Introduction to Hydrology

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DEFINITION OF HYDROLOGY

- "Hydrology is the science which deals with terrestrial waters, their occurrence, circulation and distribution on our planet, their physical and chemical properties and their interaction with the physical and biological environment, including the effect on them of the activity of man" **UNESCO,1964**
- Hydrology is that branch of physical science, which deals with the origin, distribution, and properties of water of the earth. It deals with the transportation of water through the air, over the ground surface and through the earth strata. The knowledge of hydrology is of basic importance in all walks of life that involve the use and supply of water for any purpose what so ever. Therefore the knowledge of hydrology is not only useful in the field of engineering, but also in agriculture, forestry and other branches of natural sciences.

IMPORTANCE OF HYDROLOGY

- Water is the most important resource of any country, and of the entire society as a whole, since no life is possible without water. It has this unique position among other natural resources, because the country can survive in the absence of the other resources except this one.

IMPORTANCE OF HYDROLOGY

- We cannot design any reservoir without defining the yield of its catchment, because it is the base to decide the required reservoir capacity at the proposed dam site. If we depend only in guesstimates, the study of the dam can lead to incorrect results or at least the study will remain incomplete.
- Depending on wrong yield estimates, may cause fatal errors leading to the failure of the dam, or in other side, may cause over-estimating the cost.

IMPORTANCE OF HYDROLOGICAL DATA AND USES

- The first step of any hydrological study is the data collection. This either can be collected directly from the field or indirectly from already being collected from specialized Authorities. The availability of these data is essential for any hydrological study or any hydraulic design. These data can include but not limited to the following:
    - Precipitation
    - Streamflow
    - Evaporation and other related climatological data
    - Spring flow
    - Sedimentation

IMPORTANCE OF HYDROLOGICAL DATA AND USES

- The following table (1) can present the importance of the above-mentioned data and their involvement in different hydrological studies.
- In this table, it can obviously be seen that, there are a good inter-relation between all parameters. The ideal case is to find all these parameters available for the study.

Table (1): The Importance of the Hydrological Data in Different Studies

No.	Data Type	Data Processing	Importance and studies involved
	Precipitation		
	•Daily, monthly and seasonal records	▪Isohyetal maps ▪Volume of rainfall ▪Data generation ▪Data transfer	➢Water resources ➢Water budget and catchment yield ➢Climate and climate change studies ➢Drought and desertification ➢Irrigation ➢Water harvesting ➢Water strategy and planning
	•Short period or automatic records	▪Rainfall intensity, duration and frequency	**➢Design of hydraulic structures (culverts, bridges, dams, spillways channels, canals, …etc.** **➢Flood protection** **➢Soil erosion** **➢Desertification** **➢Urbanization**

