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ELEMENTS OF HYDROLOGY (WMA 204)

COURSE SYNOPSES

Definition, scope and application of hydrology.

The concept of hydrologic cycle and drainage characteristics

Precipitation:

Forms, types e.t.c

Measurements

Factors affecting:

Interception

Evaporation

Evapo-transpiration

Surface run-off and subsurface flow

Determination and analysis of infiltration, percolation and permeability

Aquifers and groundwater movement

LECTURE NOTE

Hydrology is from the word hydro- logos

Hydro - water

Logos - study

Hydrology is therefore the 'study of water'.

Definition & scope

Water occurs in various forms and locations in the environment and these are connected together by complex processes to form what is known as hydrologic or water cycle.

Hydrology can be viewed as the scientific study of the water cycle. It is a discipline that studies the properties occurrence, distribution and movement of water on and beneath the land surface.

The international Association for scientific hydrology recognizes four district branches of the subject, of which surface and ground water have received the greatest attention. These form branches are:

(1) Surface water
(2) Ground water
(3) Snow and ice
(4) Limnology- study of lakes

Since hydrology focus on water which is an important element of the natural environment, science subjects such as Meteorology, Oceanography, Geology, Ecology, Glaciology.

Also scientific hydrology underlies the development, utilization and control of water resources. It therefore has some relationship with social science subjects like Economics, Political science and Sociology.

Application of hydrology

Application of hydrology are numerous and varied. Hydrology has practical applications in the following.

(1) Water resources management & development
(2) Flood prediction and forecasting
(3) Watershed management
(4) Design of water control & pollution abatement e.t.c.

Properties of water

(1) Water is the chemical compound obtained from the fusion of to two hydrogen atoms and one oxygen atom.H_2O.
(2) It is the only element that occurs naturally in three states in which matter can exist i.e solid, liquid and gas.
Solid- ice, snow hailstorms
Gas- water vapour
Liquid- rain, dew.
(3) Boiling point of water 100^0C & freezing point of 0^oC.
(4) Water is a universal solvent, dissolve greatly many substance and its solubility increases with increasing temperature.
(5) It is a remarkable catalyst as many reactions may be slowed down or totally inhibited by lack of water.

