<u>UNIT-3: Introduction to Hydrological aspects, Irrigation and Soil Sciences:</u>

Water resources development has had a long history, basically beginning when humans changed from being hunters and food gatherers to developing of agriculture and settlements. This change resulted in humans harnessing water for irrigation. As humans developed, they began to invent and develop technologies, and to transport and manage water for irrigation. The first successful efforts to control the flow of water were in Egypt and Mesopotamia. Since that time humans have continuously built on the knowledge of water resources engineering.

Hydrology:

Definition

Hydrology is the scientific study of the movement, distribution and management of water on Earth and other planets, including the water cycle, water resources and environmental watershed sustainability.

or

Hydrology is the science that treats the waters of the Earth, their occurrence, circulation, and distribution, their chemical and physical properties, and their reaction with the environment, including the relation to living things. The domain of hydrology embraces the full life history of water on Earth.

Precisely hydrology is the branch of science concerned with the properties of the earth's water, and especially its movement in relation to land.

Hydrologic Cycle

Water cycle, also called **hydrologic cycle**, cycle that involves the continuous circulation of water in the Earth-atmosphere system. Of the many processes involved in the water cycle, the most important are **evaporation, transpiration, condensation, precipitation, and runoff**. Although the total amount of water within the cycle remains essentially constant, its distribution among the various processes is continually changing.

The central focus of hydrology is the hydrologic cycle, consisting of the continuous processes shown in the following figure(s). Water evaporates from the oceans and land surfaces to become water vapor that is carried over the earth by atmospheric circulation. The *water vapour* condenses and **precipitates** on the land and oceans. The precipitated water may be <u>intercepted by vegetation</u>, become <u>overland flow over the ground surface</u>, <u>infiltrate into the ground</u>, flow through the soil as **subsurface flow**, and discharge as **surface runoff**. Evaporation from the land surface comprises <u>evaporation directly from soil and vegetation surfaces, and transpiration through plant leaves.</u> Collectively these processes are called

evapotranspiration. Infiltrated water may ***percolate*** deeper to **recharge** groundwater and later become spring flow or seepage into streams also to become stream flow.