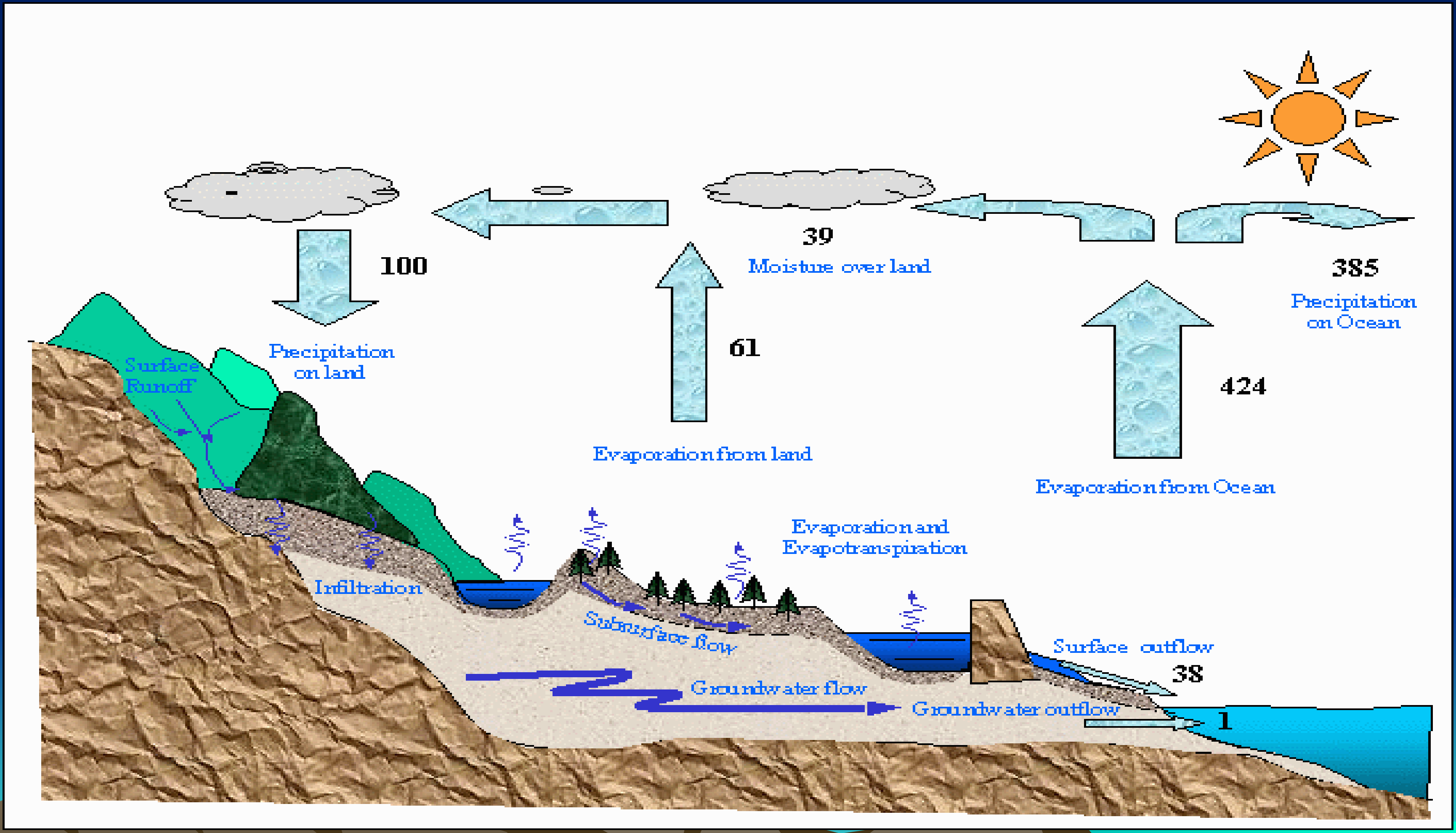
Table (1): The Importance of the Hydrological Data in Different Studies

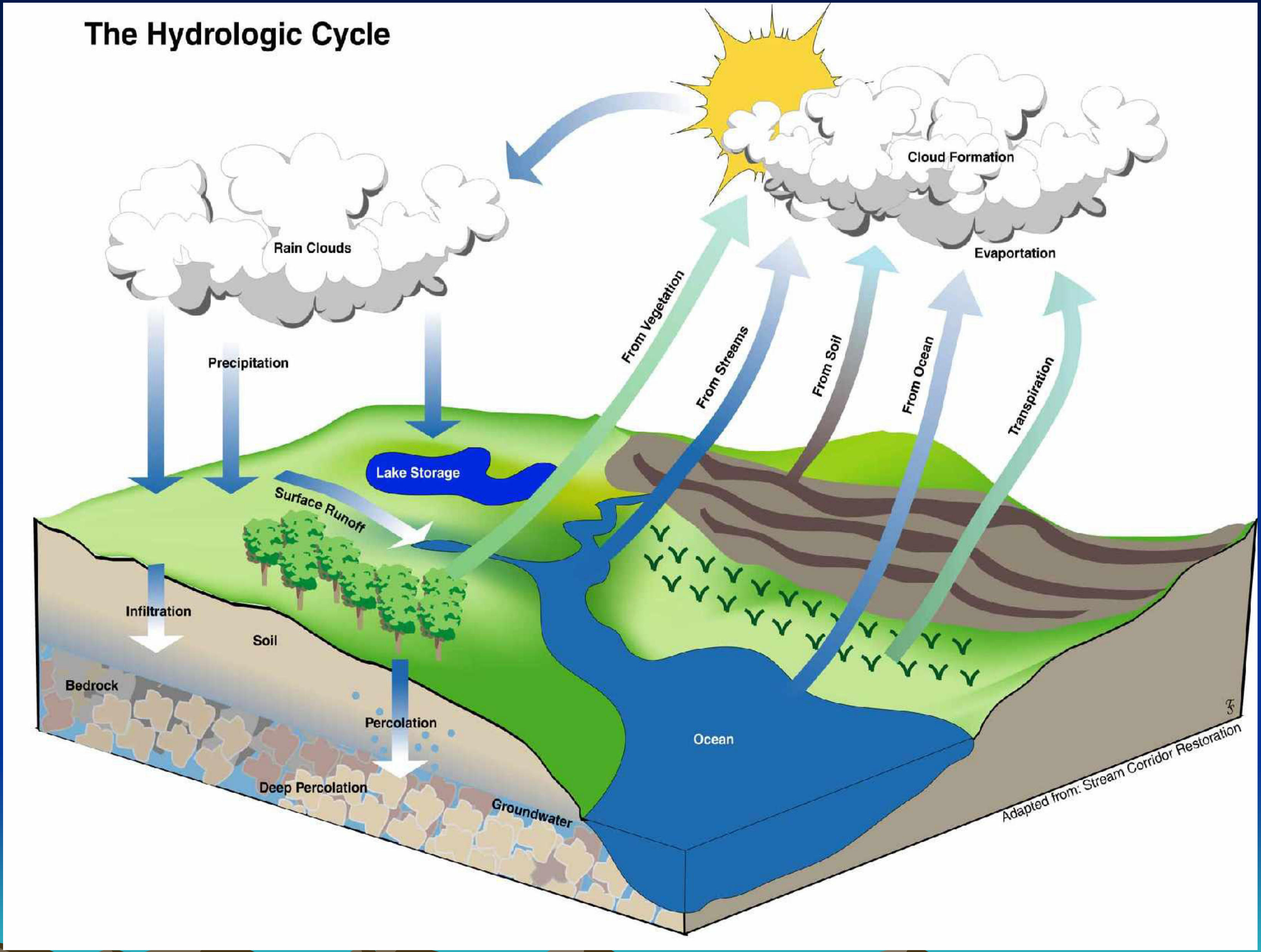
	Streamflow	▪Runoff ▪Baseflow	➢Irrigation ➢Water resources ➢Water budget and catchment yield ➢Design of hydraulic structures (such as dams) ➢Water strategy and planning ➢Feasibility studies ➢Water harvesting ➢Desertification ➢Urbanization
		▪Peak flow (floods)	➢**Design of hydraulic structures (culverts, bridges, dams, spillways channels, canals, …etc.** ➢**Flood protection** ➢**Soil erosion**
	Evaporation and other related climatological data	▪Evaporation ▪Climatological data	➢Water resources ➢Water budget and catchment yield ➢Reservoir budgeting in dams ➢Irrigation and crop requirements ➢Climate and climate change studies ➢Desertification
	Spring flow	▪Spring discharge	➢Water resources ➢Irrigation ➢Water supply ➢Water strategy and planning ➢Ground water modeling
	Sediments	▪Suspended load ▪Bed load	➢Soil erosion ➢Life of dams

