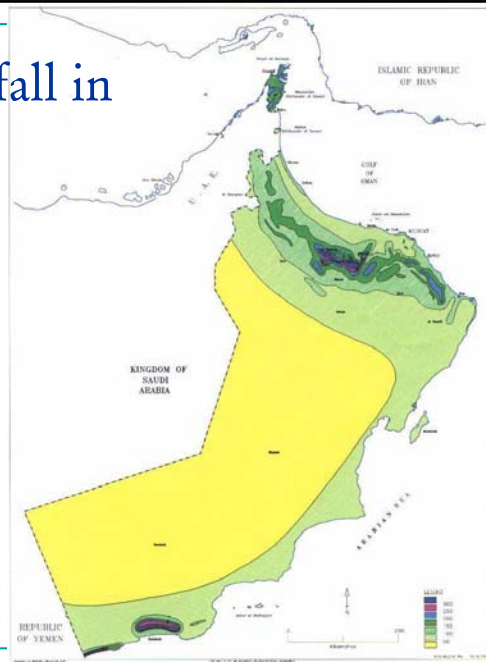
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Table 1-4. World Record Rainfalls

Duration	in.	mm	Location
1 min	1.50	38	Barot, Guadeloupe
8 min	4.96	126	Fussen, Bavaria
15 min	7.80	198	Plumb Point, Jamaica
20 min	8.10	206	Cutea de Arges, Rumania
42 min	12.00	305	Holt, MO
2 hr 10 min	19.00	483	Rockport, WV
4 hr 30 min	30.80	782	Smetport, PA
9 hr	42.79	1087	Belouve, Reunion
12 hr	52.76	1340	Belouve, Reunion
24 hr	73.62	1870	Ciliaos, Reunion
2 days	98.42	2500	Ciliaos, Reunion
3 days	127.56	3240	Ciliaos, Reunion
4 days	146.50	3721	Cherrapunji, India
5 days	151.73	3854	Ciliaos, Reunion
6 days	159.65	4055	Ciliaos, Reunion
7 days	161.81	4110	Ciliaos, Reunion
15 days	188.88	4798	Cherrapunji, India
1 mo	366.14	9300	Cherrapunji, India
2 mo	502.63	12,767	Cherrapunji, India
3 mo	644.44	16,369	Cherrapunji, India
6 mo	884.03	22,454	Cherrapunji, India
1 yr	1041.78	26,461	Cherrapunji, India
2 yrs	1605.05	40,768	Cherrapunji, India

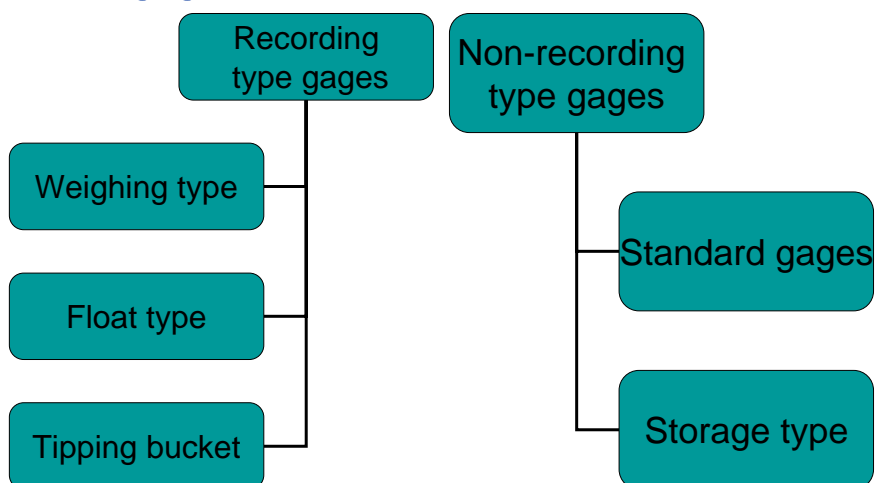
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Average annual rainfall in Sultanate of Oman