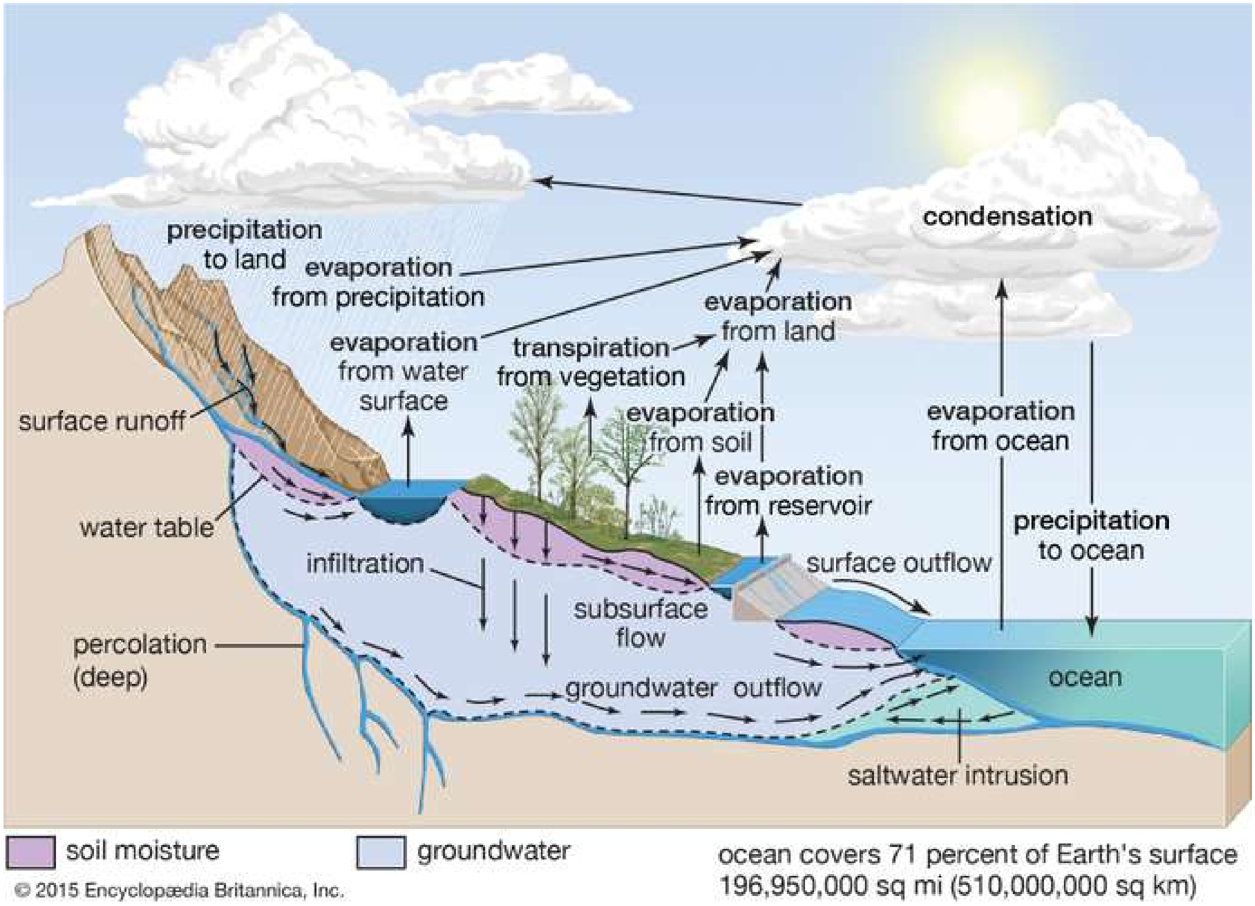


Fig 1: Hydrologic Cycle

Drainage basins, catchments, and watersheds are three synonymous terms that refer to the topographic area that collects and discharges surface stream flow through one outlet or mouth. Catchments are typically referred to as small drainage basins, but no specific area limits have been established. Figure 2 illustrates the drainage basin divide, watershed divide, or catchment divide, which is the line dividing land whose drainage flows toward the given stream from land whose drainage flows away from that stream. As shown in Figure 3, drainage basins can be pictured in a pyramidal fashion as the runoffs from smaller basins (sub-basin) combine to form larger basins and the runoffs from these basins in turn combine to form even larger basins, and so on.

Fig.2. Schematic diagram of a drainage basin. The high terrain on the perimeter is the drainage divide

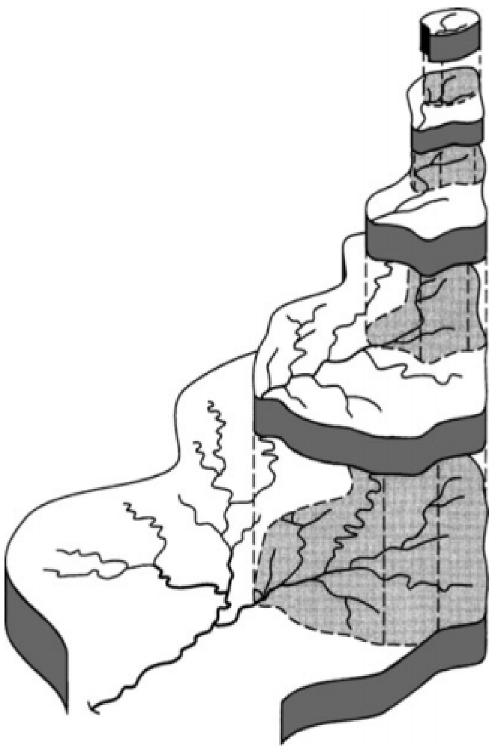


Fig.3. Illustration of the nested hierarchy of lower-order basins within a large drainage basin

Example: The following Figure 4 show **Godavari basin.** The river Godavari, the largest of the peninsular rivers, and third largest in India, drains about 10% of India's total geographical area. The catchment area of the river is 3,12,812 sq.km. and is spread in the states of Maharashtra (48.6%), Andhra Pradesh (23.4%), Madhya Pradesh (10.0%), Chattisgarh (10.9%), Orissa (5.7%) and Karnataka (1.4%). The basin lies in the Deccan plateau and is situated between latitude 160 16' 00'' North and 22 0 36' 00'' North and longitude 730 26' 00''

East and 830 07' 00" East. The river Godavari rises at an elevation of 1,067 m in the Western Ghats near Thriambak Hills in the Nasik district of Maharashrta. After flowing for about 1,465 km., in a generally south-east direction, it falls into the Bay of Bengal.

Fig.4. Drainage basin of Godavari River in India

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 outputs (O) from the system. Considering the open system in Figure 5, the **water balance equation** can be expressed for the surface water system and the groundwater system in units of volume per unit time separately or, for a given time period and area, in depth.

Surface Water System Hydrologic Budget:

$$P + Q_{\text{in}} - Q_{\text{out}} + Q_g - E_s - T_s - I = \Delta S_s$$

where P is the precipitation, Q_{in} is the surface water flow into the system, Q_{out} is the surface water flow out of the system, Q_g is the groundwater flow into the stream, E_s is the surface evaporation, T_s is the transpiration, I is the infiltration, and • S_s is the change in water storage of the surface water system.