Hydrological Cycle

The hydrological cycle is the circulation of water evaporated from the sea and land surfaces, its transport through the atmosphere to the land and its return to the sea via surface, subsurface and atmospheric routes.

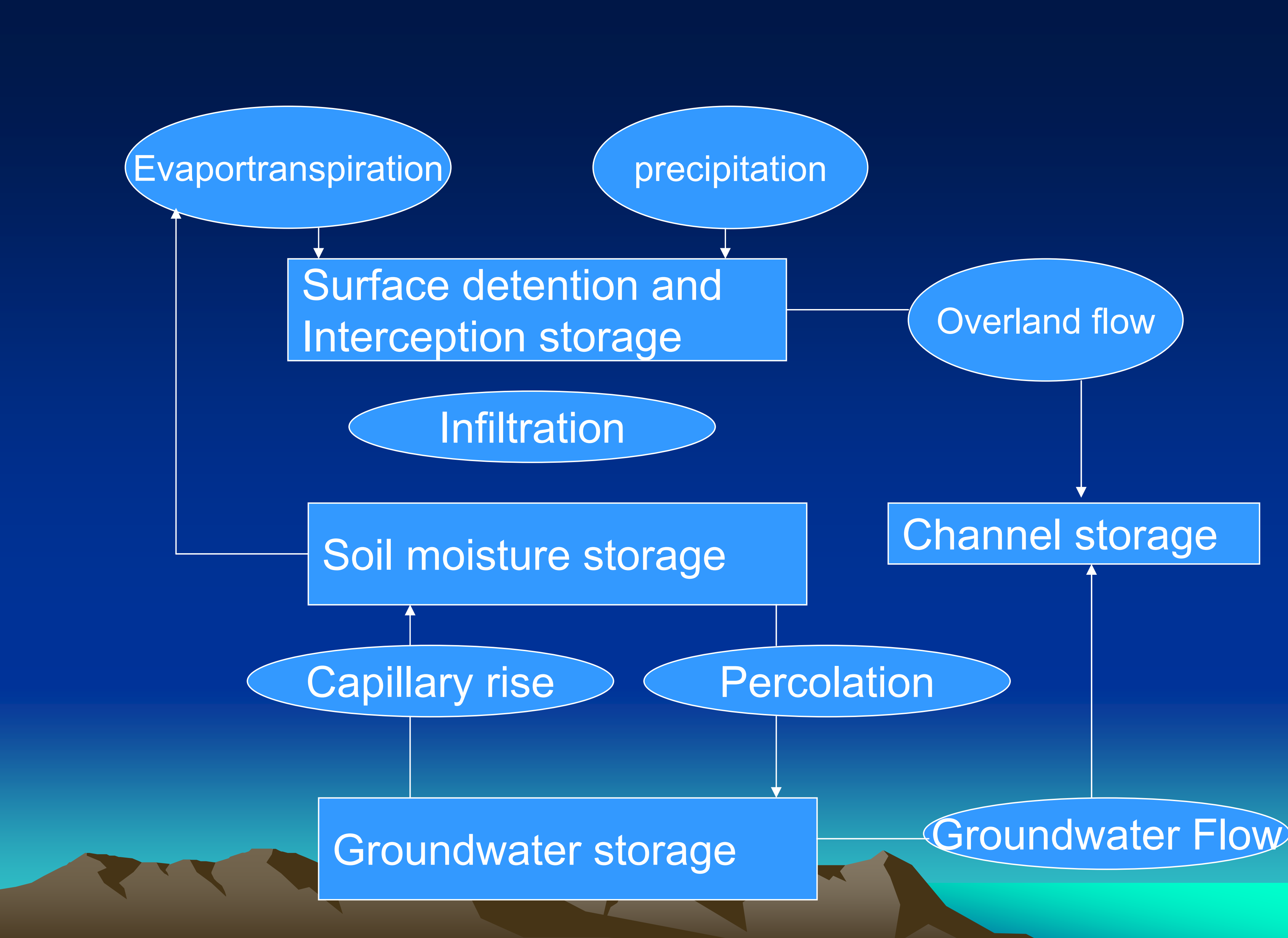
Hydrologic Cycle




The Hydrologic Cycle
Rain Clouds
Cloud Formation
Evaportation
Precipitation
From Vegetation
From Streams
From Soil
From Ocean
Transpiration
Lake Storage
Surface Runoff
Infiltration
Soil
Bedrock
Percolation
Deep Percolation
Groundwater
Ocean
Adapted from: Stream Corridor Restoration