Measurement of precipitation

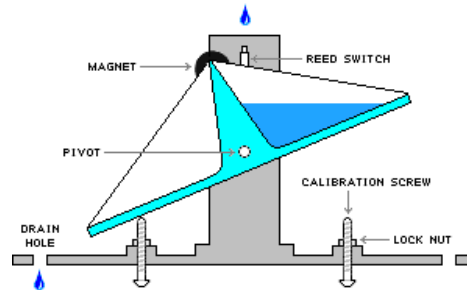
Rain gages



Rain gages



Wireless rain gage

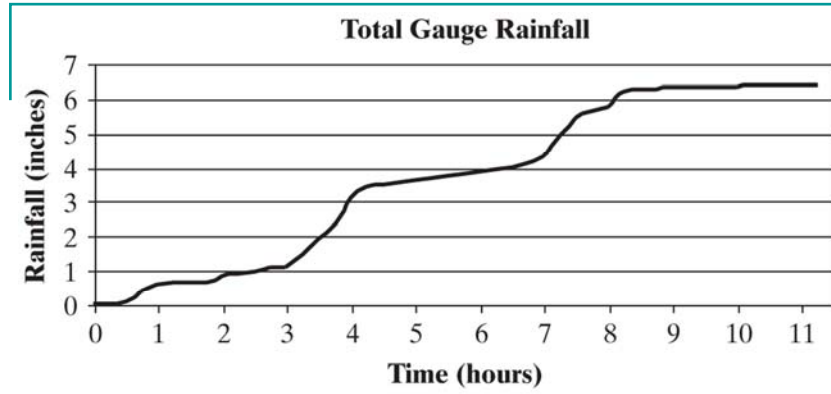


Tipping bucket type rain gage

Example 1-3

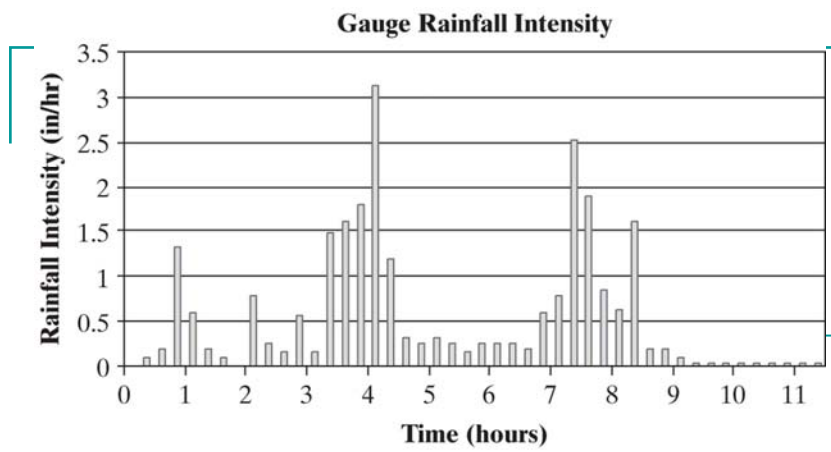
Table E1-3. Rainfall Data from a Recording Gage

Time (hr)	Gage Rainfall (in.)	Gage Intensity (in./hr)	Time (hr)	Gage Rainfall (in.)	Gage Intensity (in./hr)
0	0	0	5.75	3.78	0.24
0.25	0.02	0.08	6	3.84	0.24
0.5	0.07	0.2	6.25	3.9	0.24
0.75	0.4	1.32	6.5	3.95	0.2
1	0.55	0.6	6.75	4.1	0.6
1.25	0.6	0.2	7	4.3	0.8
1.5	0.62	0.08	7.25	4.93	2.52
1.75	0.62	0	7.5	5.4	1.88
2	0.82	0.8	7.75	5.61	0.84
2.25	0.88	0.24	8	5.77	0.64
2.5	0.92	0.16	8.25	6.17	1.6
2.75	1.06	0.56	8.5	6.22	0.2
3	1.1	0.16	8.75	6.27	0.2
3.25	1.47	1.48	9	6.29	0.08
3.5	1.87	1.6	9.25	6.3	0.04
3.75	2.32	1.8	9.5	6.31	0.04
4	3.1	3.12	9.75	6.32	0.04
4.25	3.4	1.2	10	6.33	0.04
4.5	3.48	0.32	10.25	6.34	0.04
4.75	3.54	0.24	10.5	6.35	0.04
5	3.62	0.32	10.75	6.36	0.04
5.25	3.68	0.24	11	6.37	0.04
5.5	3.72	0.16	11.25	6.38	0.04