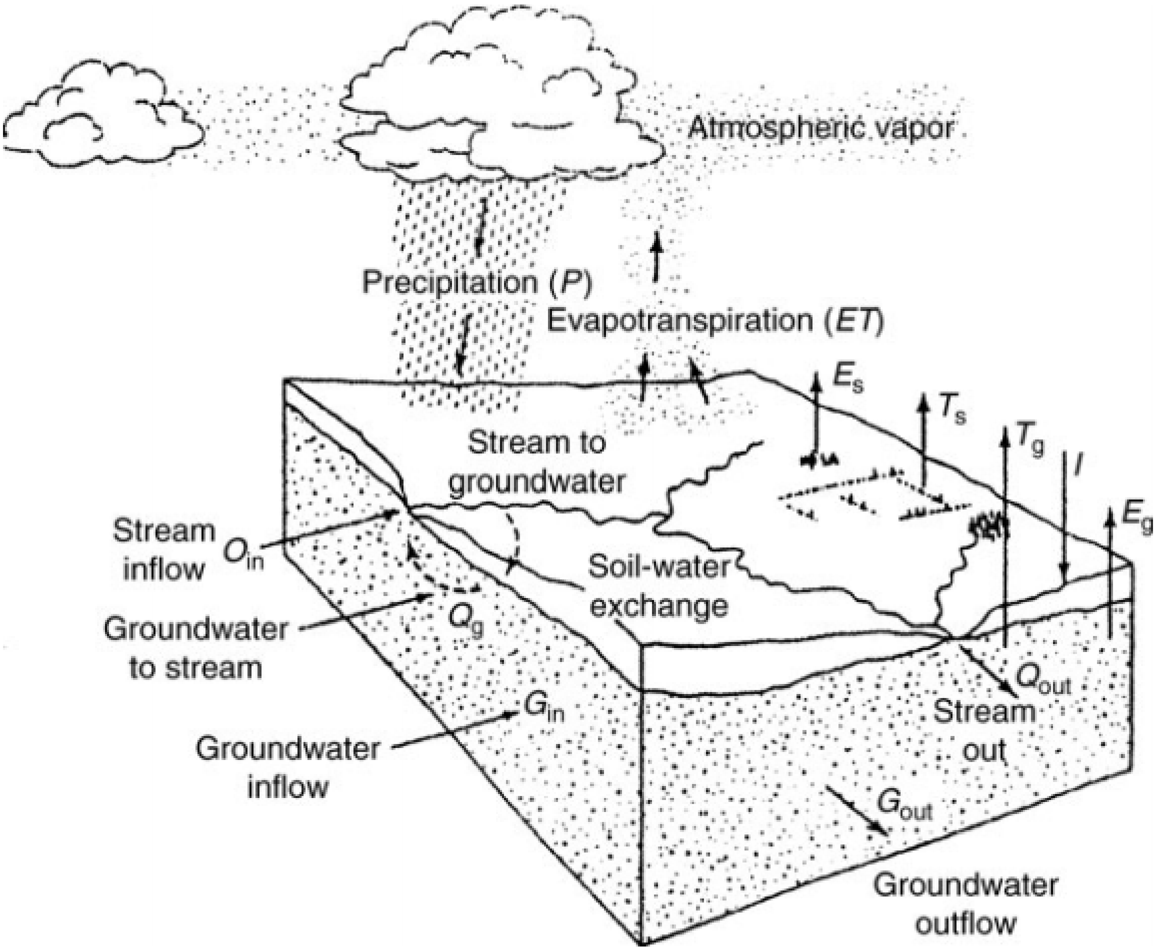


Figure 5. Components of hydrologic cycle in an open system: the major inflows and outflows of water from a parcel of land

Groundwater System Hydrologic Budget:

$$I + G_{\text{in}} - G_{\text{out}} - Q_g - E_g - T_g = \Delta S_g$$

where G_{in} is the groundwater flow into the system, G_{out} is the groundwater flow out of the system, and • S_g is the change in groundwater storage. The evaporation, E_g, and the transpiration, T_g, can be significant if the water table is near the ground surface.

System Hydrologic Budget:

The system hydrologic budget is developed by adding the above two budgets together:

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

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

$$P - Q - G - E - T = \Delta S$$

Water Resources of India:

India accounts for about 2.45 per cent of world's surface area, 4 per cent of the world's water resources and about 16 per cent of world's population. The total water available from precipitation in the country in a year is about 4,000 cubic km. The availability from surface water and replenishable groundwater is 1,869 cubic km. Out of this only 60 per cent can be put to beneficial uses. Thus, the total utilisable water resource in the country is only 1,122 cubic km. See Figure 6.

Surface Water Resources:

There are four major sources of surface water. These are rivers, lakes, ponds, and tanks. In the country, there are about 10,360 rivers and their tributaries longer than 1.6 km each. The mean annual flow in all the river basins in India is estimated to be 1,869 cubic km. However, due to topographical, hydrological and other constraints, only about 690 cubic km (32 per cent) of the available surface water can be utilised.

Precipitation in India has very high spatial variation, and it is mainly concentrated in Monsoon season. Some of the rivers in the country like the Ganga (or Ganges), the Brahmaputra, and the Indus have huge catchment areas. Given that precipitation is relatively high in the catchment areas of the Ganga, the Brahmaputra. These rivers, although account for only about one-third of the total area in the country, have 60 per cent of the total surface water resources. Much of the annual water flow in south Indian rivers like the Godavari, the Krishna, and the Kaveri has been harnessed, but it is yet to be done in the Brahmaputra and the Ganga basins.

Groundwater Resources:

The total replenishable groundwater resources in the country are about 432 cubic km. The Ganga and the Brahamaputra basins, have about 46 per cent of the total replenishable groundwater resources.

Lagoons and Backwaters:

India has a vast coastline and the coast is very indented in some states. Due to this, a number of lagoons and lakes have formed. The States like Kerala, Odisha and West Bengal

Fig. 6: India – River Basins

have vast surface water resources in these lagoons and lakes. Although, water is generally brackish in these water-bodies, it is used for fishing and irrigating certain varieties of paddy crops, coconut, etc.

