LECTURE NOTES ON

IRRIGATION AND DRAINAGE ENGINEERING

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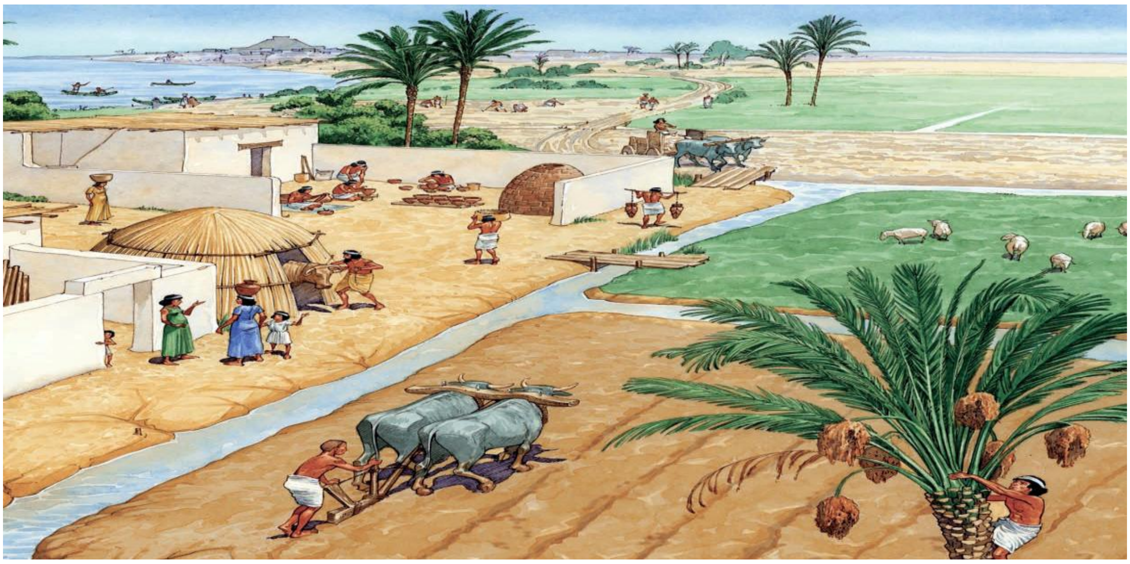
Chapter 1

Water, Irrigation and Drainage



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Chapter 1

Water, Irrigation and Drainage

1-1 Water on the Earth:

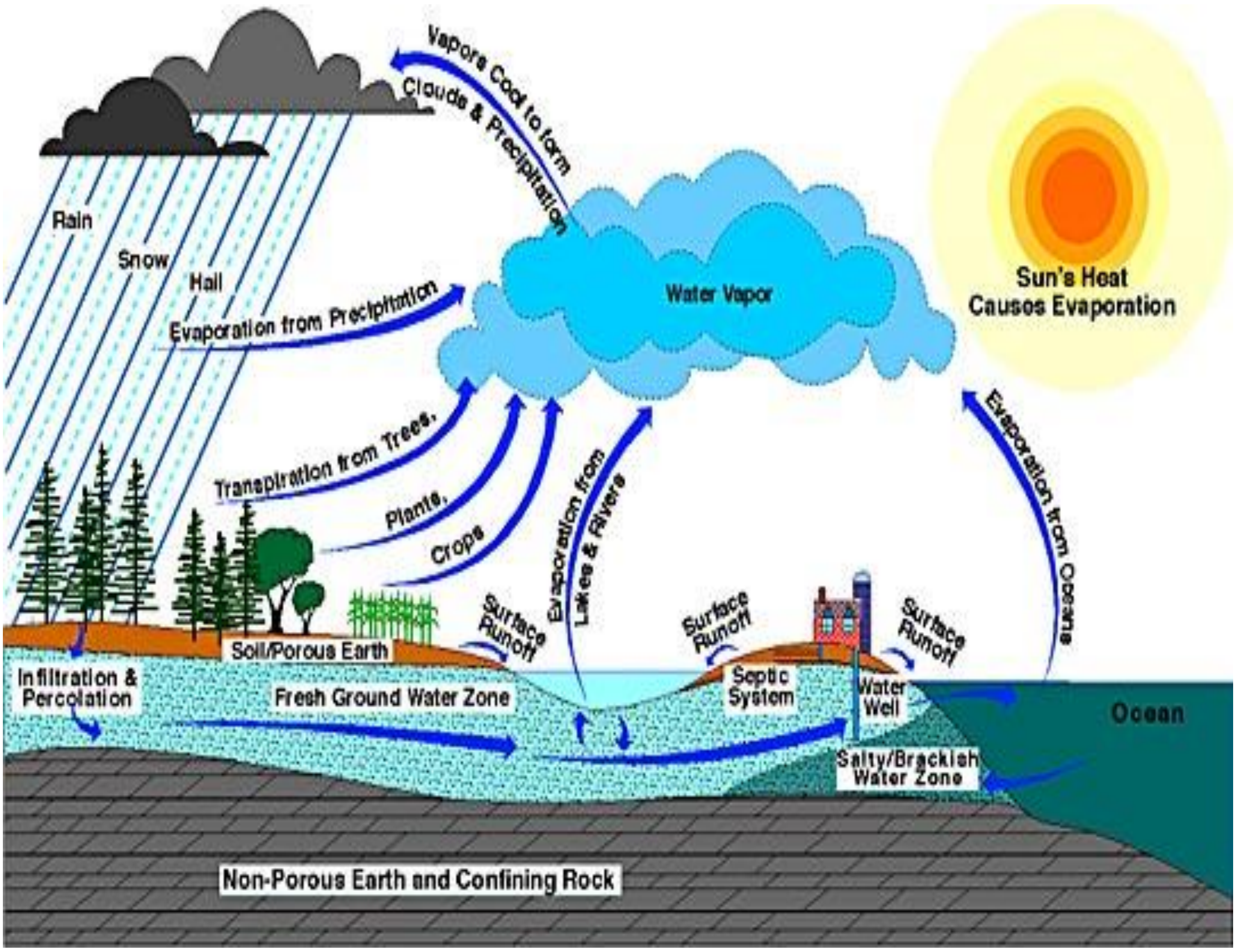


Figure (1-1): Hydrologic Cycle

The hydrologic cycle describes the continuous re-circulating transport of the waters of the earth, linking atmosphere, land and oceans.

Component	Volume 1000 km³	% of Total Water
▪ ***Atmospheric water***	13	0.001
▪ ***Surface Water***		
Salt Water in Oceans	1320000	97.2
Salt water in lakes & inland seas	104	0.008
Fresh water in lakes	**125**	0.009
Fresh water in stream channels	**1.25**	0.0001
Fresh water in glaciers and icecaps	29000	2.15
Water in the biomass	50	0.004
▪ ***Subsurface water***		
Vadose water	67	0.005
G/W within depth of 0.8 km	**4200**	0.31
G/W between 0.8 and 4 km depth	4200	0.31
Total (rounded)	1360000	100

Table (1-1): Global Water Balance

The basic hydrologic equation that is applied either on global or regional scale is:

$$\mathbf{I - O = \Delta S}$$

Where: I = inflow, O = outflow & ΔS = change in storage

Inflow (I):

1. Precipitation.
2. Import: *defined as* water channeled into a given area.
3. Groundwater inflow from adjoining areas.

Outflow (O):

1. Surface runoff outflow.
2. Export*: defined as* water channeled out of the same area.
3. Evaporation.
4. Transpiration.