(a)

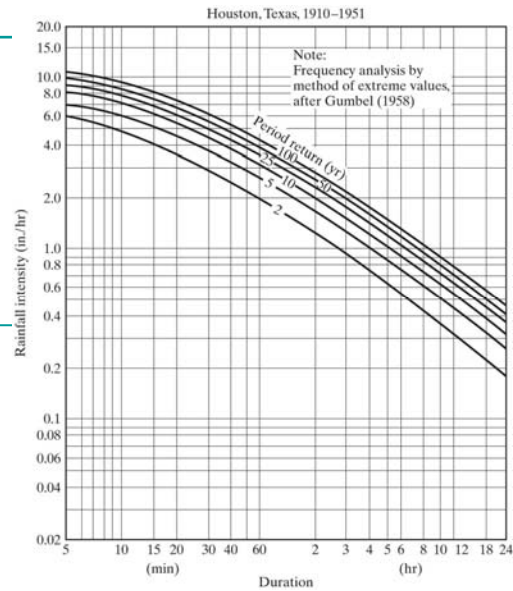
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(b)

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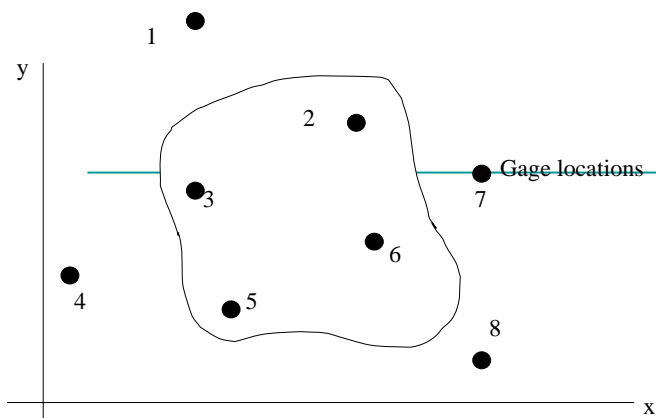
Intensity-Duration-Frequency (IDF) curves



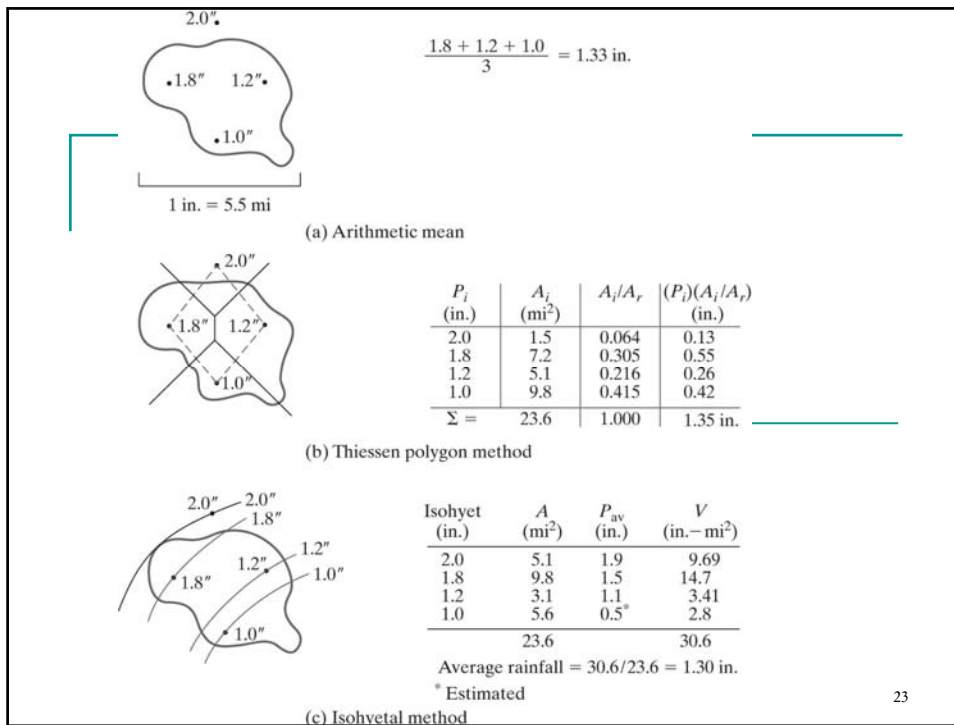
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Rainfall averaging

$$P = \frac{1}{A} \iint_A p(x, y) dx dy$$



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Tutorial:

Problem 1.5

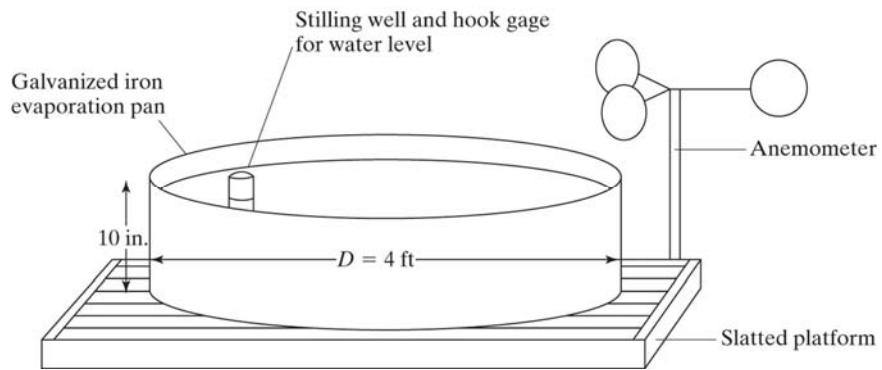
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Hydrologic measurements

Barometer

Psychrometer

Evaporation pan (Standard Class A pan)

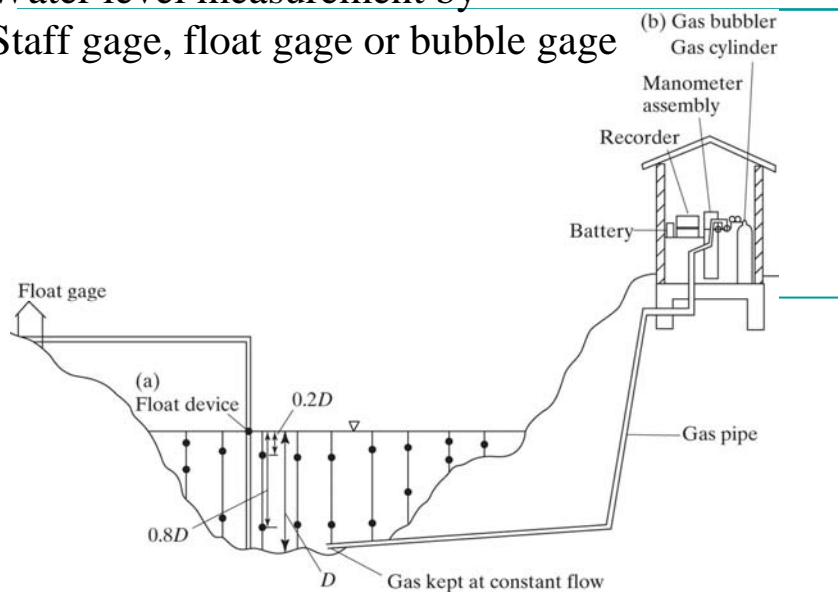


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Streamflow measurement

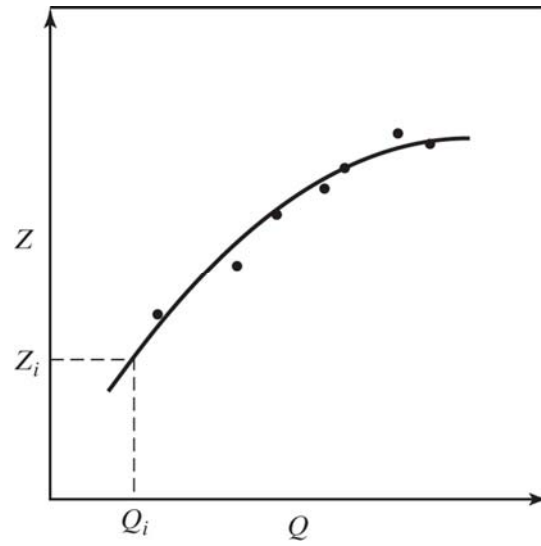
Water level measurement by

Staff gage, float gage or bubble gage



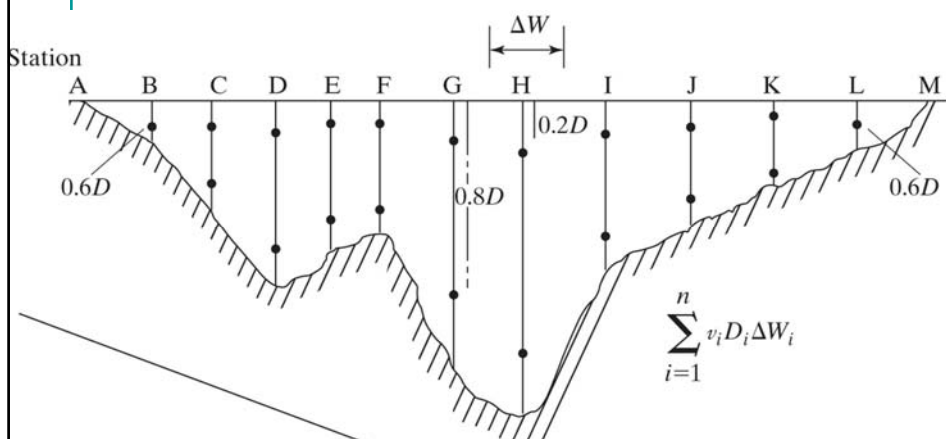
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Rating curve



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Example 1-5

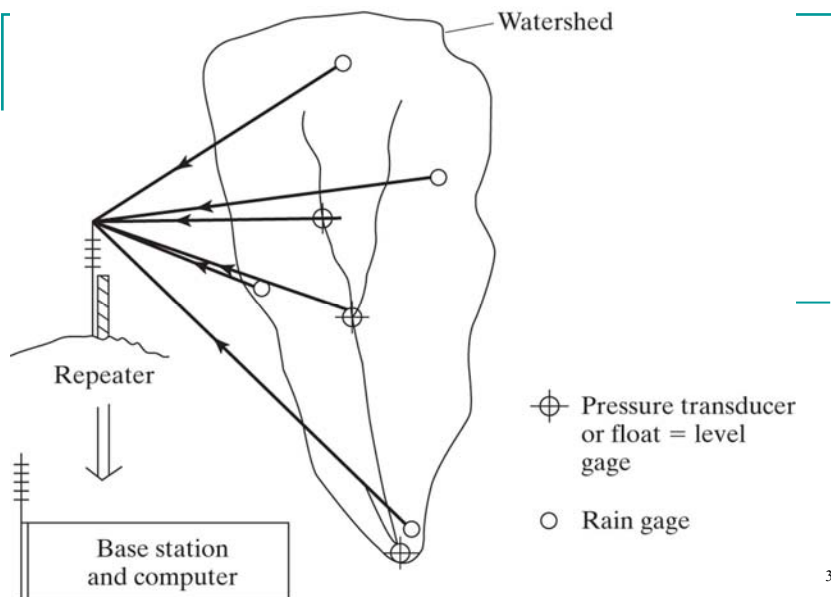


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Table E1-5.

Measurement Station	Distance Across Stream (ft)	Width ΔW (ft)	Depth D (ft)	Mean Velocity v (ft/sec)	Area $\Delta W \cdot D$ (ft ²)	Discharge (cfs)
A	0	7	0	0	0	0
B	14	13	1.1	0.43	14.3	6.15
C	26	12	2.6	0.61	31.2	19.03
D	38	11.5	3.5	1.54	40.25	61.99
E	49	11.5	3.2	1.21	36.8	44.53
F	61	14.5	3.1	1.13	44.95	50.79
G	78	17	3.9	1.52	66.3	100.78
H	95	18	4.2	2.34	75.6	176.90
I	114	19	3.3	1.42	62.7	89.03
J	133	19	2.9	1.34	55.1	73.83
K	152	19	2.1	1.23	39.9	49.08
L	171	19	1.4	0.53	26.6	14.10
M	190	9.5	0	0	0	0
Sum = 190 ft					493.7 ft ²	686 cfs
Average velocity = 1.4 ft/s						
Total discharge = 686 cfs						

Flood warning system



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Tutorial:

Rework example 1-5, increasing the mean velocity and depth by 50%.

Compare the results with Example 1-5.