Water Demand and Utilization:

India has traditionally been an agrarian economy, and about two-third of its population have been dependent on agriculture. Hence, development of irrigation to increase agricultural production has been assigned a very high priority in the Five Year Plans, and multipurpose river valleys projects like the Bhakra-Nangal, Hirakud, Damodar Valley, Nagarjuna Sagar, Indira Gandhi Canal Project, etc. have been taken up.

In fact, India's water demand at present is dominated by irrigational needs. Agriculture accounts for most of the surface and ground water utilization, it accounts for 89 per cent of the surface water and 92 per cent of the groundwater utilization.

In future, with development, the shares of industrial and domestic sectors in the country are likely to increase.

Precipitation Formation and Types:

Even though precipitation includes rainfall, snowfall, hail, and sleet, our concern in this discussion will relate almost entirely to rainfall. Condensation takes place in the atmosphere on condensation nuclei, which are very small particles (10^{-3} - 10μm) in the atmosphere that are composed of dust or salt. These particles are called aerosols. During the initial occurrence of condensation, the droplets or ice particles are very small and are kept aloft by motion of the air molecules. Once droplets are formed they also act as condensation nuclei. These droplets tend to repel one another, but in the presence of an electric field in the atmosphere they attract one another and are heavy enough (~ 0.1 mm) to fall through the atmosphere. Some of the droplets evaporate in the atmosphere, some of the droplets decrease in size by evaporation, and some of the droplets increase in size by impact and aggregation.

Basically, the formation of precipitation requires lifting of an air mass in the atmosphere; it then cools and some of its moisture condenses. There are three main mechanisms of air mass lifting: frontal lifting, orographic lifting, and convective lifting. Frontal lifting (Figure 7a) occurs when warm air is lifted over cooler air by frontal passage, orographic lifting (Figure 7b) occurs when an air mass rises over a mountain range, and convective lifting (Figure 7c) occurs when air is drawn upward by convective action such as a thunderstorm cell.