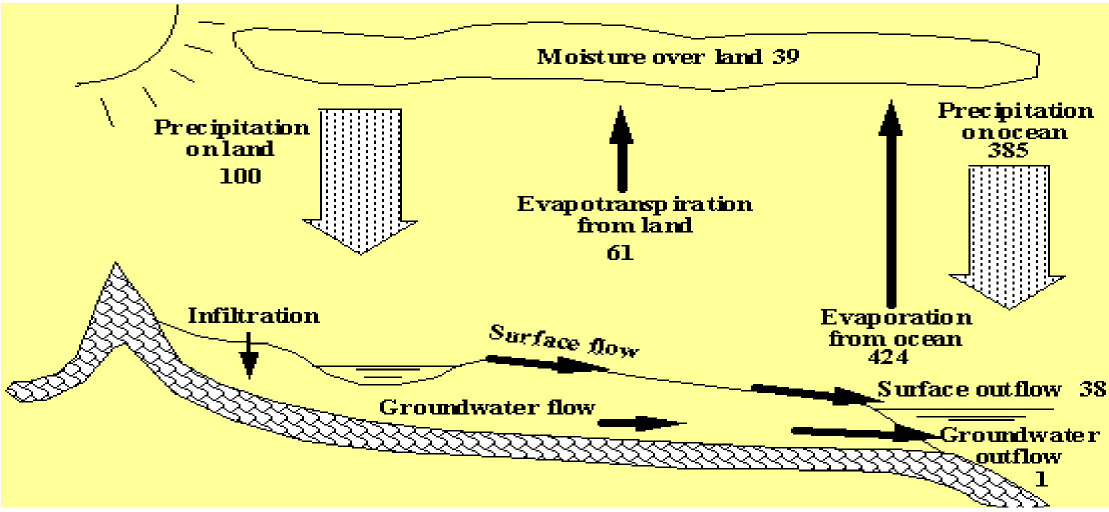
Change in Storage (ΔS):

This occurs as change in:

1. Groundwater.
2. Soil moisture.
3. Surface reservoir water and depression storage.
4. Detention Storage.

$\Delta S = I - O$ **OR** $\Delta S = P - R - ET - F$ **OR** $ET + F = P - R - \Delta S$

Example (1-1): *Global Water Balance*



1) In the atmosphere:

Precipitation (P) = Evapo-transpiration (ET)

100 + 385 = 61 + 424

2) On land:

P = Evapo-transpiration (ET) + Surface runoff (R) + Groundwater outflow

100 = 61 + 38 + 1

3) Over oceans and seas:

Ocean precipitation + Surface runoff + Groundwater outflow = Evaporation (E)

385 + 38 + 1 = 424

Surface Water: Lakes – Reservoirs – Rivers, Streams, Irrigation Canals.

Ground Water: Springs – Shallow Wells – Deep Wells.

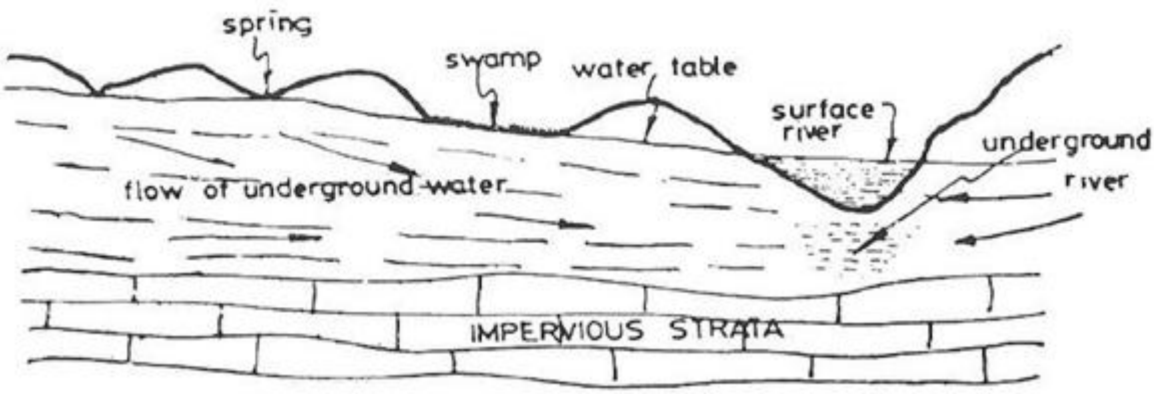


Figure (1-2): Ground Water Table

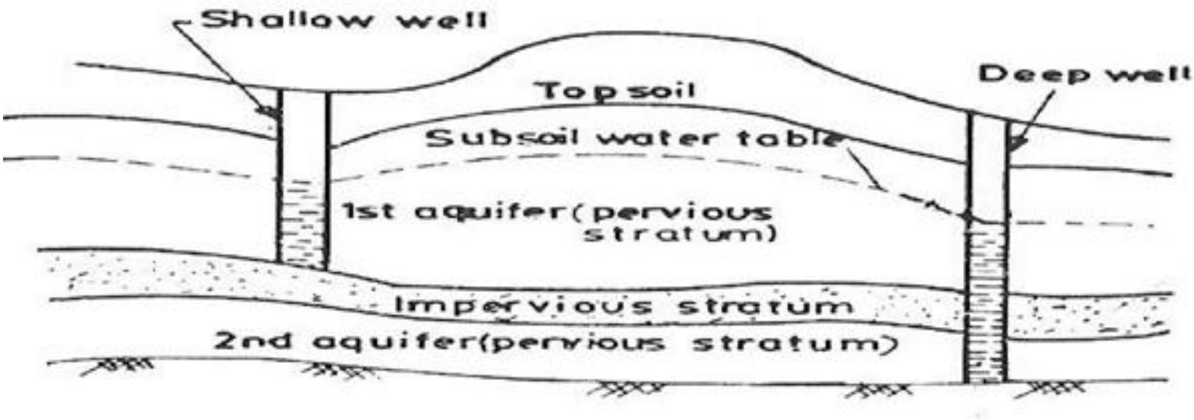


Figure (1-3): Shallow and Deep Wells

A ***Catchment*** is a portion of the earth's surface that collects runoff and concentrates it at its furthest downstream point, referred to as the catchment outlet. Generally, ***watershed*** is used to describe a small catchment (stream watershed), whereas ***basin*** is reserved for large catchments (river basins).

Example (1-2):

Four inches of runoff resulted from a storm on a drainage area of 50 mi^2.
What is the amount of this runoff in cubic meters?

Solution

$$R = 4 \text{ x } \{2.54 / 100\} \text{ x } 50 \text{ x } \{(1.609)^2 \text{ x } (1000)^2\} = 13.15 \text{ x } 10^6 \text{ m}^3$$

Example (1-3):

In a given year, a catchment with an area of 2500 km^2 received 1.3 m of precipitation. The average rate of flow measured in a river draining the catchment was 30 m^3/s.

1) How much total river runoff occurred in the year (in m^3)?
2) What is the runoff coefficient?
3) How much water is lost due to the combined effects of evaporation, transpiration, and infiltration (in m)?

Solution

1) Total runoff volume = number of seconds in a year x average flow rate
= (365x24x60x60) x 30 = 9.4608 x10^8 m^3

2) Runoff coefficient = Runoff volume / precipitation volume
= (9.4608 x10^8) / {1.3 x (2500 x 10^6)} = 0.29 = 29 %

3) $\Delta S = I - O$

$\Delta S = P - R - ET - F$

$ET + F = P - R - \Delta S$

Assume, $\Delta S = 0$ (no change in storage)

$ET + F = P – R$

$P = \{1.3 \times (2500 \times 10^6)\} = 3.25 \times 10^9\ m^3$

$R = 9.4608 \times 10^8\ m^3$ (total runoff volume)

$ET + F = P – R = 3.25 \times 10^9 – 9.4608 \times 10^8 = 2.30392 \times 10^9\ m^3$

$= (2.30392 \times 10^9) / (2500 \times 10^6) = 0.92\ m$

Example (1-4):

In a given year, a 10,000 mi^2 watershed received 20 inches of precipitation. The average rate of flow measured in the river draining the area was 6,000 cfs.

Calculate the combined amounts of water evaporated and transpired from the region during this year?