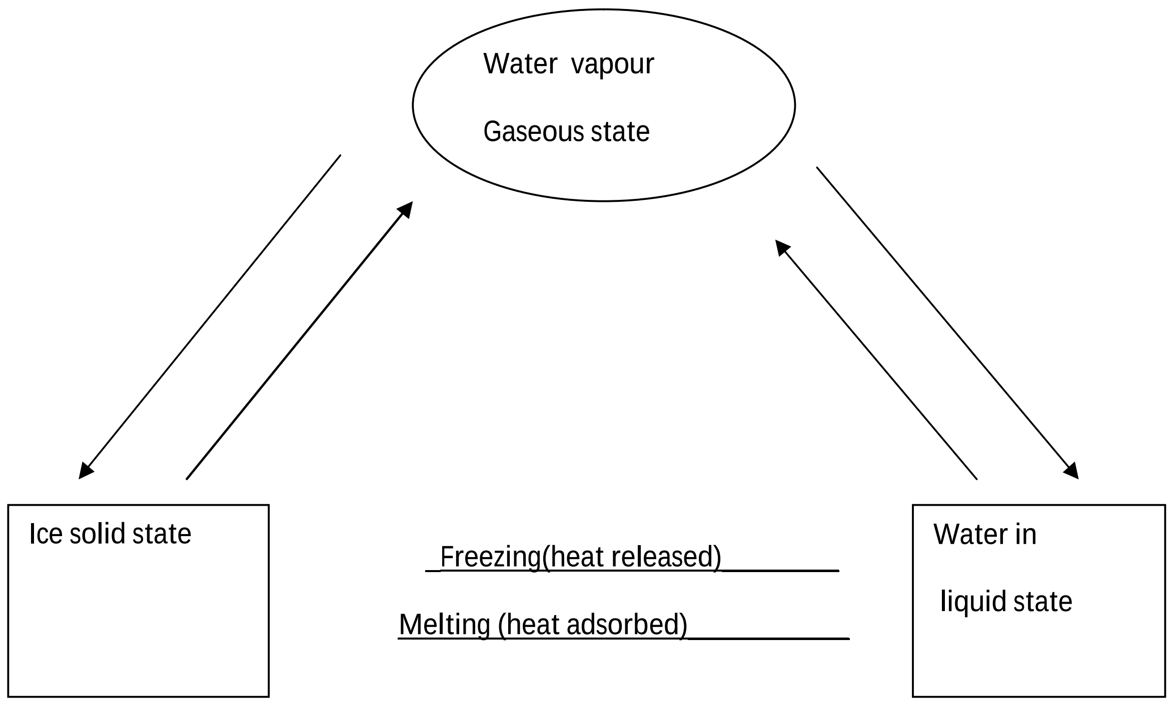
Occurrence of water

Water occurs in various locations and forms in the earth-atmosphere system. Water occurs in the atmosphere, mainly as vapour(gaseous form), as gas, solid or liquid on and beneath the earth surface. Water is also continually changing in form.

When ice, snow or hail melts, it changes from solid to liquid. This process involves adsorption of heat which is held in the water itself. This is the latent heat of fusion which amounts to about 80 calories per gram of water melted.

Water also changes from a liquid state to a solid state as a result of freezing. The latent heat if fusion is released when water freezes. Water changes from a liquid to a gas as a result of evaporation and from a gas to a liquid as a result of condensation. Evaporation involves utilization of energy which amount to about 600 calories for every water evaporated. This energy is locked up in the water vapour as latent heat. The heat is released when the vapour condenses.

Another change of state involves water vapour directly transformed into ice as sublimations. Sublimation- releases an amount of heat equal to the sum of the latent heat released by condensation and the heat released by freezing water.



The hydrological cycle (water cycle)

The hydrologic cycle is a continuous process by which water is transported from the oceans to the atmosphere to the land back to the sea or ocean viessman et al (1977). The components of the hydrologic cycle are :

(i) Precipitation
(ii) Evaporation
(iii) Transpiration
(iv) Infiltration
(v) Surface runoff
(vi) Ground water flow.

In engineering hydrology we are primarily concerned with open hydrologic systems which relating specifically to the drainage area or basin of a river or system of rivers.

For a given finite region, the water budget equation is then given by

$P-R-G-E-T = \Delta S$ where ΔS is the change in storage.

However , difficulty in solving practical problem lies mainly in the inability to properly measure or estimate the various terms of the water budget equation.

The global hydrological cycle is however not so open as there are only input and output of energy. There are no input or output of water, but rather a continually transferred from one kind of storage to another

Input (I) = output (0) ± Δstorages rainfall & inflow

Where

Input (I) includes rainfall and inflow from neighboring catchments (natural or artificial)

Output (0) includes evaporation, outflow from catchments and withdrawal by man

Δ Storages includes soil and ground water storage

River drainage basin

When rain falls on the surface, the water sink (infiltration) or remain at the surface. Surface water tends to flow under gravity from areas of higher elevation to lower ones. The stream is used to describe any body of flowing water confirmed within a definite channel and subjected to at least minimal flow. The area from which a stream draws water is its drainage basin. The volume of water in a stream at any point is related partly to the size of the area drained as well as the factors like precipitation, infiltration, evaporation, transpiration e.t.c. Where a lot of small streams flows into larger ones a complex drainage pattern is exhibited. Complexity of the drainage pattern may sometimes be defined in terms of stream order.

A tributary stream is one that follows into another stream. A first order stream is one that has no tributary and a second order stream has only first order streams as tributary. In general the higher the order of a stream, the larger the drainage area of that stream and its tributaries.

A drainage or river basin is bounded by a divide which separates it from adjacent basin. The boundary of a river basin can be demarcated very accurately on a topographic map or an aerial photograph or through direct field survey. The river basin provides a convenient natural unit area within which hydro- meteorological data can be collected and analyzed and the details of the hydrological cycle and other physical process can be meaning fully studied.