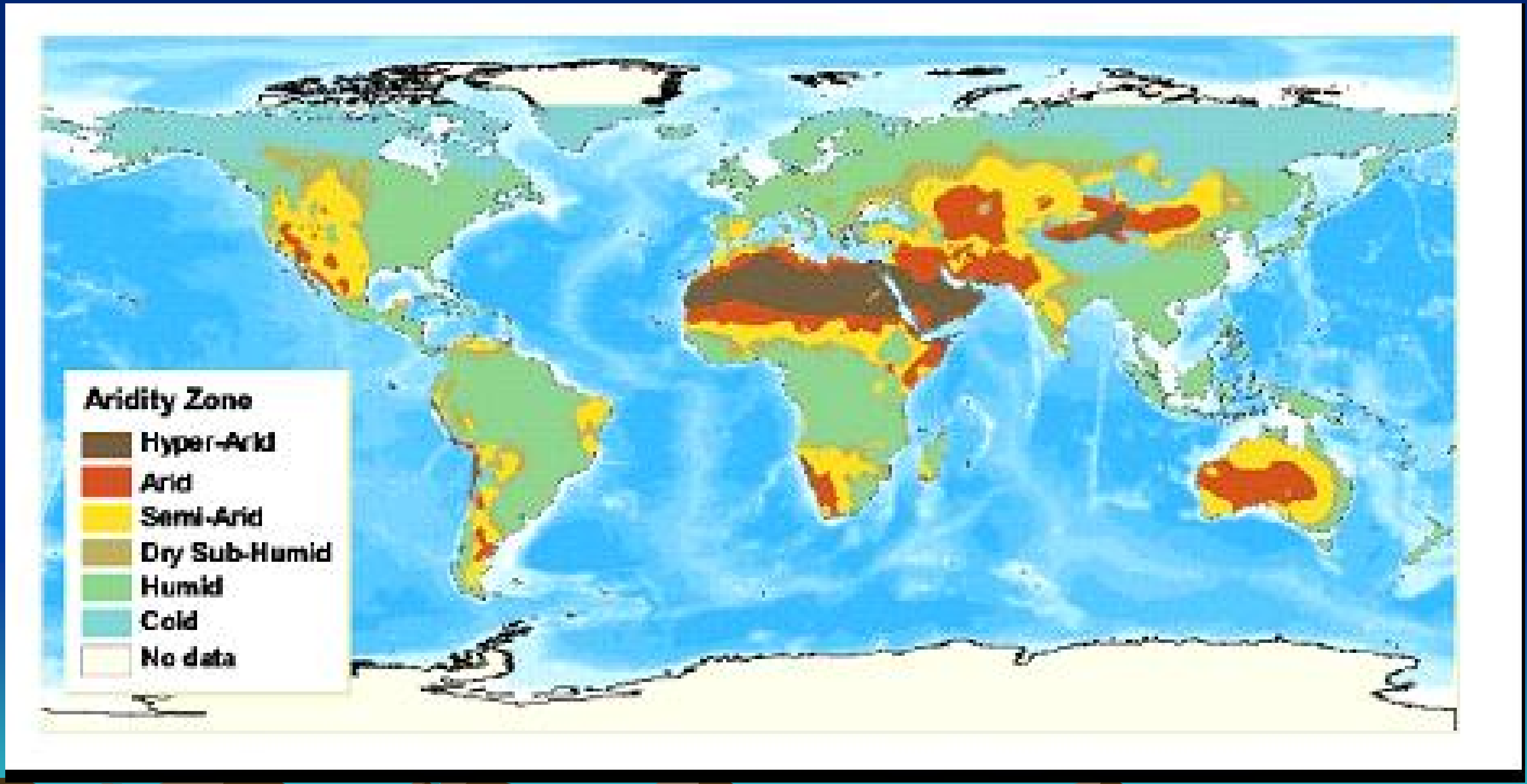
Hydrological Cycle

- A schematization of the subsystems and flow components of the terrestrial part of the Hydrologic cycle is given in Fig.



Schematization of storage and flow components

Aridity Zones of the World (WRI, 2002)



Water Balance

I-O=ds/dt

I= Input (L^3/T)

O= output (L^3/T)

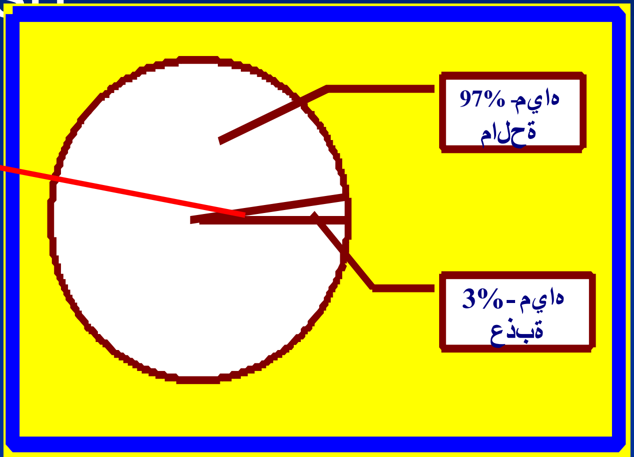
ds/dt= rate of change in storage (L^3/T)