Solution

$\Delta S = I – O$

$\Delta S = P – R – ET – F$

$ET + F = P – R – \Delta S$

Assume, $\Delta S = 0$ & $F = 0$

$ET = P – R$

$$R = \frac{6000 \times \{(12)^3 \times 3600 \times 24 \times 365\}}{10000 \times \{(1760)^2 \times (3)^2 \times (12)^2\}} = 8.14 \text{ in / year}$$

$ET = 20 – 8.14 = 11.86$ in / year

Example (1-5):

A vertical wall reservoir has an area of 500 acre. During a day, the inflow was 100 cfs and the evapo-transpiration was 1.0 inch.

1) Is water stored in the reservoir?
2) If yes, calculate the stored water?

Solution

$\Delta S = I – O$

$\Delta S = P – R – ET – F$

$P = Q$ & $R = 0$ Assume, $F = 0$

$\Delta S = Q – ET$

$Q = 100 \times (12)^3 = 172800 \times \{3600 \times 24\} = 1.49 \times 10^{10}\ in^3 / day$

$$= \frac{1.49 \times 10^{10}}{500 \times 4047 \times (3.28)^2 \times (12)^2} = 4.76 \text{ in}$$

1) $Q > ET$

$\therefore$ Water is stored in the reservoir

2) $\Delta S = 4.76 – 1 = 3.76$ in

1-2 Irrigation:

Irrigation is providing the soil artificially with water to achieve the required moisture for the plants' growth. This process is needed for both arid regions, where no rainfall, and semi-arid regions, where the available rainfall is not sufficient for the plants' growth.

Irrigation science is allocating water from its different sources, conveying water through irrigation channels to the required areas and distributing water according to the various kinds of soils and plants. Storing water may be needed in some cases according to the balance between the available water and the requirements of the plants (amounts and times).

In fact, in order to detect the suitable kinds of crops and both amounts and rates of irrigation water, many factors have to be studied concerning the soil, meteorology and hydrology.

- Soil science includes texture, thickness, depth to the impermeable layers, salinity and alkalinity, porosity, and topographic of the ground surface.

- Meteorology science studies the phenomena of the weather such as temperature, relative humidity, speed and direction of the wind.

- Hydrology science includes studying of in and out operations for all different surface and underground sources of water.

It has to be noted that the science of hydraulics is essential in all irrigation works. It guarantees the proper motion of water according to the required rates and levels.

1-3 The Soil:

Components of the soil are different from one site to another, and sometimes are different in the same site. However, the soil consists of solid particles with irregular shapes and different sizes. To identify various types of the soil, the solid particles are assumed to be found as regular spheres with different sizes. Table (1-2) shows the classification of soil particles into groups according to the diameter of the particles.

A mechanical analysis can be made for a soil sample in order to detect the ratios of different groups of the particles. Ratios are determined according to the weights with respect to the total weight of the soil sample. The soil type can be found using soil texture triangle, as shown in figure (1-4).

The Group	Diameter of the Particles (mm)
Gravel	> 1
Course Sand	1 - 0.5
Medium Sand	0.50 - 0.25
Smooth Sand	0.25 - 0.10
Very Smooth Sand	0.10 - 0.05
Silt	0.05 - 0.005
Clay	< 0.005

Table (1-2): Classification of Soil Particles.

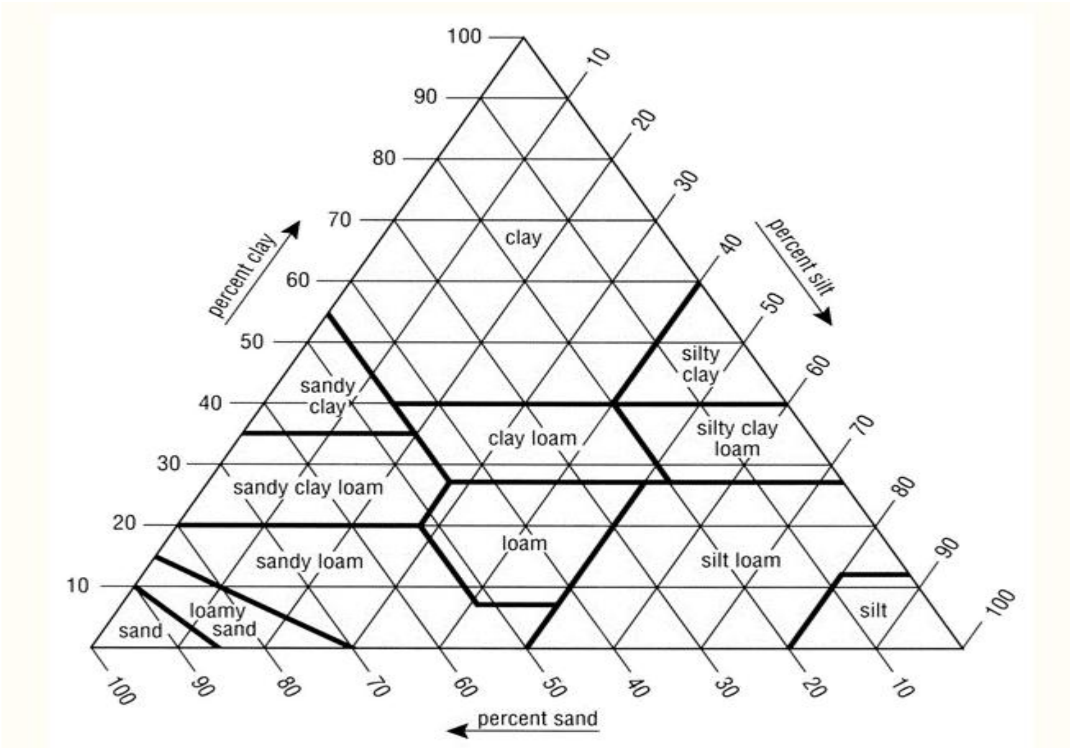


Figure (1-4): Soil Texture Triangle

<u>Example (1-6):</u>

<u>From the Soil Texture Triangle:</u>

1) Find the soil texture for the combination 10% sand, 85% silt, 5% clay?
2) State the soil texture for the combination 40% sand, 30% silt?

<u>Solution</u>

1) Silt.
2) Clay loam.

The volume of the solid particles for any soil does not represent the volume of the soil, where there are voids (or pore spaces) between these particles. For a soil profile, as shown in figure (1-5), the voids between the solid particles are occupied by both the air and the water. When the voids of the soil are fully occupied by only the water, then the soil is called a saturated soil. The air - water balance represents the ratio between the air and the water existed in the voids of the soil.

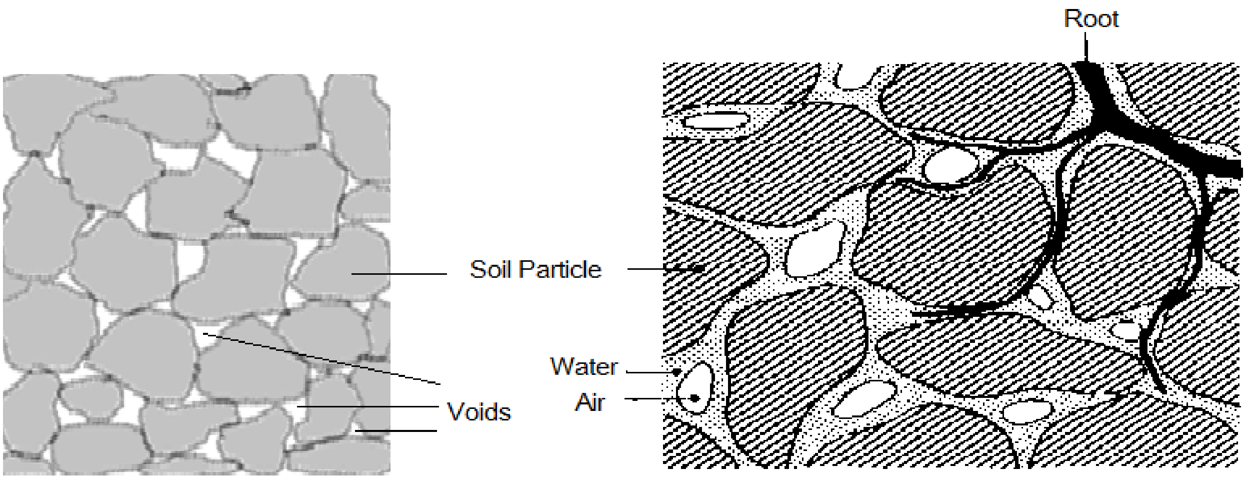


Figure (1-5): Soil Profile

1-4 <u>Water in Soil:</u>

When water is added to the ground surface either by artificial irrigation (or rainfall), a part of the water penetrates the ground surface to the pore spaces of the soil. Water moves downward due to the gravitational force.

