Hydrologic System

A hydrologic system is defined as a structure or volume in space, surrounded by a boundary, that accepts water and other inputs, operates on them internally, and produces them as output.

The boundary is a continuous surface defined in three dimensions enclosing the volume or structure. A working medium enters the system as input, interacts with the structure and other media, and leaves it as output.

Physical, chemical, and biological processes operate on the working media involved in hydrologic analysis are water, air, and heat energy.

The global hydrologic cycle can be represented as a system containing three subsystems: the atmospheric water system, the surface water system, and the subsurface water system as shown in the Fig. (2).

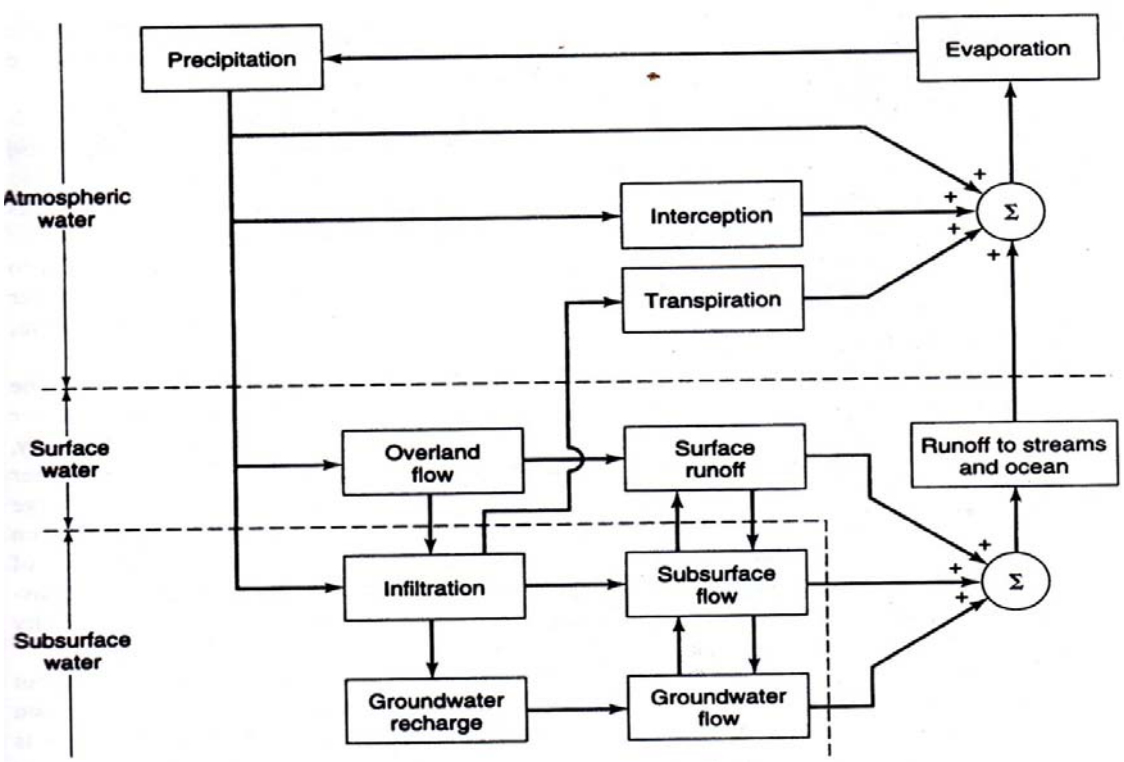


Figure (2) Block-diagram representation of the global hydrologic system.

Hydrologic budget

A Hydrologic budget ,water budget, or water balance is a measurement of continuity of the flow of water ,which holds true for any time interval and applies to any size area ranging from local-scale areas to regional-scale areas ***or*** from any drainage area to the earth as a whole .The hydrologists usually must consider an open system, for which the quantification of the hydrologic cycle for that system becomes a mass balance equation in which the change of storage of water (ds/dt) with respect to time within that system is equal to the inputs *(**I**)* to the system minus the output ***(O)*** from the system

$$ds/dt = I - O \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..(1)$$

Considering the open system in Fig (3), the water balance equation can be expressed for the surface water system in units of volume per unit time separately ,or for a given time period and area, in depth.

