ONR-002: Basics of Hydrology
Guess Paper-1

Q1. Outline the concept of hydrologic cycle.

Ans.

The unending process of circulation and redistribution of water by the atmosphere and the earth is called the hydrologic cycle or water cycle. Hydrologic cycle is defined as the circulation of water from the sea, through the atmosphere to the land and then, often with many delays, back to the sea or ocean through various stages and processes. Fig.1.1 illustrates the complete hydrologic cycle which continually keep striking a balance between the waters of the earth and the moisture in the atmosphere. Evaporation and precipitation are the driving forces in the hydrologic cycle with solar radiation as the source of energy.

There are six major components of this cycle: evapotranspiration, condensation, precipitation, infiltration, percolation and runoff. It takes place by the movement of water through the hydrosphere. Water evaporates from the oceans and the land surface; it is carried over the earth in atmospheric circulation as water vapours, precipitates again as rain or snow. Rain or snow is intercepted by trees and vegetation, provides runoff on the land surface, infiltrates into soils, recharges groundwater, discharges into streams, and ultimately, flows out into the oceans from which it eventually evaporates once again (Fig.1.1). This immense water engine fuelled by solar energy, driven by gravity, proceeds endlessly - irrespective of human activity.

The earth's total available supply of moisture and water, except for some deep groundwater supplies, is constantly in circulation. It is a gigantic system operating in and on the ground surface, oceans and in the atmosphere surrounding the earth. The cycle begins with the waters of ocean, the large source of water covering about three-fourth of the earth's surface. The entire process is very simple, divided into the following parts;

1) Evaporation
   a) Evaporation from surface of oceans, lakes and swamps. 80% of the precipitation in India is considered to be contributed by evaporation from the oceans;
   b) Evaporation from the surface of the soil; and
   c) Evaporation from plants through transpiration.
2) Lifting of the moisture to the atmosphere and eventual condensation and falling back to the earth's surface as precipitation.
3) Distribution of a portion of the precipitated water by surface to the ocean and inland bodies.
4) Part of the precipitation after interception on the foliage and wetting the ground surface runs off the surface to streams and rivers.
5) Part of the precipitation infiltrates into the ground, some of which again evaporates while the other is available for growing plants, infiltration to the deeper zones which slowly percolates into springs and streams as dry period flow.
6) Streams and rivers eventually lead back the water to the oceans, from where it originated.

The oceans are the primary source of precipitation over the earth's surface as the annual volume of evaporation from the ocean is seven times more than from the land surface. The oceans contain 96.5% of earth's water whereas land contains only 3.5% water. Out of this, about 1% water is contained in deep, saline groundwaters or in saline lakes, leaving only 2.5% of the earth's water as fresh water. 68.6% of fresh water is frozen into the polar ice caps and 30.1% contained in shallow groundwater aquifers, leaving only 1.3% of the earth's fresh water mobile in the surface and atmospheric phases of the hydrologic cycle.

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Q2. List the factors affecting rainfall.

Ans.

The following factors affect rainfall amount and distribution:

i) **Proximity to Ocean:** Air being in constant contact with water naturally has an opportunity of absorbing moisture and becoming saturated. Any slight disturbance or change of conditions, once it is saturated, causes precipitation of the moisture in the form of rain. Proximity to oceans and other large bodies of water means a greater local precipitation.

ii) **Mountain Formation:** The pattern of rainfall in India is greatly influenced by mountain formation. Elevation and alignment of hills with respect to prevailing winds, especially if they are at right angles to the directions of the moisture bearing winds, have profound influence on the distribution of rainfall. More rainfall is received on windward than on leeward slopes, the variation being greatest with steepest slopes. On West Coast of India, there is heavy rainfall along the slopes of Western Ghats on the windward side but rapidly diminishes on the eastern side of Western Ghats.

iii) **Winds:** Changes in the direction of wind currents greatly influence rainfall. Word 'Monsoon' used in India means winds changing directions.

iv) **Tract of Cyclones:** Cyclones are accompanied by heavy winds, often with high rainfall. Much of winter precipitation is cyclonic. The precipitation is induced by feeble cyclones in winter. In India, heavy rainfall occurs in coastal regions and coastal parts of the country in association with the movements of depressions and cyclonic storms.

Q3. List the Factors Influencing Percolation.

Ans.

Soil texture, water table depth hydraulic conductivity and hydraulic gradient are the main factors influencing percolation phenomenon.

Grain size distribution and porosity: The soil texture and porosity are the most important factors in percolation. Sandy soils with larger soil particles and higher porosity (more large size pore spaces) result in more percolation than the clayey soil.

Hydraulic conductivity: It is the property of soil which denotes the ease with which the water can flow through the porous medium (Soil). Sandy soils have higher hydraulic conductivity than the clay soils. The sandy soils strata are thus known as aquifers in groundwater due to high hydraulic conductivity. Higher the hydraulic conductivity more will be the percolation rate.

Water table depth: The depth of water table from the soil surface decides hydraulic gradient which when combined with hydraulic conductivity results in water movement in the soil profile. Shallower the water table depth, more will be the hydraulic gradient resulting in more percolation.