The upper layers of the soil hold a fraction of the water due to the hygroscopic property of the solid particles and the surface tension force. The hygroscopic property of the solid particles of the soil is that these particles allocate moisture (water) from the atmosphere which contains water vapor.

If water is still added to the ground surface, the pore spaces of the upper layers of the soil are fully filled with water. Consequently, these layers become saturated.

Adding more water, water motion will occur in the lower layers of the soil.

The root zone, where the roots of plants grow, includes the upper layers of the soil, as shown in figure (1-6). From the agricultural point of view, water in the root zone is important to get maximum crop yields.

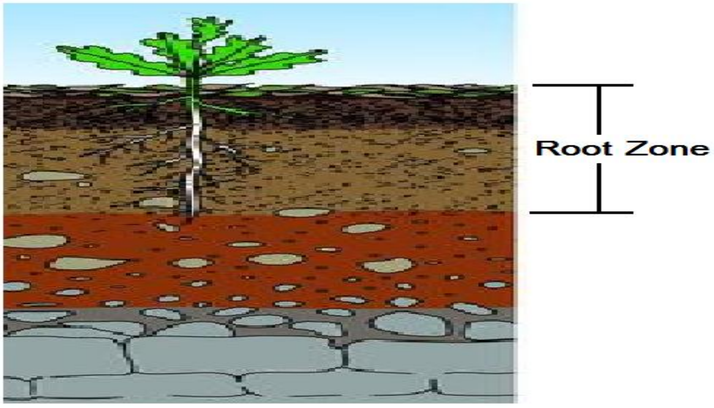


Figure (1-6): The Root Zone

♦ As shown in figure (1-7), water in the soil can be divided into three forms:

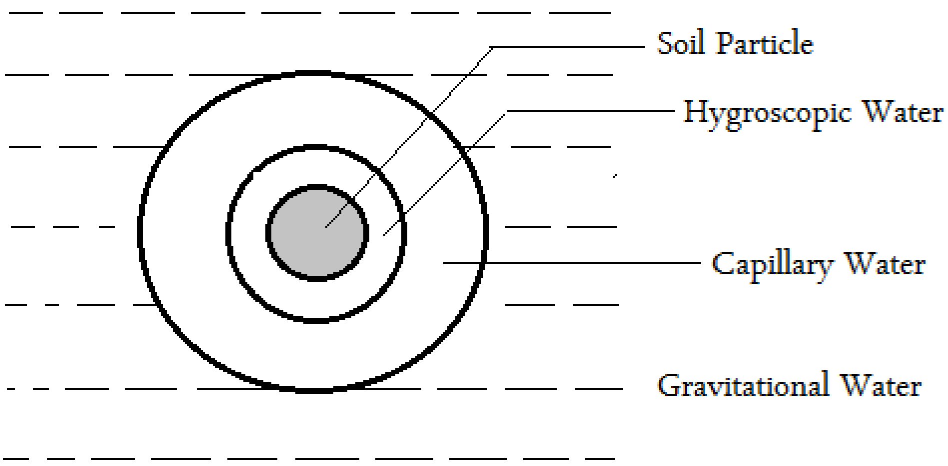


Figure (1-7): Forms of Water in the Soil

1) Hygroscopic Water:

It is a thin film of water around the soil particle. It is held to the soil particle by a great force that prevents water to move in any direction.

Thus, this form of water is unavailable to the plants.

2) Capillary Water:

It is a thick film of water around the soil particle next to the hygroscopic film. It is held to the soil particle by the force of surface tension. This water moves in all directions forming capillary zones. In the capillary zone, the air - water balance can be achieved where both air and water are found together. Thus, the roots of plants can breathe and grow, where the bacteria can grow and transport the essential elements from the soil to the roots.

3) Gravitational Water:

It includes water outside the hygroscopic and the capillary films. This form of water occupies the pore spaces of the soil, especially the big voids, and it moves downward due to the gravitational force.

When the quantity of the gravitational water increases, the upper layers of the soil (root zone) become saturated. For saturated soil, the pore spaces are filled only by water and there will be no air. The roots of plants cannot find air and the plants die.

1-5 Drainage:

It is removing the excess gravitational water from the root zone of the soil to achieve the air - water balance and to permit the plants use well the capillary water.

It is obvious that the root zone of the soil, which represents the upper layers of the soil in which the roots of plants live, has not to reach the saturation case. So, the drainage process has to be employed.

1-6 Soil Moisture Coefficients:

These coefficients define the limits for the moisture contents in the soil according to the different forms of water.

These coefficients may be called also the “Soil Constants”.

Water content can be quantified on both a gravimetric (g water/g soil) and volumetric (cm^3 water/ cm^3 soil) basis. The volumetric expression of water content is used most often. Since 1 gram of water is equal to 1 cm^3 of water, the weight of water can easily be determined and immediately its volume is known.

1) Hygroscopic Coefficient:

It is the maximum moisture content that the soil can take from a surrounding atmosphere of a certain relative humidity. This coefficient is approximately 0.5 - 2 % for sandy soils, 4 - 9 % for silt soils and 11 % for clayey soils.

2) Wilting Point:

It is the moisture content in the soil that the plant cannot adsorb. The wilting point can be determined by measuring the moisture left in a soil sample after being exposed to a force = 15 atmospheric pressure in a centrifugal instrument.

However, the wilting point is about 1 - 3 % for sandy soils, 6 - 13 % for silt soils and 16 % for clayey soils.

3) Field Capacity:

It is the maximum moisture content that the soil can keep after being drained, which occurs at 1-3 days after irrigation. The field capacity can be determined by measuring the moisture left in a soil sample after being exposed to a force = 1/3 atmospheric pressure in a centrifugal instrument.

At the field capacity, the films of the capillary water have the maximum thickness. So, this is the best case for the plants' growth where the air - water balance is well achieved.

But it has to be noted that the soil can keep its field capacity only for a short period of time. That is because of the weather conditions, the soil properties and the retention power by which the soil can keep the moisture. The sandy soils keep moisture less than the silt soils. Also, the silt soils keep moisture less than the clayey soils.

4) Maximum Water Capacity:

It is the moisture content when the soil is fully saturated (all the pore spaces of the soil are filled with water).

Figure (1-8) illustrates the main soil moisture coefficients.

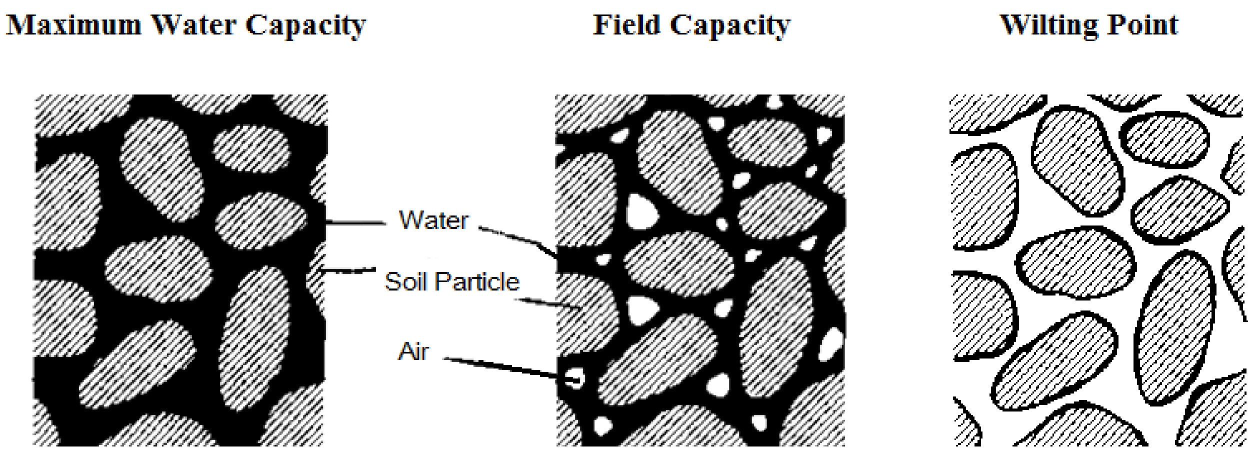


Figure (1-8): Soil Moisture Coefficients

1-7 <u>Classification of Water in the Soil according to Plants' Usage:</u>

1) Excess Water:

It is the moisture content more than the field capacity of the soil. This water percolates to the deep layers of the soil (below root zone) where the plant cannot use.