Geometry of drainage basin

Most stream systems exhibit a branching drainage pattern in which stream channel are irregular and tributaries joins larger stream at different angles. This pattern is called Dentritic Pattern is from a Greek word meaning (roots).

Very often the geology of the subsurface may cause the river network to assume a more regular geometry particularly where sets of parallel fractures or joints cause zones of weakness thereby establishing a rectilinear Structure called the trellis Pattern in which case tributary join the main stream at right angles.

Trellis drainage pattern may also develop where the topography is dominated by parallel reaches resistant rock and stream tend to flow between these ridges. Sets of intersecting joints may create rectangular drainage with right angle bend in all streams.

Drainage basin characteristics

(i) **Basin area** – the area of a river basin which contributes to surface run-off and drains into the rivers during storms is called the drainage basin, water or catchment area of river. The boundary line separating two drainage areas along a topographic divide is called drainage divide. The time required for the rain falling at the most distant point in a drainage area so reach the measuring point (point of flow from the basin) is called the concentration time.

(ii) **Stream order**- drainage basins are classified first by the stream order concept which designates the smallest tributes of the watershed as order 1. When two 1st order streams join, they form a 2nd order stream. Similarly, when two 2nd streams join they give a 3rd order stream. If however 1st order stream joins a 2nd order stream they give a 2nd order stream.

Stream-order definition

Stream lengths are obtained by measuring their vertical projections on a horizontal plane. In this topographic maps are required. For a stream, the mean length of stream segment L_u of order say u can be designated by L_m and estimated as

$$Lu = \frac{\sum_{i=1}^{Nu} Li\ u}{Nu}$$

Where N_U= the number of stream segment of order u.

For example, the mean length of all 1st order streams can be estimated as

$$L1 = \frac{\sum_{i=1}^{N} Li\ 1}{N}$$

(iii) Stream density (D_s)

If N_s = the number of streams in the basin,

Stream density $D_S = \frac{Ns}{A}$

(iv)Drainage Density (D_d)

If the length of all Streams is L_S then the drainage density is

$$D_d = \frac{Ls}{A}$$

The drainage density gives an idea of the areal channel development of the basin. For example, a high value of D_d will indicate a well developed network, usually associated with torrential runoff that causes intense floods. A low D_d on the other hand would indicate moderate runoff and high permeability of the terrain.

(v) Length of overland flow (L_0)

The average length of overland flow is approximated by

$$L_0 = \frac{1}{2Dd}$$

(vi) Form factor and compactness coefficient

The shape of drainage basin can be defined by the form factor and compactness coefficient. Before introducing these parameters the axial length and axial width of the catchment will be required.

Form factor (F_f)

This is defined by $F_f = \frac{W_b}{L_b}$

Since A = W_b L_b this gives $W_b = \frac{A}{L_b}$

Hence $F_1 = \frac{A}{L_b^2}$

(b) Compactness coefficient (C_c)

This is defined as $\frac{the\ perimeter\ of\ the\ basin}{circumference\ of\ equivalent\ circular\ area}$

Now, if circumference if basin = P_b

The equivalent circular area A =πR^2

The perimeter = $2\pi R$

Hence $P_C = 2\pi R\frac{\sqrt{A}}{} - 2\sqrt{A}$

Thus $C_c = \frac{P_b}{P_C} = \frac{P_b}{2\sqrt{A}}$

The compactness factor is believed to be dependent on the catchment slope rather than area.

(vii) Elongation Ratio (E_r)

This is a term defined as

$E_r = \frac{diameter\ of\ circle\ of\ same\ area}{maximum\ basin\ length}$

And $E_R = \frac{2R}{L_b}$

The value is found to range from 0.4- 1.0

(viii) Circularity ratio (C_r)

It is defined as

$C_r = \frac{basin\ area}{area\ of\ a\ circle\ having\ the\ same\ perimeter\ as\ the\ basin}$

Hence, $C_r = \frac{A}{(R*)2}$

Where R^* = radius of circle of an equivalent basin perimeter

The value ranges from 0.2-0.8.