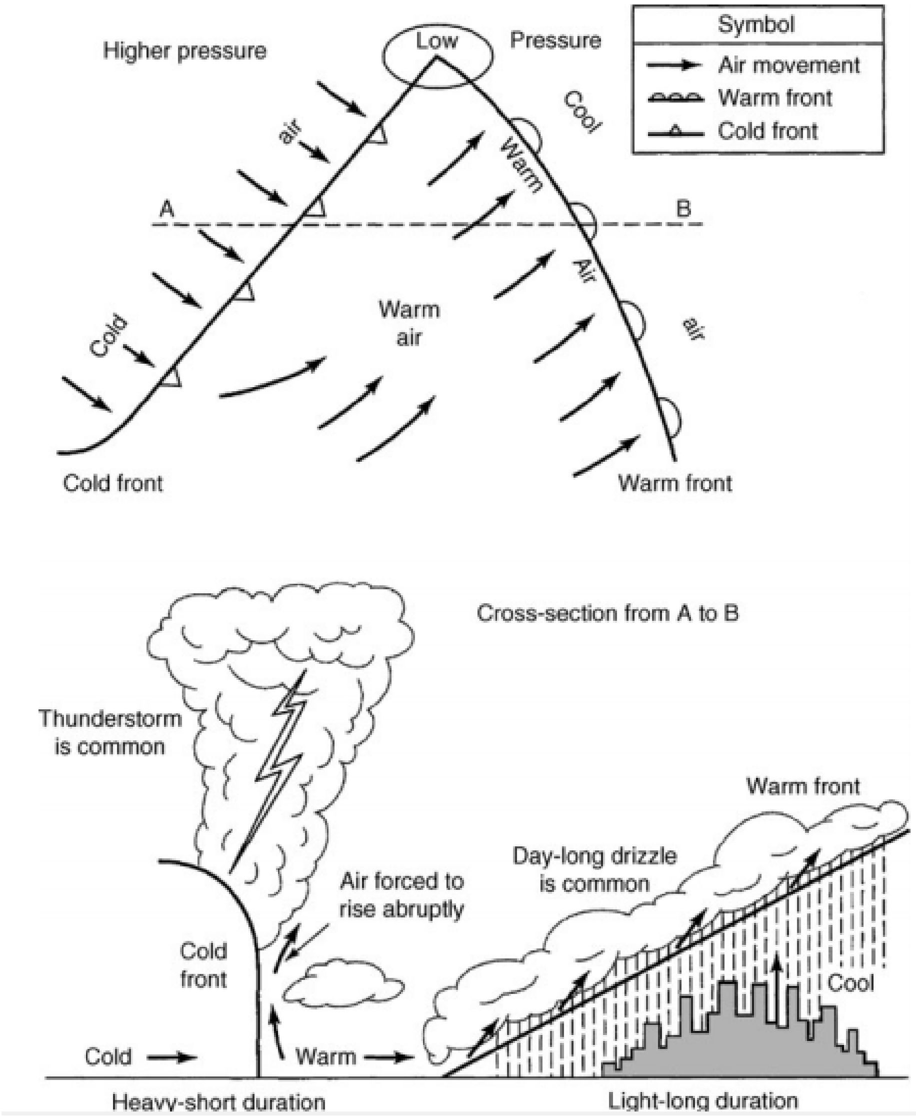


Fig 7(a). Cyclonic storms in midlatitude

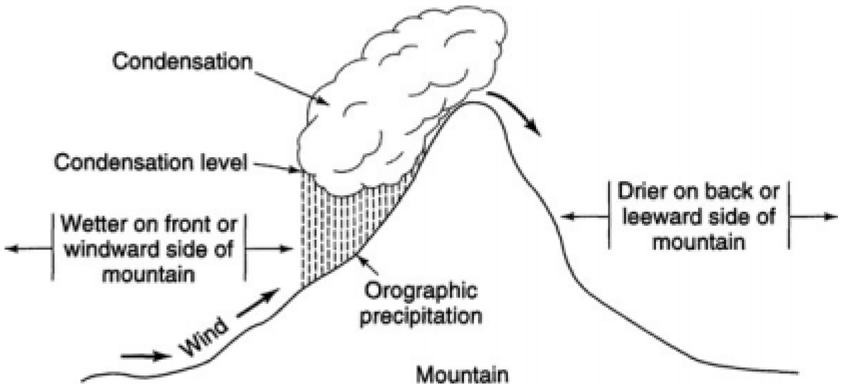


Fig 7(b): Orographic storm

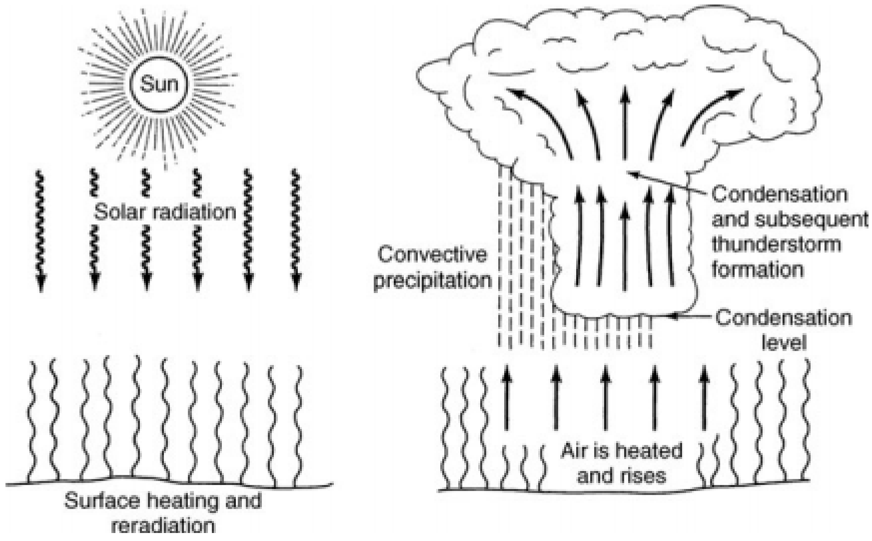


Fig 7(c): Convective storm

Rainfall Measurement:

Precipitation is expressed in terms of the vertical depth to which water from it would stand on a level surface area if all the water from it were collected on this surface.

The amount of precipitation is measured using a rain gauge (also called pluviometer, ombrometer, hyetometer etc). A breif study on different rainguages and selection of raingauage stations are explained below.

A rain gauge consists of a cylindrical vessel assembly kept in the open to collect rain. Rainfall collected in the rain gauge is measured at regular intervals.

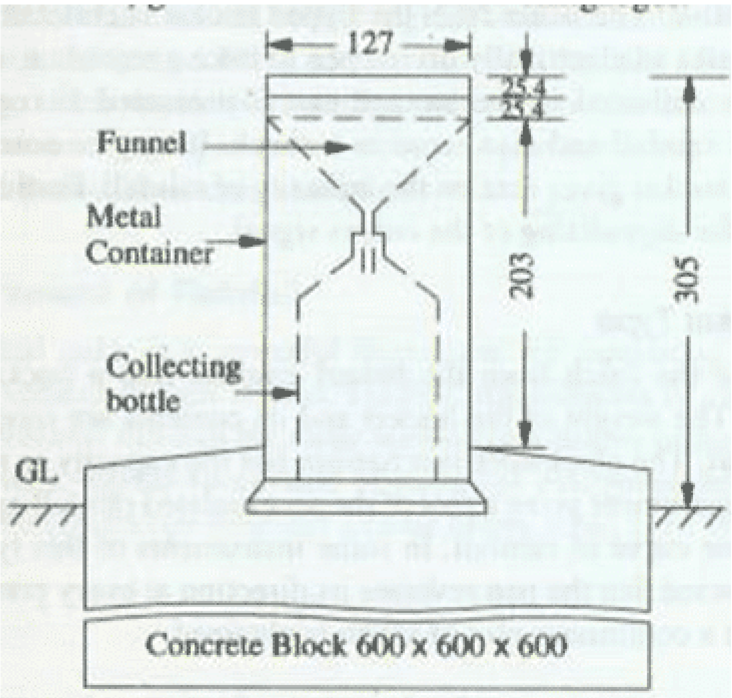
Rainfall catch is affected by the exposure conditions of the rain gauge. Rain gauges may be broadly classified into 2 categories:

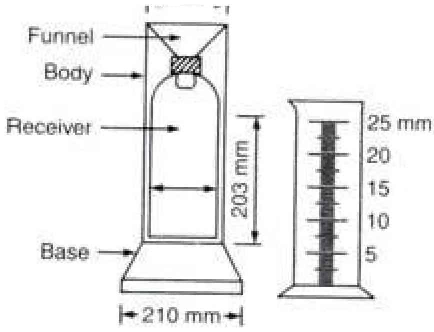
1. Non-recording raingauges and
2. Recording raingauges

Non-recording raingauges:

These rain gauges just collect the rainwater but do not record the quantity of rainfall. The most extensively used non-recording rain gauge is Symon’s gauge. Circular collecting area of 12.7 cm diameter connected to a funnel. The rim of the collector is set in a horizontal plane at a height of 30.5cm above the ground level.

The funnel discharges the rainfall catch into a receiving vessel. The funnel and collecting vessel (bottle) are housed in a metallic container. Water collected in the bottle is measured using a suitably graduated measuring jar with 0.1mm accuracy. Rainfall is measured in mm or cm of water depth.





Symons Rain gauge with graduated glass of accuracy 0.1mm

Recently IMD has started adopting fibreglass reinforced polyester raingauges. These are available in different combinations of collector and bottle. The collector is in two sizes – having 100 and 200 sq.m area. For details see IS:5225 and IS:4986.

Rainfall is measured every day at 8.30AM IST and is recorded as the rainfall of that day.

Recording raingauges:

Recording raingauges give a permanent automatic record of rainfall. It has a mechanical arrangement by which the total amount of rainfall since the start of record gets automatically recorded on a graph paper. It produces a plot of cumulative rainfall vs time (mass curve of rainfall). These rain gauges are also called integrating raingauges since they record cumulative rainfall.

What's the Difference Between Weather and Climate? *(Source: NASA)*

The difference between weather and climate is a measure of time. Weather is what conditions of the atmosphere are over a short period of time, and climate is how the atmosphere "behaves" over relatively long periods of time.

What exactly is weather?

More specifically, weather is the mix of events that happen each day in our atmosphere. Even though there's only one atmosphere on Earth, the weather isn't the same all around the world. Weather is different in different parts of the world and changes over minutes, hours, days, and weeks.

Most weather happens in the part of Earth's atmosphere that is closest to the ground—called the troposphere. And, there are many different factors that can change the atmosphere in a certain area like air pressure, temperature, humidity, wind speed and direction, and lots of other things. Together, they determine what the weather is like at a given time and location.

What exactly is climate?

Whereas weather refers to short-term changes in the atmosphere, climate describes what the weather is like over a long period of time in a specific area. Different regions can have different climates. To describe the climate of a place, we might say what the temperatures are like during different seasons, how windy it usually is, or how much rain or snow typically falls.

When scientists talk about climate, they're often looking at averages of precipitation, temperature, humidity, sunshine, wind, and other measures of weather that occur over a long period in a particular place. In some instances, they might look at these averages over 30 years. And, we refer to these three-decade averages of weather observations as Climate Normals.

What is climate change?

Climate change is the global phenomenon of climate transformation characterized by the changes in the usual climate of the planet (regarding temperature, precipitation, and wind) that are especially caused by human activities. As a result of unbalancing the weather of Earth, the sustainability of the planet's ecosystems is under threat, as well as the future of humankind and the estability of the global economy.

NASA's definition of climate change says it is *"a broad range of global phenomena created predominantly by burning fossil fuels, which add heat-trapping gases to Earth's atmosphere. These phenomena include the increased temperature trends described by global warming, but also encompass changes such as sea-level rise; ice mass loss in Greenland, Antarctica, the Arctic and mountain glaciers worldwide; shifts in flower/plant blooming; and extreme weather events."*

Reliable temperature records began in 1850 and our world is now about one degree Celcius hotter than it was in the period between 1850 and 1900 – commonly referred to as the "pre-industrial" average.

The change is even more visible over a shorter time period – compared to average temperatures between 1961 and 1990, 2017 was 0.68 degrees warmer, while 2016 was 0.8 degrees warmer, thanks to an extra boost from the naturally-occurring El Niño weather system.

While this temperature increase is more specifically referred to as global warming, climate change is the term currently favoured by science communicators, as it explicitly includes not only Earth's increasing global average temperature, but also the climate effects caused by this increase.

Global efforts are now focussed on keeping temperatures from increasing more than two degrees above that pre-industrial average, and ideally no more than 1.5 degrees. That goal may still be possible if the international community pulls together.

What are the effects of climate change?

The effects of anthropogenic – human-caused – climate change range from more frequent and severe droughts to snowstorms and extreme winter weather in temperate regions as a result of warming Arctic weather fronts.
It's not only humans that are affected. Warming ocean temperatures are increasing the frequency of coral reef bleaching; warmer, drier weather means that forests in some regions are no longer recovering from wildfires and wildlife habitats around the world are becoming less hospitable to animals.
Climate change is having economic and socio-political effects, too. Food security is already being impacted in a number of African countries and researchers are studying suggestive links between climate change and an increased likelihood of military conflict.
We're already seeing the first climate refugees as people are displaced by rising sea levels, melting Arctic permafrost and other extreme weather.