2) Total Available Water:

It is the moisture content in the range between the field capacity and the wilting point. The plant can use this water in general.

3) Readily Available Water:

Practically, the wilting point has not to be reached to avoid difficulties in the plants' growth. So, the readily available water is assigned to be equal to 2/3 - 3/4 of the total available water.

4) Unavailable Water:

It is the moisture content less than the wilting point.

Figure (1-9) shows a scheme diagram for the classification of water in the soil according to the plants' usage.

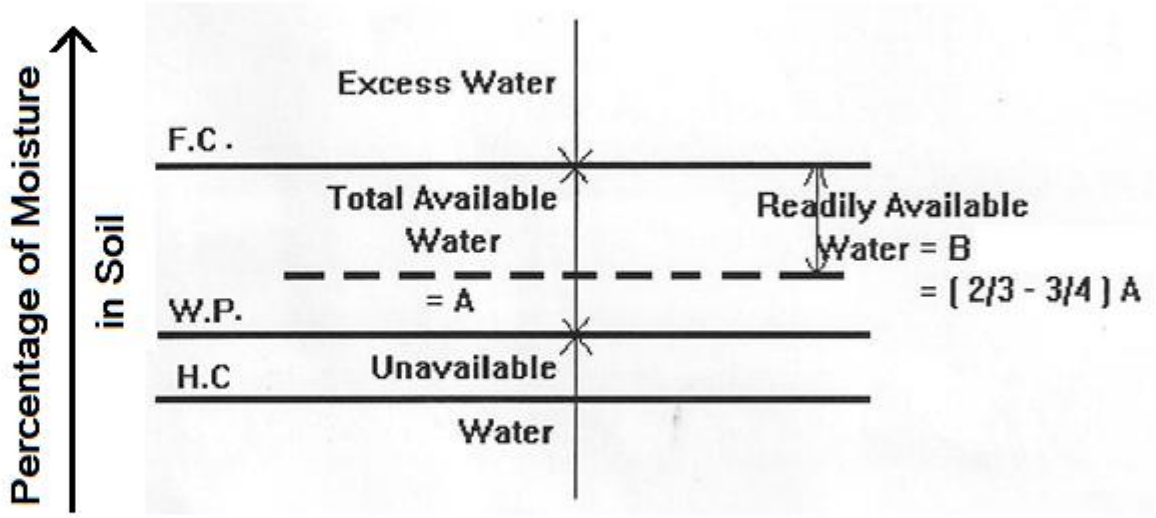


Figure (1-9): Classification of Water in the Soil according to the Plant's Usage

1-8 <u>Consumptive Use:</u>

It is the quantity of water required, in a certain period, for the plant's growth in addition to the losses due to the transpiration and evaporation processes.

<u>The transpiration</u> is losing water through the leafs of the plant, while <u>the evaporation</u> is losing water from the soil cultivated by the plant.

The consumptive use is expressed as a volume of water or an equivalent depth of water. For irrigation science, in general, quantities of water are expressed as either volumes or equivalent depths.

The rainfall, for example, in an area is said to be 1.5 mm/day. This depth represents a quantity of water, which can also be expressed *as follows:*

For an area of one feddan, the common unit for areas in Egypt:

The quantity of water from the rainfall = (1.5/1000) x 4200 = 6.3 m^3/Fed/day

- One feddan is equal to 4200 m^2.
- One acre is equal to 4000 m^2.
- One hectare is equal to 10,000 m^2.

The following equation is employed to calculate ***the consumptive use (C)*** in each one irrigation process per feddan (unit area).

$$C = 4200 \text{ x R x } \frac{\gamma_s}{\gamma_w} \text{ x RAW}$$

Where,
- C : The consumptive use, m^3/Fed.
- 4200 : 1 Feddan = 4200 m^2.
- R : Effective root depth, m.
- γ_s : Specific weight of the soil, t/ m^3.
- γ_w : Specific weight of the water, γ_w = 1 t/m^3.
- RAW : Readily available water, % - age ratio.

The maximum period, in days, between irrigation processes **(P_{max})** can then be calculated *as follows:*

$$P_{max} = \frac{C}{F}$$

Where, F : The field irrigation requirements, m^3/Fed/day.

The field irrigation requirements **(F)** is the quantity of water required daily including the field losses per feddan. The field losses include the water lost due to surface run-off and deep percolation.

$$F = \frac{D - r_e}{1 - L_f}$$

Where,
- D : The daily consumptive use, m^3/Fed/day.
- r_e : The quantity of effective rainfall, m^3/Fed/day.
- L_f : The field losses, % - age ratio.

For arid regions, there is no rainfall.
For semi-arid regions, the quantity of rainfall is small.
However, the quantity of effective rainfall is assumed to be zero if it is not given in the problems.

It has to be noted that giving less quantities of water in each irrigation process with less periods between irrigation processes, will decrease the field losses and consequently will increase the efficiency of the field irrigation.

The field water duty **(F.W.D.)** is the quantity of water applied to the field and it is expressed as m^3/Fed/day.

$$\text{FWD} = \frac{\text{F x P}_{\text{max}}}{\text{On Interval}}$$

Where, On-interval is the number of days in which irrigation is permitted by the water existed in the canals.

The irrigation water reaches the field from the main source of water through a network of canals. So, there will be losses due to conveying water from the main source to the field.

The conveyance losses include seepage of water from the bed and the sides of the canals, evaporation of water from the surfaces of the canals, and transpiration by plants and weeds along the canals.

These losses are considered when calculating the water duty for the canals *as follows:*

D.C.W.D. = F.W.D. x 1.10

B.C.W.D. = F.W.D. x 1.15

M.C.W.D. = F.W.D. x 1.20

Where,
D.C.W.D.: Distributor canal water duty.
B.C.W.D.: Branch canal water duty.
M.C.W.D.: Main canal water duty.

Example (1-7):

An area of clayey soil has 1.2 t/m^3 specific weight, 36 % field capacity and 20 % wilting point. This area is cultivated by cotton that requires a quantity of water of 24 m^3/day for each one feddan in July when its effective root depth is 90 cm.

1) If the field losses are 40 %, determine the field irrigation requirements?
2) Calculate the maximum period between irrigation processes?
3) If the on-interval is 5 days, determine the water duties for the field and the distributor canal?
4) Explain in detail how to increase the efficiency of the irrigation process?

Solution

Given:

γ_S = 1.2 t/m^3	F.C. = 0.36
W.P. = 0.20	D = 24 m^3/fed/day
R = 90 cm = 0.9 m	r_e = 0 (as it is not given)
L_f = 0.40	On-interval = 5 days

Required:

1) F?
2) P_{max}?
3) F.W.D. & D.C.W.D.?
4) How can the efficiency of irrigation process be increased?