Hydraulic gradient: The hydraulic gradient is the ratio of hydraulic head and the length of path of flow. More the hydraulic gradient more is the deep percolation.

Q4. Define evaporation and name the most important factors that influence it.

Ans.

Evaporation is the primary process of water transfer in the hydrological cycle. It is the physical process of vaporization by which liquid is transformed to a gaseous stage from its free surface through the absorption of heat energy. The moisture reaches the atmosphere from the ocean and the land surface and finally results in the rainfall which is the basic source of water for all the living beings including plants.

Importance of Evaporation

Evaporation is an important process of the hydrologic cycle. Approximately 75% of the total annual precipitation is returned to the atmosphere by evaporation and transpiration. In hot climates, the loss of water from rivers, canals and open-water storages through evaporation is quite significant. Most of the water withdrawn for beneficial uses ultimately returns to streams and aquifers and becomes available for reuse, while the loss of water due to evaporation is entirely lost from the usable supply. Even in humid areas, evaporation loss is significant. High evaporation loss in relation to the usable yield is characteristic of river systems in the country due to the climate, character of stream flow, and the great seasonal variations and pattern of runoff. Storage reservoirs are a major source of water loss through evaporation as they are exposed to wide surfaces.

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The evaporation is influenced by following factors:

Atmospheric pressure: The evaporation decreases with increase in atmospheric pressure. Atmospheric pressure is the pressure at any point in the earth's atmosphere. Low pressure areas have less atmospheric mass above their location and *vice versa*. Similarly, as elevation increases, there is less overlying atmospheric mass, so that pressure decreases with increasing elevation.

Vapour pressure: The rate of evaporation is proportional to the difference between the saturation vapour pressure at the water temperature and the actual vapour pressure in the air. More the vapour pressure difference, more is the evaporation.

Temperature: Temperature of water surface increases the evaporation. Other factors being same, the rate of evaporation increases with an increase in the water temperature.

Wind velocity: Increase in wind velocity enhances evaporation. Wind aids in removing the evaporated water vapour from the zone of evaporation and consequently creates greater scope for evaporation. The rate of evaporation increases with the wind speed up to a critical speed beyond which any further increase in the wind speed has no influence on the evaporation rate. This critical wind speed value is a function of the size of the water surface. For large water bodies, high-speed turbulent winds are needed to cause maximum rate of evaporation. A change of 10 % in wind velocity changes evaporation by 1 to 3%.

Relative humidity: The increase in relative humidity of atmosphere decreases evaporation.

Water table depth: Shallow is the water table, more is the evaporation. In case of water table very close to the ground surface, evaporation is as high as from the open water surface.

Soluble Salts: Evaporation rate from salty water is less than the pure water due to higher vapour pressure of the pure water. For example, under identical conditions, evaporation from sea water is about 2-3% less than that from fresh water.

Depth of water bodies: Deep water bodies have more heat storage than the shallow ones. A deep lake may store radiation energy received in summer and release it in winter causing less evaporation in summer and more evaporation in winter compared to a shallow lake exposed to a similar situation.

Soil surface: Evaporation from wet surface is much higher that of the dry surface. Rate of evaporation is directly proportional to water surface area, larger the area more is the evaporation and *vice versa*.

Q5. Explain types of rainfall.

Ans.

Moisture is always present in the atmosphere and adiabatic cooling of the moist air through lifting to higher altitudes is the main reason of condensation and consequently formation of clouds and rainfall.

There are mainly four types of rainfall namely convective, orographic cyclonic and thunderstorm depending on the factors reponsible for lifting the air mass. Let us learn about them one by one.

3.2.1 Convective Rainfall

During summer air in contact with earth's surface gets heated, expands rises due to less density. Air from cooler surroundings flows to replace it and in turn gets heated and rises and sets up a convective cell. The warm air continues to rise, undergoes cooling resulting in rainfall. This type of rainfall has the following characteristics.

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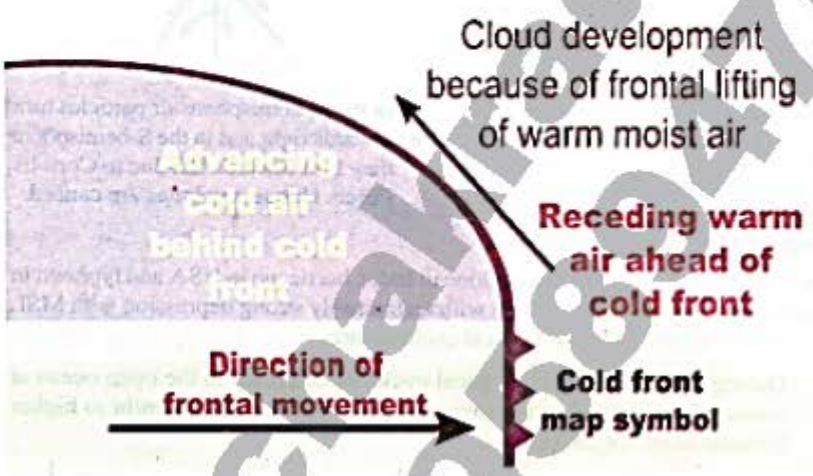
- Depending upon moisture content, cooling and other factors, the rainfall intensity may vary from light to thunderstorms;
- Covers limited areal extent;
- Found close to equator; and
- Rain drops freeze to form hail due to upward wind currents more than 150 km/hr.