What are the causes of climate change?

We are. While a wide range of natural phenomena can radically affect the climate, publishing climate scientists overwhelmingly agree that global warming and resultant climate effects that we're witnessing are the result of human activity.

Life on Earth is dependent on an atmospheric "greenhouse" – a layer of gasses, primarily water vapour, in the lower atmosphere that trap heat from the sun as it's reflected back from the Earth, radiating it back and keeping our planet at a temperature capable of supporting life.

Human activity is currently generating an excess of long-lived greenhouse gasses resulting in a continuing buildup of heat.

Key greenhouse gasses include carbon dioxide, methane and nitrous oxide. The main source of excess carbon dioxide emissions is the burning of fossil fuels, while deforestation has reduced the amount of plant life available to turn CO_2 into oxygen.

Methane, a more potent but less abundant greenhouse gas, enters the atmosphere from farming – both from animals such as cattle and arable farming methods including traditional rice paddies – and from fossil fuel exploration and abandoned oil and gas wells.

Chlorofluorocarbons and hydrofluorocarbons – once widely used in industrial applications and home appliances such as refrigerators – were key greenhouse gasses released during the 20th century, but are now heavily regulated due to their severe impact on the atmosphere, which includes ozone depletion, as well as trapping heat in the lower atmosphere.
Our warming climate is also creating a feedback loop as greenhouse gasses trapped in Arctic permafrost are released.

Climate Change Definition vs. Global Warming Definition:
According to the **US Geological Survey**, global warming is just one aspect of climate change. In fact, they say that global warming refers to the rise in global temperatures due mainly to the increasing concentrations of **greenhouse gases** in the atmosphere. On the other hand, climate change refers to the increasing changes in the measures of climate over a long period of time – including precipitation, temperature, and wind patterns.
Following the same line of thought, according to **Climate.Gov**, global warming refers only to the Earth's rising surface temperature, while climate change includes warming and the "side effects" of warming—like melting glaciers, heavier rainstorms, or more frequent drought. Ultimately, this means that global warming is one side of the much larger problem of human-caused climate change).

Climate Change Impacts on Water
(https://ral.ucar.edu/projects/ccimpact_h20/)

- Freshwater resources are highly sensitive to variations in weather and climate. The changes in global climate that are occurring as a result of the accumulation of greenhouse gases in the atmosphere will affect patterns of freshwater availability and will alter the frequencies of floods and droughts.
- Climate model simulations and other analyses suggest that total flows, probabilities of extreme high or low flow conditions, seasonal runoff regimes, groundwater-surface water interactions and water quality characteristics could all be significantly affected by climate change over the course of the coming decades.
- While it is virtually certain that there will be changes in the global quantity and distribution of precipitation and runoff, there are significant uncertainties regarding the specific nature of the local and regional impacts of climate change on hydrologic regimes.
- Nevertheless, some types of changes can be foreseen with relatively high confidence. For example, a large and growing body of research suggests a high likelihood of the following changes.
- First, in watersheds where stream-flow currently depends on snowmelt, warmer temperatures will increase the fraction of precipitation falling as rain rather than as snow, causing the annual spring peak in runoff to occur earlier. Depending on changes in the amount and seasonal distribution of precipitation, these watersheds may experience an increased likelihood of winter flooding and reduced late summer flows.
- Second, saltwater intrusion into coastal aquifers is likely to become an increasing problem as a result of sea-level rise.

- And finally, for many watersheds, there will be an increased likelihood of warmer summer water temperatures with associated impacts on aquatic ecosystems and water quality.
- Climate change should be considered in the context of all of the other stresses impinging on our water resources: it may not be the largest source of stress, but it can potentially make it more difficult to deal with other challenges like population growth, endangered species and water quality issues.

IRRIGATION ENGINEERING:

Direct irrigation method:
In this project water is directly diverted from the river into the canal by constructing a diversion structure like weir or barrage across the river.

Indirect (or storage) irrigation method:
For this type of irrigation schemes part of the excess water of a river during monsoon which otherwise would have passed down the river as a flood is stored in a reservoir or tank found at the upstream of a dam constructed across a river or stream.

IRRIGATION AND ITS METHOD PRESENTED

1. Introduction:
   - Irrigation is the artificial application of water to the land or soil.
   - It is used to assist in the growing of agricultural crops, maintenance of landscapes, and revegetation of disturbed soils in dry areas and during periods of inadequate rainfall.

Necessity of Irrigation

- Insufficient rainfall
- Uneven distribution of rainfall
- Improvement of perennial crop
- Development of agriculture in desert area.