Solution:

1) $F = \frac{D - r_e}{1 - L_f}$ $\qquad F = \frac{24-0}{1-0.4}$ = 40 m^3/Fed/day

2) $P_{max} = \frac{C}{F}$

$C = 4200 \text{ x } R \text{ x } \frac{\gamma_s}{\gamma_w} \text{ x RAW}$

RAW = = (2/3 - 3/4) x (F.C. - W.P.) = (3/4) x (0.36 - 0.20) = 0.12

Assume γ_W = 1 t/m^3

$C = 4200 \text{ x } 0.9 \text{ x } \frac{1.2}{1} \text{ x } 0.12$ = 544.3 m^3/Fed

$P_{max} = \frac{544.3}{40}$ = 13.6 ≈ 13 days

3) $FWD = \frac{F \text{ x } P_{max}}{\text{On Interval}} = \frac{40 \text{ x } 13}{5}$ = 104 m^3/Fed/day

D.C.W.D. = F.W.D. x 1.10

D.C.W.D. = 104 x 1.1 = 114.4 m^3/fed/day

4) Discussion.

1-9 Crop Rotation:

It is the sequence of different crops cultivated in the land during a specific period.

The objectives of the crop rotation are as follows:

1) Maintaining the land suitable for being cultivated. That is by keeping a balance between the different food elements in the soil. Each crop needs a specific kind of food elements in the soil. Some crops leave in the soil some food elements which are useful for other crops.
2) Optimum usage of the soil and the subsoil. That is by cultivating the crops of short roots after the crops of tall roots, and so on.
3) Giving a sufficient time for land service. That is by choosing the crops such that there will be enough time between collecting the old crop and cultivating the new crop.
4) Rehabilitating some lands by leaching them from salts. That is by cultivating these lands with rice.
5) Improving the properties of some lands and providing them by natural organic fertilizers. That is by cultivating these lands with clover.

The kinds of the crop rotation are as follows:

1) Two turn rotation, where the crop is cultivated each two years.
2) Three turn rotation, where the crop is cultivated each three years.
3) Special rotation, where the main objective is to leach and improve the properties of the lands required to be reclaimed.

1-10 Irrigation Rotation:

Water is discharged in the distributor canals for a specific period of time called "working period" or "on-interval". Then, water is prevented from being discharged in these canals for other period of time called "closing period" or "off-interval". The sum of the two periods is called "the length of the irrigation rotation".

The objectives of the irrigation rotation are as follows:

1) Protecting the lands beside the distributor canals from continuous seepage of water. That is because the distributor canals in the off-intervals act as drains that collect the excess water percolated to these lands during the on-intervals.
2) Helping the irrigation engineer to supervise different areas in sequent periods, which leads to achieving the required distribution of water among the different canals.

3) Helping the farmer to irrigate the land in the on-interval, and to do the required agricultural processes in the off-interval.
4) Decreasing the dimensions required for the sections of the canals. So, the cost is decreased.
5) Decreasing the losses, where the water does not exist in the canals for long periods.

Two factors have to be considered in the irrigation rotation:

a) The on-interval has to be actually sufficient for allowing water to fill the distributor canals and to reach the designed levels. It has to be also sufficient for allowing the farmers to irrigate the land.

b) The maximum period between the irrigation processes detects the length of the irrigation rotation. This maximum period depends on the soil moisture coefficients of the soil and the kind of the cultivated crop, as discussed previously. If several crops are cultivated, then the crop of minimum P_{max} will detect the length of the irrigation rotation.

The irrigation rotation can be classified according to:

1) Period of the year at which the irrigation rotation is executed:

1. Summer irrigation rotation: It is done from the half of April either till the half of August if three turn rotation (6 and 12 days, for cotton and sharaki) or till the half of September if two turn rotation (4 and 4 days, for rice, cotton and sharaki).

2. Nile irrigation rotation: It is done from the half of August till the end of November. It may be either three turn rotation (5 and 10 days, for cotton) or two turn rotation (4 and 4 days, for rice).

3. Winter irrigation rotation: It is done from the end of November till the half of March. It is usually three turn rotation (6 and 12 days). It includes the period of January where no water for irrigation is discharged. Establishing the required irrigation constructions, maintenance and cleaning of the canals are well executed during this month.

4. Spring irrigation rotation: It is done from the half of March till the half of April. It is usually three turn rotation (5 and 10 days).

2) Number of turns:

First of all, for planning an irrigation network, it has to be noted that any canal is represented by a continuous line. This line has the symbol (H.R.) at its beginning to represent the head regulator (H.R.) necessary for distributing the water. Also, each canal has to end at a suitable drain (a dashed line) through a tail escape (T.E.) with the symbol (T.E.). That is to dispose safely any excess water from the canal into the drain.

1. <u>*Two turn irrigation rotation:*</u>

The distributor canals are divided into two turns A and B of almost equal area served. One intermediate regulator (I.R.) or partial regulator (P.R.) is constructed on the branch canal at the location that divides the total area served into the two turns A and B, as shown in figure (1-10).

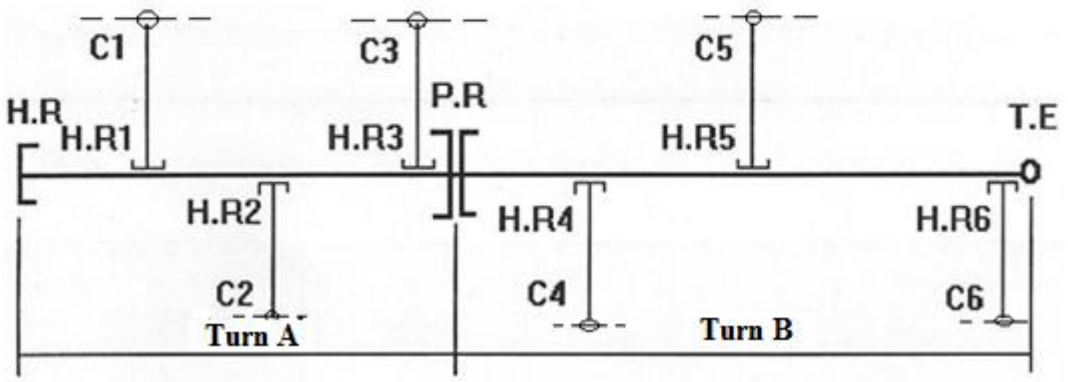


Figure (1-10): Two Turn Irrigation Rotation

At the beginning of the two turn rotation, the P.R. is closed to keep the water required for the group A. The head regulators H.R.1, H.R.2 and H.R.3 are opened for passing the water into the distributor canals C1, C2 and C3. This process continues during the first interval, as shown in figure (1-11).

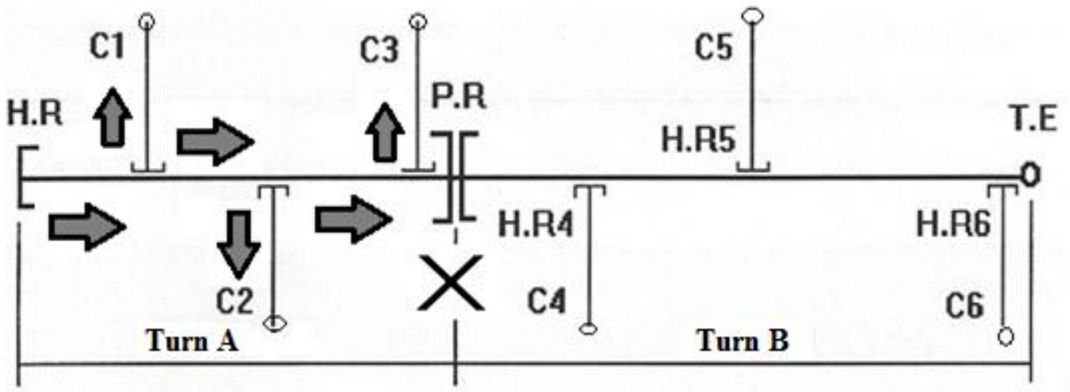


Figure (1-11): Turn A of Two Turn Irrigation Rotation

It has to be noted that the two turn rotation is composed of two equal intervals. The first interval is on-interval for the distributor canals of group A, and also it is off-interval for the distributor canals of group B.
Similarly, the second interval is off-interval for the distributor canals of group A, and also it is on-interval for the distributor canals of group B.