PRECIPITATION

Precipitation is the term used by meteorologist to describe any aqueous deposit, in liquid or solid form, derived from the atmosphere, precipitation is considered a meteorology concept when it has not reached the ground. When it reaches the ground it becomes a hydrological concept.

Forms of precipitation

There are two basic forms of precipitation.

(1) Solid
(2) Liquid.

From these two forms of precipitation we have several kinds of precipitation these are.

Solid precipitation

(1) Snow
(2) Frost
(3) Hail
(4) Glaze
(5) Rime
(6) Sleet

Liquid precipitation

(1) Rain
(2) Drizzle
(3) Dew

With the exception of hail, solid forms of precipitation do not with occur in the tropics. Dew, frost and glaze are generally in significant forms of precipitation compared to rain and snow. But in certain environments these forms of precipitation can be important since of moisture for crop growth. Similarly in the cold desert the forms of solid precipitation are move important than snowfall.

Factor influencing precipitation

(i) Sufficient atmosphere moisture
(ii) Cooling of the moisture
(iii) Condensation of water vapour into liquid or solid form.
(iv) The growth of condensation product to precipitation size.

Description of precipitation forms

Drizzle, sometime called must, consist of tiny liquid water droplets; usually with diameters between 0.1 and 0.5mm with occasionally appears to float. Drizzle usually falls from low stratus and rarely exceeds 1mm/h.

Rain consists of liquid water drops mostly larger than 0.5mm in mm in diameter. Rainfall usually refers to amounts of liquid precipitation. It is usually reported in three intensities.

Light-rate of fall up to 2.5mm/hr
Moderate- rate of fall from 2.8 to 7.6mm/hr.
Heavy: over 7.6mm/hr.

Glaze: is the coating generally clear and smooth but usually containing some air pockets, formed on exposed surface by the freezing of super – cooled water deposited by rain for drizzle. Its specific gravity may be as high as 0.8 to 0.9.

Rime : is a white , opaque granular deposit of ice compose the essentially of ice granular more or less separated by trapped air and formed by rapid freezing of super cooled water drops impinging on exposed objects. Its specific gravity may be as low as 0.2 to 0.3.

Snow; is composed of white or translucent ice crystal, chiefly in complex, branched hexagonal form often mixed with simple crystals and often agglomerated into snowflakes, which may reach several inches in diameter. The density of freshly fallen snow varies greatly 125 to 500 mm of snow is generally required to equal 25mm of liquid water. The average density is often assumed to be 0.1.

Hail: is the form of balls or irregular lumps of ice, produced in convective clouds, mostly cumulonimbus. Hailstone may be opheroidal or irregular in shape range from about 5 to over 125mm in diameter.

Sleet: generally transparent globular, solid grains of ice formed by the freezing of rain drops or refreezing of largely meted ice crystals falling through a layer of subfreezing air near the earth's surface.

Types of precipitation

Precipitation is often typed according to the factor mainly responsible for lifting the air to effect the large-scared cooling required for significant amounts of precipitation.

(1) Cyclonic precipitation results from the lifting of air converging into low-pressure area, or cyclone. It can be classified frontal or non-frontal.

(i) Frontal precipitation results from lifting of warm air on one side of a frontal surface over cooler, denser air on the other.

(ii) Warm- front precipitation – is formed when the warm air is advancing upward over a colder air mass.

(iii) Cold- front precipitation- on the others hand, is of showery nature and is formed when the warm air is forced upward by an advancing mass of cold air, the leading edge of which is the surface cold front.

(2) Non- frontal precipitation- is precipitation unrelated to fronts.

Convective precipitation

Convective precipitation is caused by the rising of warmer lighter air in colder denser surroundings. The difference in temperature may result from unequal heating at the surface, unequal cooling at the top of the air layer, or mechanical lifting when the air is forced to pass over a denser, colder air mass or over a mountain barrier. Convective precipitation is spotty and its intensity may range from light showers to cloud bursts.

Orographic precipitation

Orographic precipitation- results from mechanical lifting over mountain barrier. In rugged terrain the orographic influence is so marked that storm precipitation pattern tend to resemble that of mean annual precipitation.