3.2.2 Orographic Rainfall

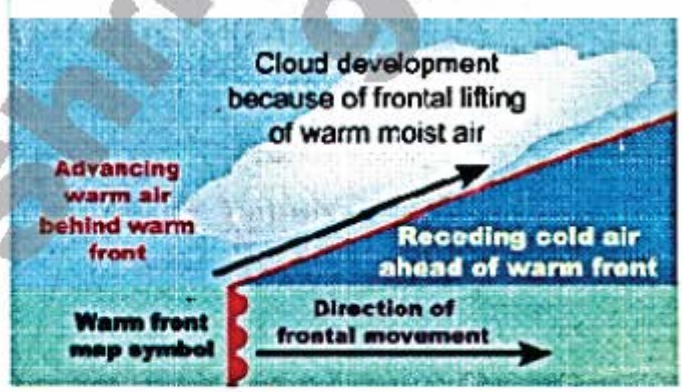
The moist air masses may be lifted to higher altitudes due to the presence of mountain-range barriers. Dynamic cooling occurs resulting in orographic rainfall on the side of blowing wind (Fig. 3.1). Rainfall is heavier on the windward and lighter on the leeward side. In India, orographic features are responsible for heavy rainfall in Himalayan region and west coast. Orographic rainfall results in medium to high intensity rainfall for longer duration.

3.2.3 Cyclonic Rainfall

A cyclone is a large low-pressure region with circular wind motion. Cyclonic rain is caused by depressions and originates where warm tropical air meets cold polar air with warm air overriding the cold air. The interface between two distinct air masses is called a Front and it is accompanied by abrupt changes in temperature, pressure and humidity. Under certain favourable conditions when a warm air mass and cold air mass meet, the warmer air mass is lifted over the colder one with the formation of a front as shown in Fig.3.2.



(A) Cold Front



(B) Warm Front

Fig.3.2: Schematic diagram showing (A) Cold and (B) Warm Front

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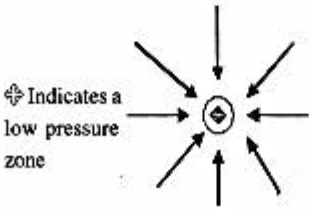
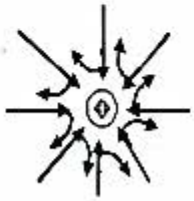
The ascending warmer air cools adiabatically with the consequent formation of clouds and precipitation. Two types of fronts are generally recognized namely warm front and cold front. Warm front is formed in warm air moving gradually upward over a wedge of cold air, where warm air replaces colder air. The resulting precipitation is light to moderate with larger bases than cold fronts a nearly continuous until after passage of warm front and may usually extend up to 500 km ahead of the surface front. The cold front is formed in the warm air which is forced upward by an advancing wedge of cold air and generally of showery nature occurring near the surface front. Two types of cyclones are recognized: tropical cyclones and extra tropical cyclones.



Arrows showing rushing of air particles towards the low pressure zone



In the N-hemisphere air particles turn towards right and in the S-hemisphere they turn towards left due to Coriolis Force. Hence, cyclones are caused.

Tropical Cyclone

A tropical cyclone, also called cyclone in India, hurricane in USA and typhoon in South-East Asia, is a wind system with an intensely strong depression with MSL pressures. Characteristics of tropical cyclones are:

- During summer months, tropical cyclones originate in the open ocean at around 5-10° latitude and move at speeds of about 10-30 km/hr to higher latitudes in an irregular path.
- They derive their energy from the latent heat of condensation of ocean water vapour and increase in size as they move on oceans.
- While they move on land, the source of energy is cut off and the cyclone dissipates its energy very fast. Hence, the intensity of the storm decreases rapidly.
- Tropical cyclones cause heavy damage to life and property on their land path and intense rainfall and heavy floods in streams are its usual consequences.
- Tropical cyclones give moderate to excessive precipitation over very large areas, of the order of 10^3 km² for several days.

Extra Tropical Cyclone

Extra Tropical Cyclone, sometimes called mid-latitude cyclones or wave cyclones. They occur in the middle latitudes of the Earth having following characteristics:

- These are cyclones formed in locations outside the tropical zone.
- Associated with a frontal system.
- They possess a strong counter-clockwise wind circulation in the northern hemisphere.
- The magnitude of precipitation and wind velocities are relatively lower than those of a tropical cyclone.
- The duration of precipitation is usually longer and the aerial extent also is longer.

3.2.4 Thunderstorms

An air mass moving from ocean to land results in increase fraction over land. While moving towards land, these air masses rise gradually resulting in condensation and rainfall over a limited area. Sometime these storm result in highly intense rainfall.

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