However, for the second interval, the P.R. is opened to pass the water required for the group B. The head regulators H.R.1, H.R.2 and H.R.3 are closed to pass no water, while the other head regulators H.R.4, H.R.5 and H.R.6 are opened for passing the water into the distributor canals C4, C5 and C6, as shown in figure (1-12).

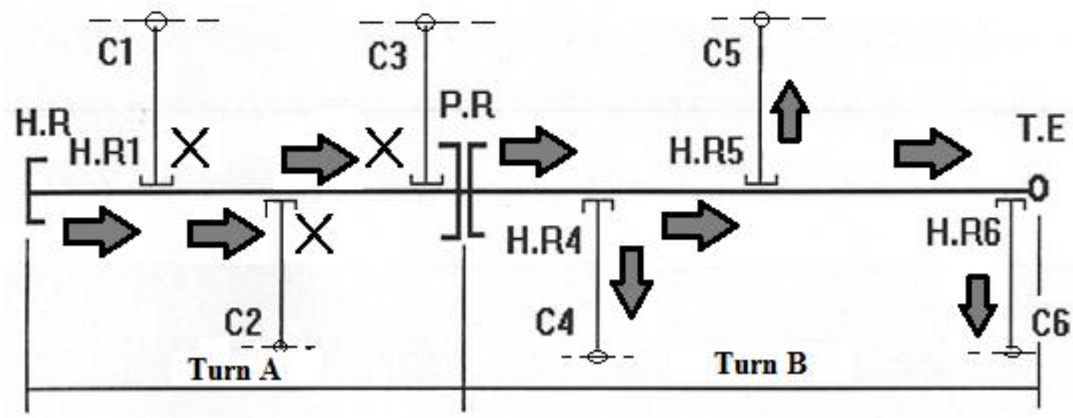


Figure (1-12): Turn B of Two Turn Irrigation Rotation

Thus, the two turn irrigation rotation continues according to this sequence.

2. *Three turn irrigation rotation:*

The distributor canals are divided into three groups A, B and C of almost equal area served. Two partial regulators (P.R.1 and P.R.2) are constructed on the branch canal at the two locations that divide the total area served into the three groups A, B and C, as shown in figure (1-13).

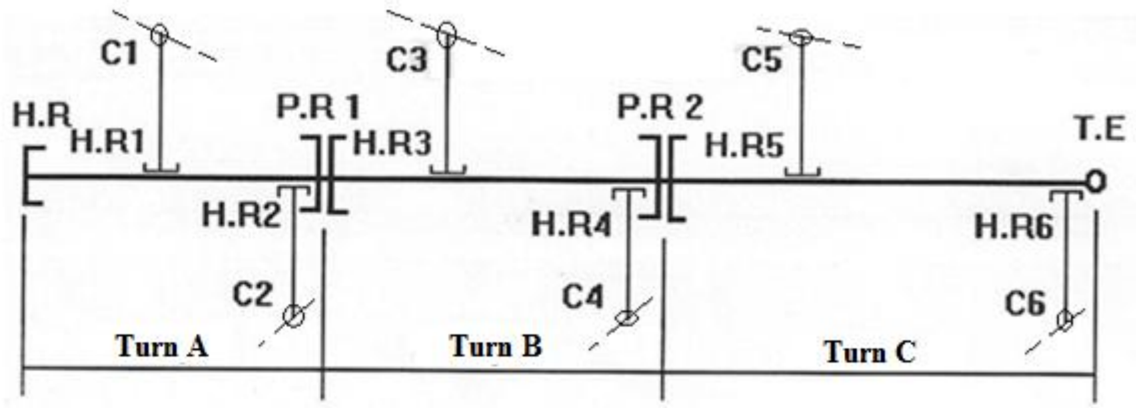


Figure (1-13): Three Turn Irrigation Rotation

It has to be noted that the three turn irrigation rotation is composed of three time intervals. For the first interval, the P.R.1 is closed to keep the water required for the group A. The head regulators H.R.1 and H.R.2 are opened for passing the water into the distributor canals C1 and C2. Thus, the group A is irrigated, as shown in figure (1-14).

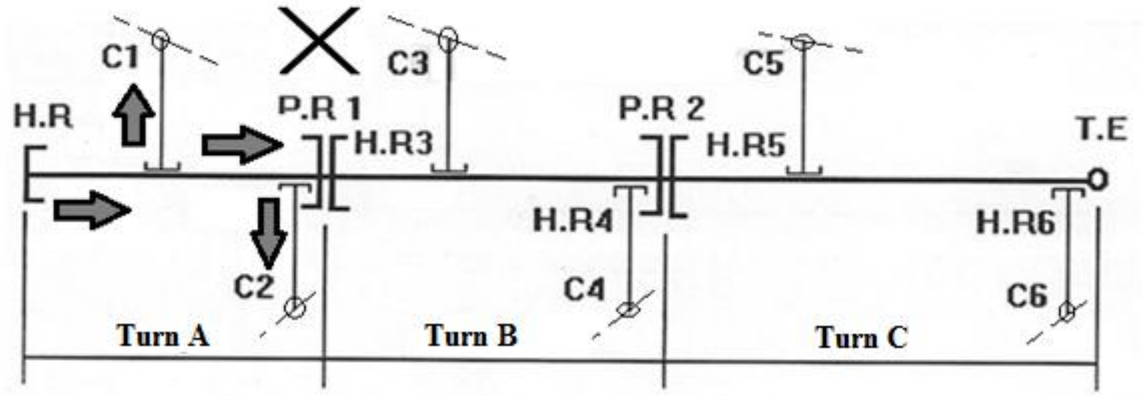


Figure (1-14): Turn A of Three Turn Irrigation Rotation

Similarly, for the second interval, H.R.1, H.R.2 and P.R.2 are closed, while H.R.3, H.R.4 and P.R.1 are opened. Thus, the group B is irrigated, as shown in figure (1-15).

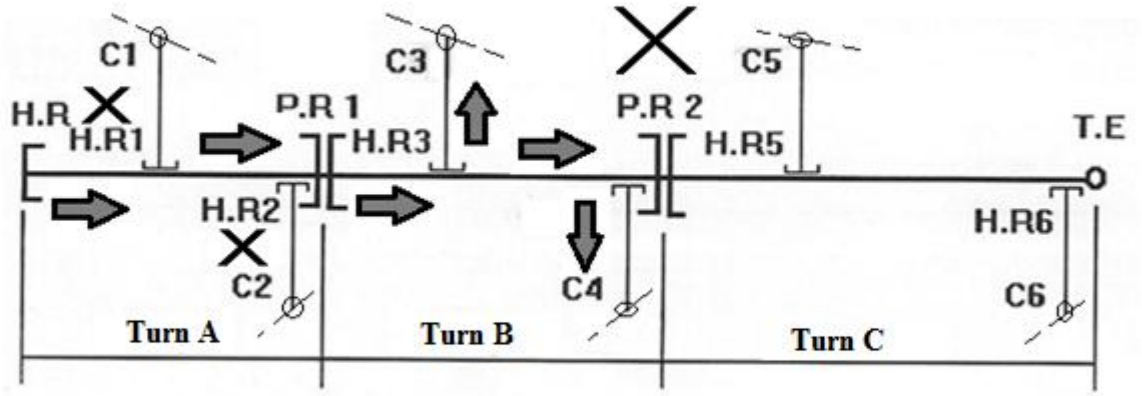


Figure (1-15): Turn B of Three Turn Irrigation Rotation

Following the same sequence, for the third interval, H.R.1, H.R.2, H.R.3 and H.R.4 are closed, while H.R.5, H.R.6, P.R.1 and P.R.2 are opened. Thus, the group C is irrigated, as shown in figure (1-16).