Precipitation measurement

(1) Rain gauge
   (i) Recording
   (ii) Non recording

Non-recording consists of support overflow can, measuring tube or stick collection or receiver, funnel.

Recording

(1) Tipping- bucket gauge
(2) Weighing-type gauge
(3) Float recording gauge
(4) Radar
(5) Satellite

EVAPORATION AND EVAPOTRANSPIRATION

Evaporation is the term used to describe water loss from water and bare ground surfaces. It is a process by which moisture is converted into water vapour and removed and transported upward into the atmosphere. On vegetated surface where transpiration is an important component of water loss the term evapotranspiration is used. Evapotranspiration is thus the combined process of evaporation and transpiration.

Process of evapotranspiration

(1) Movement of water within the soil towards the ground surface or zone of adsorption around the roots of plants.
(2) Transpiration
(3) Vaporization of the water at soil or plant surface (intercepted water) or the stomata of leaves (transpired water).
(4) Removal and transport of evaporated water, now in gaseous formal into the atmosphere.

Factors influencing the process evaporation-evapotrnapiration.

(1) Availability of moisture at given surface.
(2) Ability of the atmosphere to vaporize the water and remove and transport the vapour upwards.

If moisture is always available in sufficient qualities at the evaporating (non limiting water), then evaporation or evapotranspiration wills occur at the maximum rate possible for that environment. The concept of maximum water availability in an evaporating surface is called **Potential evapotranspiration**.

Potential evapotranspiration is the water loss that would occur from a permanently moist surface.

Factors controlling rate of evaportranspiration

(1) Climatic factors.

Major

(a) Amount of energy available (solar radaition).
(b) Atmosphere (air) humidity
(c) Wind speed.

others are derived from the major component

(d) Sunshine duration
(e) Temperature

(2) Non climatic factor

(a) Characteristics of evaporating surface
(b) Whether it is water or soil.
(c) If soil whether vegetated or not.
(d) Type of soil and land management
(e) Moisture content of soil profile,

If water surface:

(f) Turbidity of water
(g) Depth of water
(h) Surface area of water body.

INTERCEPTION

Where the ground surface is covered whether artificially by man or naturally by vegetation, part of the precipitation is intercepted by that cover. The intercepted water is temporally stored on the cover surface until it eventually falls to the ground or is as a evaporated back into the atmosphere. if there is a thick vegetation cover, the precipitation amount recorded in the open is much greater than the amount actually reaching the soil surface below the vegetation canopy.

Component of interception.

(1) Interception loss is the part of precipitation remaining on the plant and leaf surfaces and later evaporated into the atmosphere by these surfaces.

(2) Through fall is the part of precipitation that reaches the ground directly through spaces in it and as a drip from leaves and stems.
(3) Stem-flow is that part of precipitation which having canopy reaches the ground by running down the stems.

Factors controlling interception loss

Categorized into factor influencing precipitation and vegetation canopy.

Factor influencing precipitation (characteristics)

(1) Type
(2) Amount
(3) Duration of intensity of precipitation
(4) Frequency of rainstorm and the length of time and evaporative conditions of between storms.
(5) Wind

Vegetable cover.

Structural properties of vegetation:

(1) Morphology and foliage characteristics of vegetable.
(2) Density of stands, age (Interception losses tend to increase with crop maturity and plant density).

Surface runoff

The terms stream flow, runoff, discharge and yield of drainage basin are used almost synonymously. However, yield is usually considered in term of total volume per year or as average flow for long period of time. Whereas the other term ordinarily are applied to instantaneous rates to rates for shorter periods.

Runoff are defined in two different ways:

(1) Runoff which includes all the water in stream channel past any given section.
(2) Surface Runoff which is only the water that reaches stream channel without first percolating down the water table.
Unit $\rightarrow m^3 s^{-1}$

Sources of runoff

(1) Precipitation falling directly on the surface of the stream and its tributes.