Benefits of Irrigation

- Increase in crop yield
- Protection from famine
- Cultivation of superior crops
- Elimination of mixed cropping
- Economic development
- Domestic and industrial water supply
- Hydro power generation

Ill Effects of Irrigation

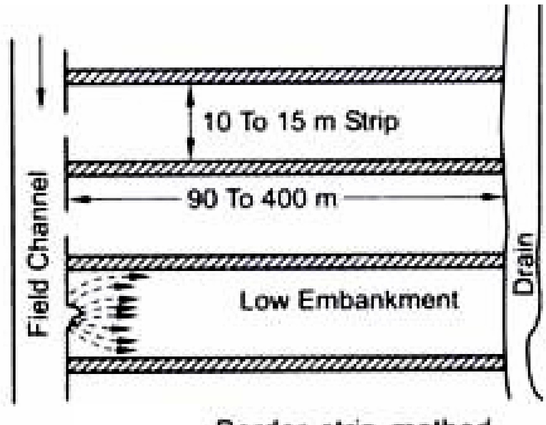
- Loss of valuable lands
- Dampness in weather
- Formation of marshy land
- Rising of water table

2. Methods Of Irrigation
    - Surface irrigation (a) Uncontrolled (or wild or free) flooding method (b) Border strip method (c) Check method (d) Basin method and (e) Furrow method.
    - Sub-surface irrigation
    - Sprinkler irrigation
    - Trickle (Drip) irrigation

3. Surface Irrigation
    - In all the surface methods of irrigation, water is either ponded on the soil or allowed to flow continuously over the soil surface for the duration of irrigation.
    - It does not result in high levels of performance.

4. Uncontrolled Flooding
    - When water is applied to the cropland without any preparation of land and without any levees to guide or restrict the flow of water on the field, the method is called ‘uncontrolled’, wild or ‘free’ flooding.
    - Uncontrolled flooding generally results in excess irrigation at the inlet region of the field and insufficient irrigation at the outlet end.
    - Efficiency is reduced because of either deep percolation or flowing away of water from the field.
    - The advantage of this method is the low initial cost of land preparation.

5. Border Strip Method
    - Border strip irrigation (or simply ‘border irrigation’) is a controlled surface flooding method of applying irrigation water. In this method, the farm is divided into a number of strips. These strips are separated by low levees (or borders).
    - The border strip method is suited to soils of moderately low to moderately high intake rates and low erodibility.
    - This method, however, requires preparation of land involving high initial cost.



Border strip method

6. Furrow Method
    - An alternative to flooding the entire land surface is to construct small channels along the primary direction of the movement of water and letting the water flow through these channels which are termed ‘furrows’, ‘creases’ or ‘corrugation’.
    - Furrows necessitate the wetting of only about half to one-fifth of the field surface. This reduces the evaporation loss considerably.
    - Furrows provide better on-farm water management capabilities for most of the surface irrigation conditions, and variable and severe topographical conditions.
    - Furrow irrigation requires more labour than any other surface irrigation method.

7. Subsurface Irrigation
   Subsurface irrigation (or simply sub irrigation) is the practice of applying water to soils directly under the surface. Moisture reaches the plant roots through capillary action. The conditions which favour sub irrigation are as follows:
   •Impervious subsoil at a depth of 2 meters or more,
   •A very permeable subsoil
   •A permeable loam or sandy loam surface soil,
   •Uniform topographic conditions, and
   •Moderate ground slopes

8. Sprinkler Irrigation Sprinkling is the method of applying water to the soil surface in the form of a spray which is somewhat similar to rain. Rotating sprinkler-head systems are commonly used for sprinkler irrigation. Each rotating sprinkler head applies water to a given area, size of which is governed by the nozzle size and the water pressure.

Sprinklers have been used on all types of soils on lands of different topography and slopes, and for many crops. The following conditions are favourable for sprinkler irrigation:
• Very previous soils which do not permit good distribution of water by surface methods, • Lands which have steep slopes and easily erodible soils,
• Irrigation channels which are too small to distribute water efficiently by surface irrigation, and
• Lands with shallow soils and undulating lands which prevent proper leveling required for surface methods of irrigation

Advantages
• Low water loss (efficiency up to 80%)
• Saving in fertilizer
• Suitable for any topography
• No soil erosion
• Better seed germination, free aeration of root zone
• Uniform application of water

Disadvantages
• High initial cost, cannot adopt by ordinary farmers
• Poor application efficiency in windy weather and high temperature
• High evaporation losses
• Water should be free of debris
• Physical damage to crops by application of high intensity spray

9. Trickle (Drip) Irrigation
• Trickle irrigation system comprises main line, sub mains, laterals, valves (to control the flow), drippers or emitters, pressure gauges, water meters, filters, pumps, fertilizer tanks, vacuum breakers, and pressure regulators.

• The drippers are designed to supply water at the desired rate (1 to 10 liters per hour) directly to the soil. Low pressure heads at the emitters are considered adequate as the soil capillary forces causes the emitted water to spread laterally and vertically.

Advantages:

- Low water loss and hence saves water
- Enhances plant growth and plant yield
- Saves labour and energy
- Control weed growth
- No soil erosion
- Improves fertilizer application efficiency

Disadvantages:

- High skill in design, installation, and subsequent operation
- Clogging of small conduits and openings in emitters due to sand, clay particles, debris, chemical precipitates and organic growth
- Not suitable for closely planted crops such as wheat and other cereal grains

Please refer text books: Irrigation Engineering and Hydraulic Structures. S.K.Garg or B.C. Punmia for complete and more information