Water Balance

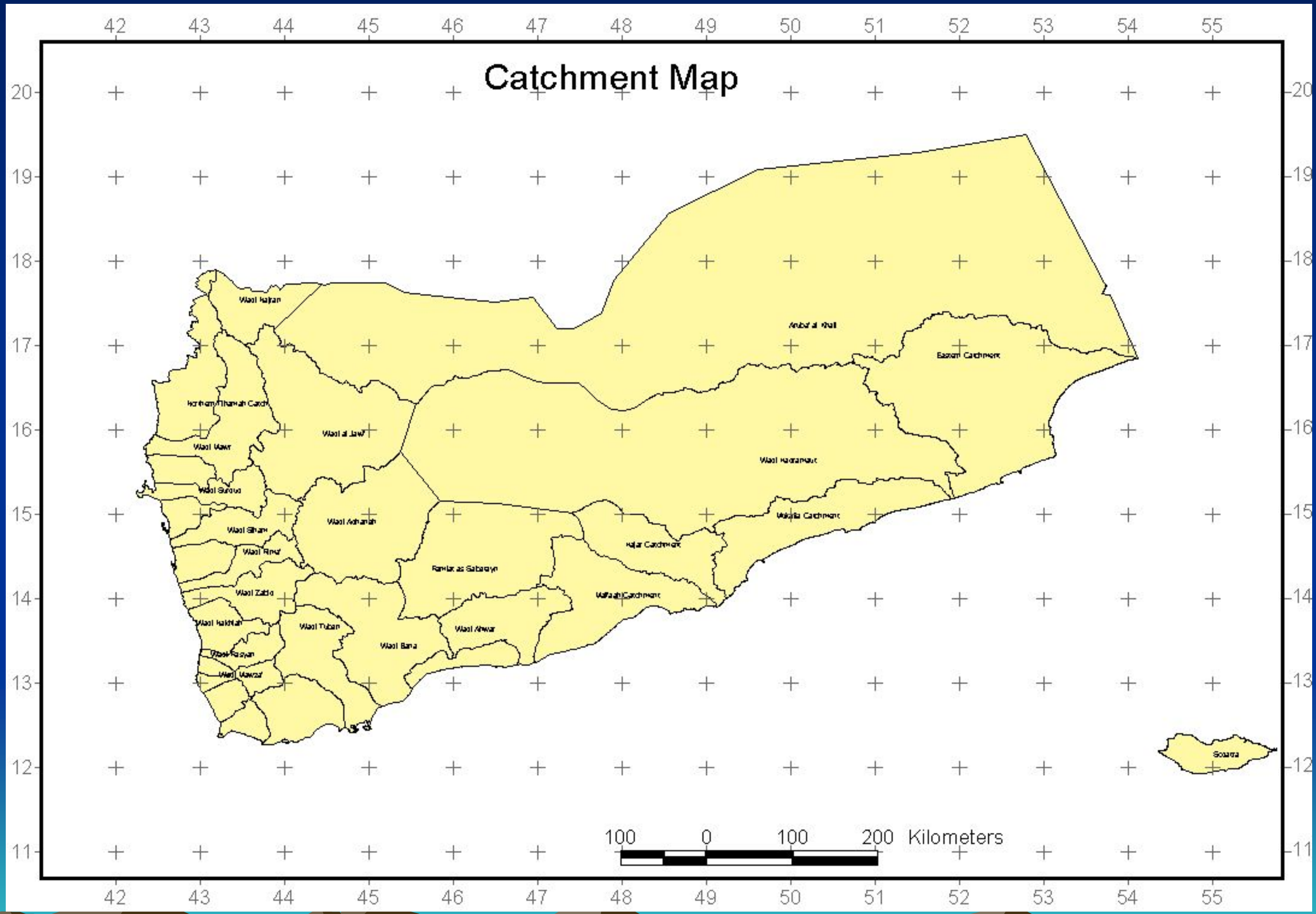
- Water Balance can be:
- Water Balance of the earth;
- Water Balance of a drainage basin;
- Water Balance of the Water diversion cycle
- Water Balance of a local area like a city, a forest

Water balance

- Water Balance on the earth (see table 1.2,1.3,1.4,1.5) 97% salt 3% fresh
- 77.63% Ice
- 21.8 Groundwater
- 0.335 in Lakes
- 0.003 in water courses
- 0.003 in plants and living organisms
- 0.178 in soils and subsurface water
- 0.035 in atmosphere



Water balance in a drainage basin



Water Balance

- Water balance of a drainage basin
- (P-E) *A-Q= ds/dt

  ds= change of storage over the time step dt

  A= surface area of the catchment

  P= Precipitation (input)

  Q = Discharge (output)

  E = Evaporation

Water Balance

- Conversion of m^3/s into mm/d for a catchment area of 200 km^2.
- Conversion of second to days $1 m^3/s$ = 86400 m3/d
- Conversion of m^3 to mm= $1m^3/200\ km^2$= $10^3/(200*10^6)$ mm
- Resulting in: 86400 (m^3/d) /$2.10^8\ m^2$ *10^3 mm/m = 0.43 mm/d

Water Balance Example

- A dam’s lake had a water surface elevation 103.200 m above datum at the beginning of a certain month. In that month the lake received an average inflow of 6.0 m3/s from surface runoff sources. In the same period the outflow from the lake had an average value of 6.5 m3/s. further, in that month, the lake received a rainfall of 145 mm and the evaporation from the lake surface was estimated as 6.10 cm. write the water budget equation from the lake and calculate the water surface elevation of the lake at the end of the month. The average lake surface area can be taken as 5000 ha. Assume that there is no contribution to or from the groundwater storage.