(2) Surface runoff, that is water that falls as precipitation on the ground surface and find it way into the stream channel without infiltrating into the soil and percolating down to the water table.
(3) Ground water or water that has its origin in precipitation but infiltrated into the soil, joined by the ground water and then, after days, weeks or even much longer period, found its way through the soil into the stream.

Factors affecting runoff

The flow of any stream is determined by two entirely difference sets of factors:

(1) Depending upon the climate with special reference to precipitation
(a) Type of precipitation
(b) Rainfall intensity
(c) Duration of rainfall
(d) Distribution of rainfall on the basin
(e) Soil moisture
(f) other climatic condition that affect evaporation & transpiration.

(2) The second group is determined by the flowing drainage basin characteristics.
(a) Land use
(b) Types of soil
(c) Area of basin
(d)Shape of basin
(e)Elevation of site
(f)Slope of basin
(g)Type of drainage
(h)Extent of indirect drainage
(i)Artificial drainage.

INFILTRATION

Infiltration is the term used to describe the flow of water through the soil surface (surface layers of the soil).

Percolation: is used to describe the downward flow of water, through the zone of aeration, towards the water table.

Infiltration process

This can be seen as having three parts:

(1) Surface entry
(2) Movement of water through the soil

(3) Reduction of the soils storage capacity

For infiltration to occur, water has to enter the soil surface concerned, be transmitted through the soil and eventually be stored within it to make good any soil moisture deficit.

The transmission capacity of the soil profile depends on the texture and structure of successive horizon making up the soil profile. The storage available in any soil horizon and indeed, the soil profile as a whole is determined by porosity, thickness of the horizon or profile and the amount of moisture already present.

Infiltration capacity

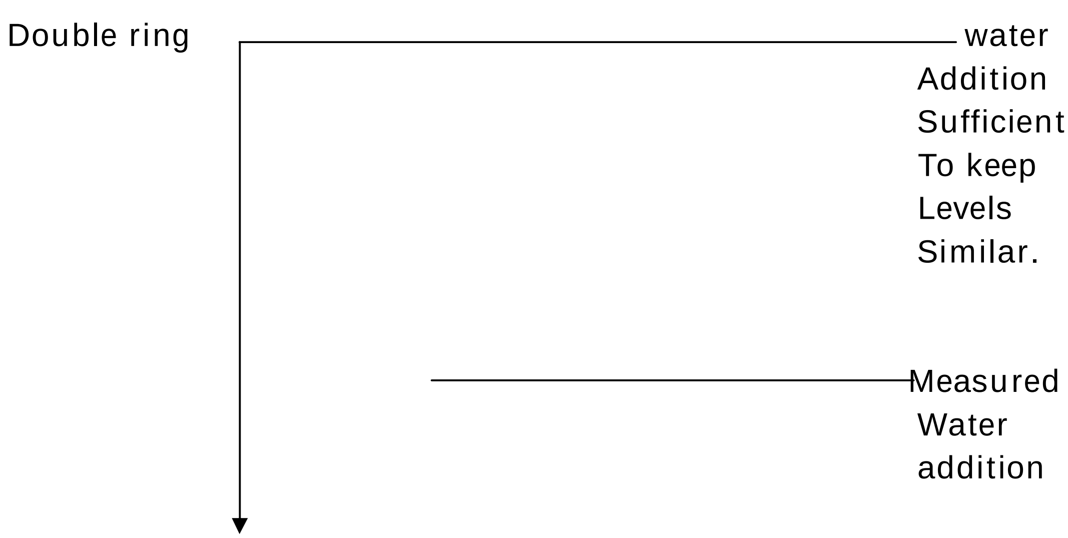
The maximum rate at which rain water can be absorbed by a soil in a given conduction is known as the infiltration capacity of that surface. The infiltration rate refers to the unit of rainwater that passes into the ground surface in unit time. This amount is expressed in units of depth such as millimeters.