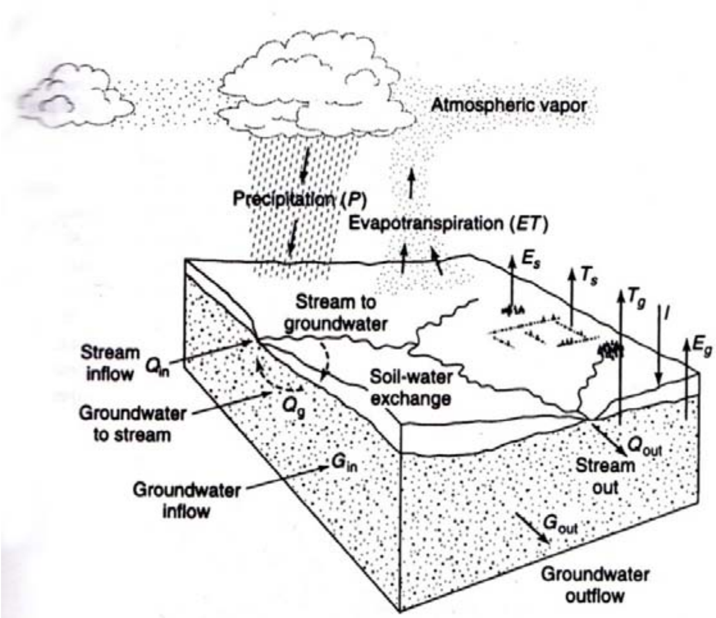


Figure (3) Components of hydrologic cycle in an open system: the major inflows and outflows of water from a parcel of land.

Surface Water System Hydrologic Budget

$$P + Q_{in} - Q_{out} + Q_g - E_s - T_s - \text{Infilt.} = \Delta S_s \qquad \text{.................(2)}$$

Where: P is precipitation

Q_{in} is surface water flow into the system

Q_{out} is surface water flow from the system

Q_g is the ground water flow - GW to stream

E_s is the surface evaporation

T_s is the transpiration

Infilt. is the infiltration, and ΔS_s is the change in water storage of the surface system.

Groundwater System Hydrologic Budget

$$\text{Infilt.} + G_{in} - G_{out} - Q_g - E_g - T_g = \Delta S_g \qquad \text{..................(3)}$$

Where: Infilt. is the infiltration

G_{in} is groundwater flow into the system

G_{out} is groundwater flow from the system

Q_g is the ground water flow

E_g is the evaporation, and the transpiration T_g, can be significant if the water table is near the ground surface

ΔS_g is the change in groundwater storage

System Hydrologic Budget

This system is developed by adding the above two budgets together:

$$P - (Q_{out} - Q_{in}) - (Es + E_g) - (T_s + T_g) - (G_{out} - G_{in}) = \Delta (S_s + S_g) \qquad \text{......(4)}$$

Using the mass exchanges, the above system hydrologic budget can be expressed as :

$$P - Q - G - E - T = \Delta S \qquad \text{.............(5)}$$

Equation (5) can be written as:

$P – Q – G – ET = \Delta S$ …………..(6)

Where : P is precipitation

Q is surface flow-discharge-

G is ground flow

ET is evapotranspiration

Hydrologic budgets can be used for numerous studies related to ground water including:

1) Estimating groundwater exchange with lakes.
2) Estimating surface water and groundwater interaction.
3) Computing recharge from a well- hydrograph data.

<u>Example</u>(1)

The water budget for a lake included : precipitation (p) of 1.1 m/yr , Evaporation (E)1.35 m/yr, surface water inflow (Q_{in}) 0.0254 m/yr, surface out flow (Q_{out})4.39 m/yr, and change in volume (ΔS) of -0.051 m/yr .Determine the net groundwater flow (the groundwater inflow minus the ground water outflow).

<u>Solution</u>: *Assuming Tg = 0 the water budget equ. (5) to define the net ground water flow for the lake is:*

$$G = \Delta S + E - P - Q_{in} + Q_{out}$$
$$= -0.051+1.35-1.1-0.025 +4.39$$
$$= 4.563 \text{ m/yr} \quad [180 \text{ inch/ yr}]$$

Precipitation

Precipitation included rain and melted snow or sleet, and snowfall, and is in (mm).

After water vapor condenses forming ice crystals and water droplets, it can take on a variety of forms as it falls to the earth as precipitate.

Forms of precipitation

1- **Drizzle**: a light steady rain in fine drops (0.5 mm) and intensity (<) less than 1mm/hr.