RECIPITATION

- Falling the moisture from the clouds to the earth is termed as precipitation. This can include drizzle, rain, glaze, sleet, snow and hail.
- The precipitation can form as many types depending on the size of droplets and state of the water usually liquid or solid. The forms of the precipitation can be as drizzle, rain, glaze, rime, snow, hail and ice pellets. The following table (2) is giving these forms with some of their physical characteristics.
- The practical hydrologist-engineer is mostly concerned with rainfall and sometimes, in cold countries, with snow. Rainfall and hail are of interest at the place and time of occurrence, which are much more important form of the precipitation occurring in warmer countries

Convectional precipitation

- This type of precipitation is most common in tropics and sub-tropics. It rarely occurs in other areas. The upward movement of the air that is warmer than its surroundings causes it. Generally, this occurs on hot days when the ground surface gets heated unequally, causing the warmer air to lift up, as the colder air comes to take its place. The vertical air currents develop tremendous velocities and are hazardous to aircrafts. Precipitation occurs in the form of heavy showers of high intensities and short durations.

Orographic precipitation

- This type of precipitation results from mechanical lifting of air masses over mountain barriers. Due to the topographic barriers of mountains, the moisture-laden air is forced to rise to higher levels, where it expands and cools, resulting in precipitation. The precipitation occurring on windward slopes is heavier than those on leeward slopes. Where conditions are favorable for the production of orographic rainfall, the heaviest precipitation takes place in Ibb area in Yemen.

Cyclonic precipitation

- a cyclone is a circular or nearly circular area of low pressure in which wind blows anti-clock wise in the Northern Hemisphere. A typical cyclone is a large whirling mass ranging from 800 to 1600 km or more in diameter and may have a wind velocity of about 50 km/hour. At the center of this mass the barometric pressure. Is low.

Measurement of Precipitation

- All forms of precipitation are measured on the basis of the vertical depth of water that would accumulate on a level surface, if the precipitation remained where it fell.
- Probably rainfall is the first meteorological element, which was measured by man. There is evidence that rainfall measurements were taken and records maintained in the fourth century (probably in India).

Type of Rain Gauges

Two main type of gauges are being used in measuring the precipitation. These are as follows:

- Recording type
- Non-recording type.
- The recording type gauges can be grouped as weighing bucket, tipping bucket, or siphon type gauge. These types are recording the precipitation either on chart paper or digital. They record the data continuously and in most cases they are more precise than those of non-recording ones. These records are much helpful in the computations of rainfall intensities and in the preparation of what so called intensity-duration-frequency (IDF) curves.

Computation of Average Rainfall over a Basin:

- To compute the average rainfall over a catchment area or basin, rainfall is measured at a number of gauges by suitable type of measuring devices. A rough idea of the number of the needed rain gauges to be installed in a practical area is depending on experience of the hydrologist although this was determined by the regulation of the World Meteorological Organization (WMO).
- In areas where more than one rain gauge is established, following methods may be employed to compute the average rainfall:
- Arithmetic average method
- Weighing mean method or Thiessen polygon method
- Isohyetal method.

Arithmetic Average Method

- This is the simplest method of computing the average rainfall over a basin. As the name suggests, the result is obtained by the division of the sum of rain depths recorded at different rain gauge stations of the basin by the number of the stations.
- If the rain gauges are uniformly distributed over the area and the rainfall varies in a very regular manner, the results obtained by this method will be quite satisfactory and will not differ much than those obtained by other methods. This method can be used for the storm rainfall, monthly or annual rainfall average computations.

Example: During a storm the rainfall observations in a selected basin were found as follows:

Table : Computation of average precipitation over a basin using Arithmetic mean method

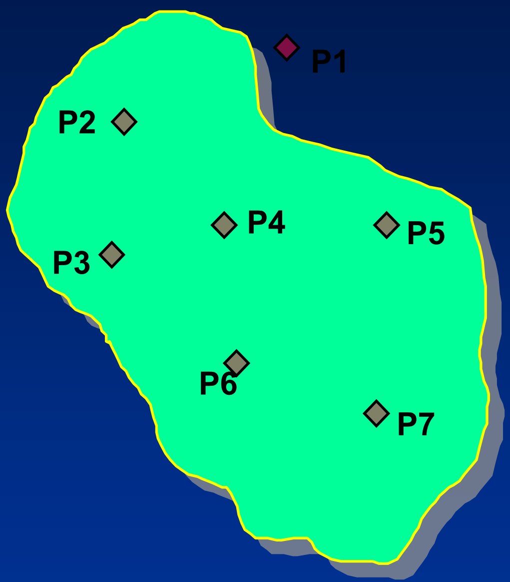
Station No.	Precipitation in [mm]	Average precipitation [mm]
1	15	**P = 120.6/6 = 20.1 mm**
2	19	
3	20	
4	16.6	
5	22	
6	28	
Total [mm]	**120.6**	