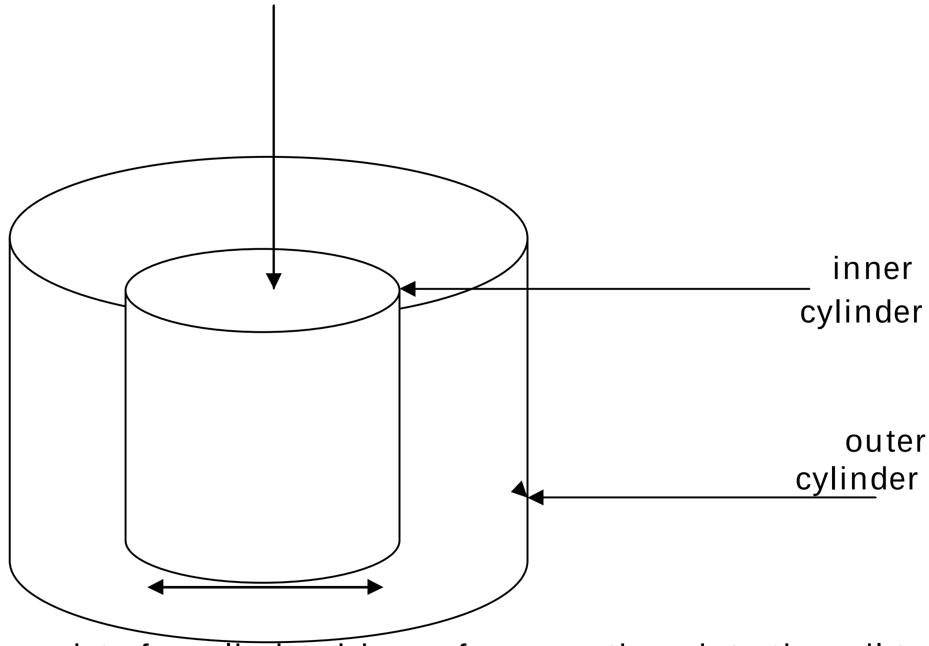
Methods of determination

(1) Infiltrometer
(2) Hydrograph analysis
(3) Use of equations

Infiltrometer

Double ring infiltrometer
Flooding infiltrometer
Sprinkling infiltrometer (rainfall simulation).





The very infiltration consist of a cylinder driver a fewer continue into the soil to prevent leakage. There are really two cylinder one inside the other and forming two concentric rings on the outside. The inner ring, which is usually 23cm in diameter is the one used to determine infiltration rate. The outer ring 36cm in diameter is meant to reduce the border effects on the inner rings.

(1) Holtan (1961)- infiltration rate equation

$$f = a(s - f)n + fc$$

When f= rate of infiltration

S= storage potential of soil taken as the volumetric difference between pore saturation and wilting point

F= accumulated infiltration

Fc= constant rate of infiltration after prolonged wetting

a & n are empirical constant for a particular soil in a given condition.

(2) Horfon (1939) is for infiltration capacity of a surface and is of the form.

$F_p = F_c + (f_0 - f_c) \exp(-kt)$

Where F_p= infiltration capacity in (infiltration).

T= time (hr)

F_0= initial infiltration capacity

F_c= minimum constant infiltration capacity
K= constant

Flow rate= $\frac{Q}{t}$ = AV= $\frac{Ah}{t}$

Darly's law of saturated flow

Darly's shows experimentally that fluid velocity of flow through a porous medium was directly relative to the hydraulic gradient causing the flow.

$$V \alpha i$$

Where V= velocity of flow

I= hydraulic gradient (which is the head loss per unit length)

I= $\frac{h}{n}$

V = Ki

Where K is the constant which involves the properties of both the fluid and the porous medium.

In soil, we are concerned with water flow so to determine the constant K we use test in which the permit is water. The particular value of K obtained form this test is what is called the coefficient of permeability K.

Theoretical determination of K

Provided the hydraulic gradient is less than 1 (i<1) as in most seepage problem the flow of water through is very linear.