2- **Rain**: the condensed water vapor of the atmosphere falling in drops (> 0.5 mm, maximum size -6mm) from the clouds.

3- **Glaze**: freezing of drizzle or rain when they come in contact with cold objectives.

4- **Sleet**: frozen rain drops while falling through air at subfreezing temperature.

5- **Snow**: ice crystals resulting from sublimation (i.e. water vapor condenses to ice).

6- **Snowflakes:** ice crystals fused together.

7- **Hail**: small loupes of ice(>5mm) formed by alternate freezing and melting, when they are carried up and down in highly turbulent air currents.

8- **Dew**: moisture condensed from the atmosphere in small drops upon cool surface.

9- **Frost**: a feathery deposit of ice formed on the ground or on the surface of exposed objects by dew or water vapor that has frozen.

10- **Fog**: a thin cloud of varying size formed at the surface of the earth by condensation of atmosphere vapor (interfering with visibility)

11- **Mist**: a very thin fog.

Types of precipitation

1- *Thermal convection (convectional precipitation):* it is in the form of local whirling thunder storms and is typical of the tropics.
2- *Conflict between two air masses (frontal precipitation):* when two air masses due to contrasting temperatures and densities clash with each other, condensation and precipitation occur at the surface of contact.
3- *Orographic lifting(Orographic precipitation):*The mechanical lifting of moist air over mountain barriers, causes heavy precipitation on the windward side
4- *Cyclonic (cyclonic precipitation):* It is due to lifting of moist air converging in to low pressure belt…. i.e., due to low pressure differences created by the unequal heating of the earth's surface.

Measurement of precipitation

A variety of instrument and techniques have been developed for gathering information on various phases of precipitation

Rainfall may be measured by rain- gauges which either recording or non-recording type.

1) The non-Recording rain- gauge is Symon's rain - gauge: It consists of

a) A funnel with a circular rim of 12.5 cm in diameter

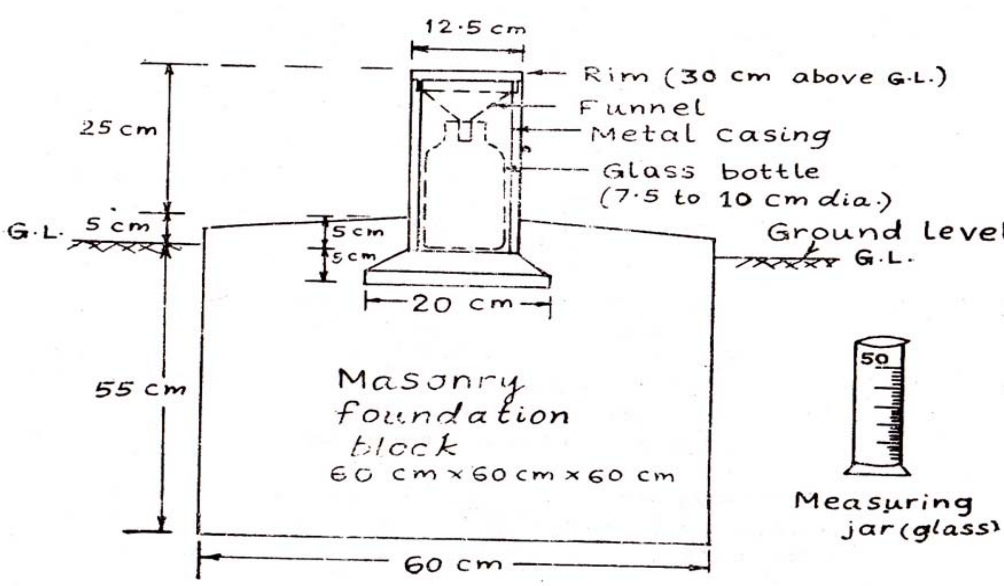
b) Glass bottle as a receiver (7.5-10 cm) in diameter

c) Measuring Glass (Jar) - Cylinder

Generally any open receptacle with vertical sides may serve as rain gauge, but in order to permit more accurate observations the certain above refinements are necessary.

The rainfall is measured every day at 8:30 hours, during heavy rains it must by measured 3 or 4 times daily.

- It gives only the depth of rainfall.
- It doesn't give intensity and duration of rainfall during different time interval of the day.



Symon's Rain Gauge