Thiessen Polygon Method

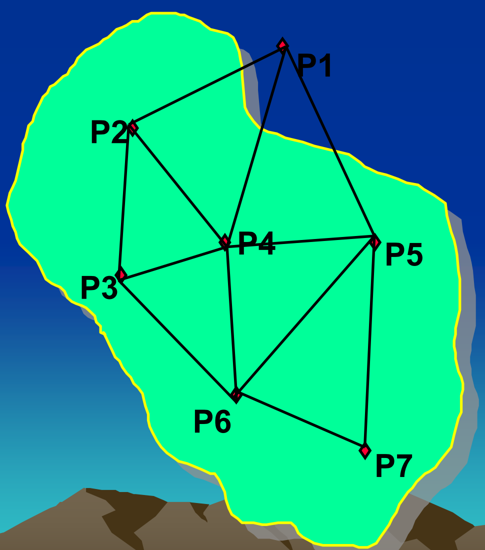
- This is the weighted mean method. The rainfall is never uniform over the entire area of the basin or catchment, but varies in intensity and duration from place to place. Thus the rainfall recorded by each rain gauge station should be weighted according to the area, it represents. This method is more suitable under the following conditions:
- For areas of moderate size.
- When rainfall stations are few compared to the size of the basin.
- In moderate rugged areas.

For the construction of the polygon, the following procedure is to be followed:

Figure (1):Basin and location of stations



Step 1: Draw the area concerned to a suitable scale, showing its ***boundary***, ***locations of the raingauges*** in the area and outside but close to the boundary



Step 2: Join location of the raingauges to form a network of triangles

Figure (2): Drawing of the triangles

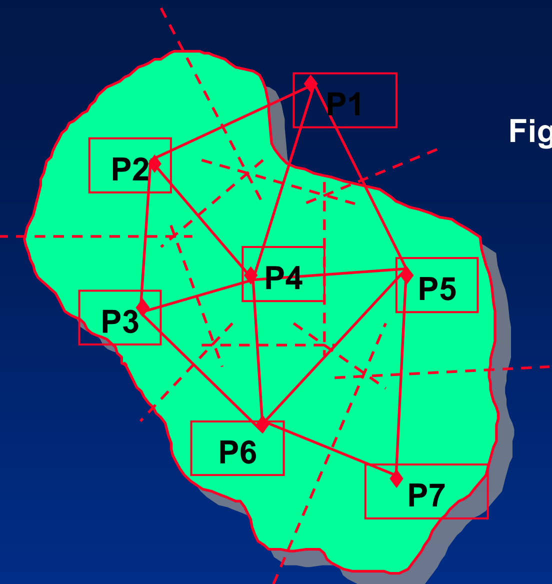
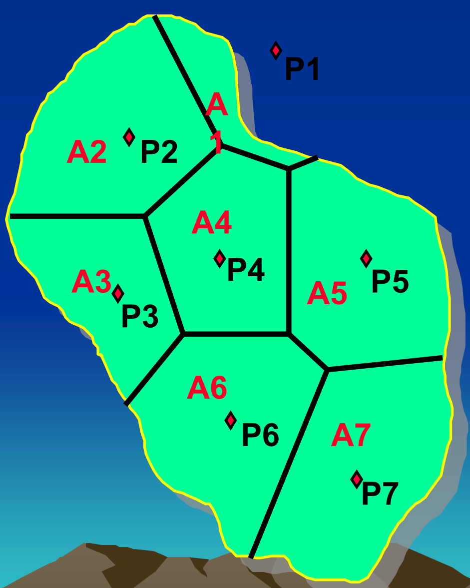


Figure (3): Drawing the perpendicular bi-sectors of the triangles

Step 3: Draw perpendicular bisectors to the triangle sides. These bisectors form polygons around the stations

Figure (4): Drawing of the polgons



Step 4: Delineate the formed polygons and measure their areas using a planimeter or by converting them into smaller regular geometric shapes (i.e. triangles, squares, rectangles, etc.)

Step 5: Compute the average rainfall using the following formula

$$P_{av} = \frac{xA_1 + P_2 xA_2 + ... + P_n xA_n}{A_1 + A_2 + ... + A_n}$$

Table (4): Bi-sectional areas (A) of Theissen polygon, and the measured precipitation (P) for stations

Station No.	Bi-sectional areas (Ai) [km^2]	Measured precipitation (Pi) [mm]	(Col. 2 * Col. 3) (Ai *Pi)
P1	25	10	250
P2	125	15	1875
P3	80	20	1600
P4	90	17	1530
P5	120	25	3000
P6	115	40	4600
P7	130	12	1560
Total	**685**		**14415**

Then the average precipitation over the catchment will be computed by the total of the column 4 to the total area in column 2. The result will be found as: 21.04 mm.