For i < 1

From darcy's law V = Ki

and

q= $\frac{Q}{T}$

Where Q = volume of flow

T= time of flow

Q= discharge (rate of flow)

But also q = AV (V= velocity of flow)

$: V = \frac{q}{A} = \frac{Q}{t} \times \frac{1}{A} = K_i$

$\frac{Q}{At} = K_I$

$K = \frac{Q}{Ati} = \frac{Q}{t} \times \frac{1}{Ai}$

$K = \frac{q}{Ai}$

q = Aki

From this expression Coefficient of permeability can be defined as the rate of flow of water per unit area in soil when under a unit hydraulic gradient.

Determination of "K" in the laboratory

(1) <u>Constant Head Permeameter</u>

Water flows through the soils sample under a head which is kept constant by means of an overflow arrangement, the head lost "h" between two point along the length"L" of the sample is measured by means of a manometer (in practice there are more then just two manometer). A series of reading can be obtained from each test and average value is obtained by Darcy law. The fact is useful for gravely soil and could be useful for coal soil material.

<u>Falling head permeameter</u>

In this test which is suitable for silt and some clay, the flow of water through the sample at the inlet, the height h, in the stand pipe is measured and the valve is then opened as a stop clock is started. After a measured time (t), the height to which the water level has fallen h_2 is determined. During a small interval "dt" the stand pipe "dh". Therefore the velocity of fall = $\frac{-dt}{dt}$ but from Darcy's law

q = Aki.

Therefore av = Aki

$$\frac{-adh}{dt} = Ak\frac{h}{l} \quad \left(i = \frac{h}{l}\right)$$

$$\frac{-adh}{h} = \frac{Ak}{l} \quad dt$$

Integrate both sides

$$-a \int_{h1}^{h2} \frac{dh}{h} = \frac{Ak}{L} \int_{ti}^{t2} dt$$

$$-a[\![\log_e h]\!]_{hi}^{h2} = \frac{AK}{L} [t]_{t1}^{t2}$$

$$-a[\log_e h\,2 - \log_e h1\,] = \frac{Ak}{i} [t]_{t1}^{t2}$$

$$-a[\log_e h2 - \log_e h1] = \frac{AK}{i}[t2 - t1]$$

$$a\log e\frac{h1}{h2} = \frac{AK}{i}[t2 - t1]$$

$$a\log e\frac{h1}{h2}\ \frac{L}{A}\ (t2 - t1) = K$$

$$K = \frac{a \times L}{A(t2 - t1)} \quad \log e\ \frac{h1}{h2}$$

$$K = \frac{2.3al}{A(t2 - tI)} \quad \log 10\ \frac{h1}{h2}$$

<u>Field determinant of K</u>

The pumping out test is used to measure the value of K of a stratum of soil below the water and it is effective up to depth of about 45m. A casing is driven into the impermeable strata. The observation well of 75mm diameter. The observation well are put down in radial line in the casing.

The test consists of pumping out water from central casing. The rate at which the pumping test is done is q. while the test is going, the rate of draw down is observed.

Consider an elemental strip dh, the surface area is given as

$$\int 2 \times dr\ dlr$$

dr = diameter of elemental strip

dh= thickness of elemental strip

$$= 2\times \int dr \int dh$$

Surface area = $2\pi rh$

From the precious study

$$q = Aki$$

$$q = 2\pi rh\ K \frac{dh}{dr}$$

Cross multiply

$$q\ dr = 2\pi rhkdh$$

$$\int_{r1}^{r2} q \ \frac{dr}{r} = \frac{2K}{Q} \int hdh$$

$$\log_e r2 - \log_e r1 = \frac{k}{q} (Z_1^2 - Z_2^2)$$

$$\log e \ \frac{r2}{r1} = \frac{K}{q} (z^2 - z^2)$$

$$K = \frac{q}{(Z^2 - z^2)} \ x \ \log e \ \frac{r2}{r1}$$

$$= \frac{2.3q}{(Z^2 - Z^2)} \ \log 10 \ \frac{r2}{r1}$$

The pumping out test is used where the bedrock is very deep or where the permeability of different strata are required at intervals during the test.

The coefficient of permeability of the soil depends on the porosity which in itself is related to the particle size distribution curve of the soil e.g a gravel and clay material the gravel will be more permeable therefore it will seems possible to know the particle size distribution.