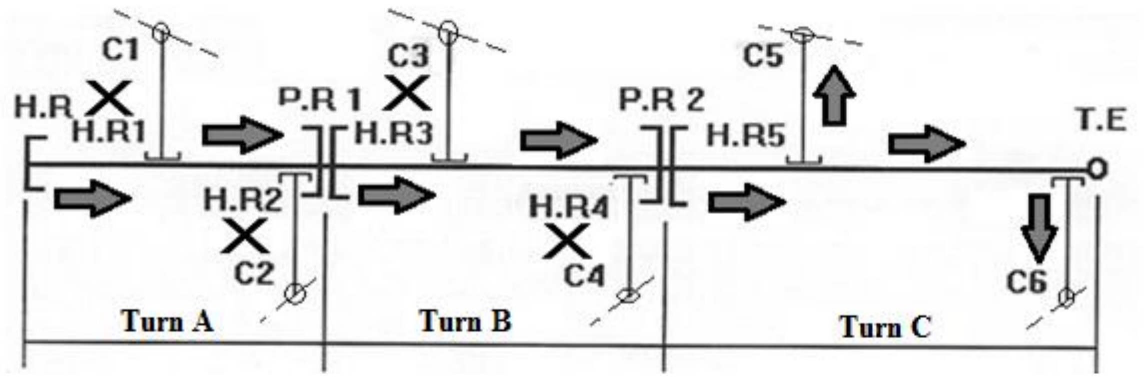


Figure (1-16): Turn C of Three Turn Irrigation Rotation

Thus, the three turn irrigation rotation continues in the same manner.

Example (1-8):

A branch canal of 25 km length serves an area of 48,400 feddan and has 6 distributor canals *as follows:*

Canal	Km	Location	Area Served, Fed
C 1	10.0	Left	5,400
C 2	10.0	Right	11,100
C 3	15.0	Left	10,000
C 4	15.0	Right	6,010
C 5	21.0	Left	5,900
C 6	21.0	Right	8,000

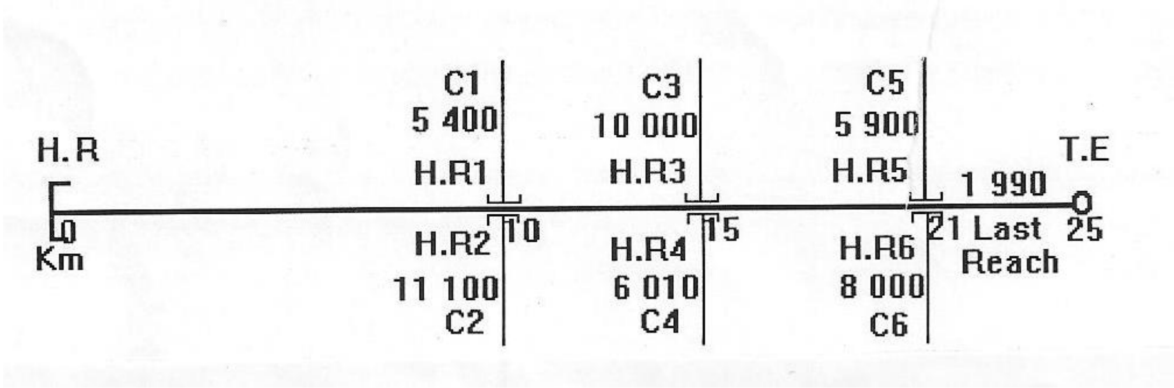
It is required to draw a diagram for the branch canal with its distributor canals indicating the locations of suggested constructions and showing the area served for each turn *in the cases of:*

1) Two turn irrigation rotation?
2) Three turn irrigation rotation?

Solution:

The sum of area served for the 6 distributor canals =
5,400 + 11,100 + 10,000 + 6,010 + 5,900 + 8,000 = 46,410 Fed

∴ The area served by direct irrigation after km 21.00 =
48,400 – 46,410 = 1,990 Fed

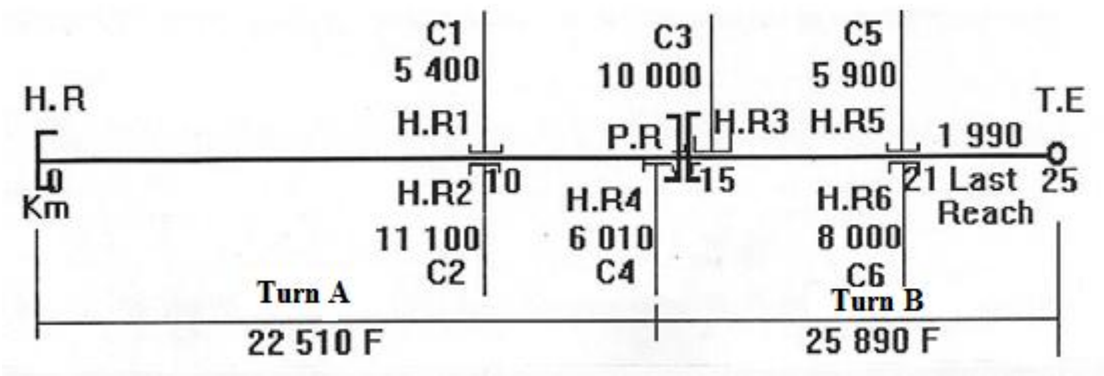


1) ***Two turn irrigation rotation:***

Average required area served for each turn = 48,400 / 2 = 24,200 Fed

∴ For the first turn, take group A = C1 + C2 + C4 = 22,510 Fed

& For the second turn, take group B = C3 + C5 + C6 + L.R. = 25,890 Fed



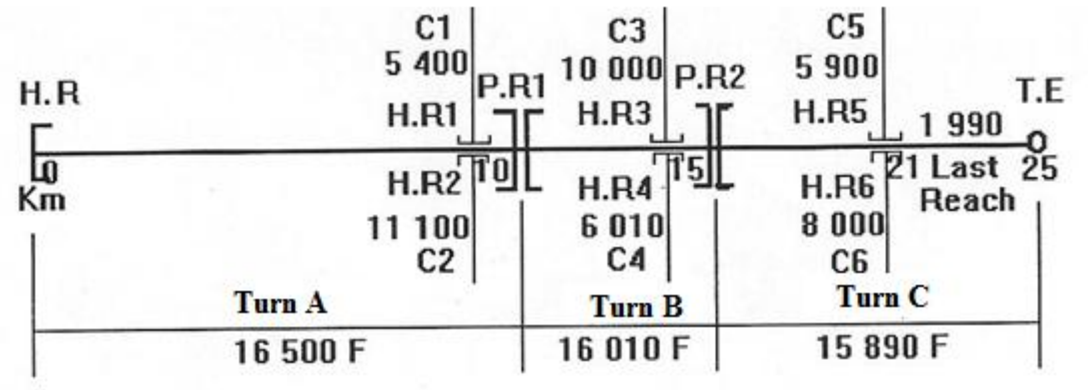
2) ***Three turn irrigation rotation:***

Average required area served for each turn = 48,400 / 3 = 16,133.3 Fed

∴ For the first turn, take group A = C1 + C2 = 16,500 Fed

& For the second turn, take group B = C3 + C4 = 16,010 Fed

& For the third turn, take group C = C5 + C6 + L.R. = 15,890 Fed



1-11 <u>Water Duty and the Discharge:</u>

The water duty is defined as the quantity of water applied to the field. It depends mainly on the kind of crop, where each crop requires a specific quantity of water for its growth and also it has to be irrigated each specific period of time.

- Each one feddan cultivated by rice requires a quantity of water of 420 m^3 / Fed / irrigation, and it has to be irrigated each 8 days.

- For cotton, summer crops (such as maize) and wheat; the required quantity of water is 350 m^3 / Fed / irrigation, and the period between irrigation processes has not to exceed 18 days.

- For fallow irrigation or sharaki (preparing the land for cultivating maize), the required quantity of water is 760 m^3 / Fed / one irrigation, and the sharaki ends within about 36 days.

So, in case of rice, a two turn irrigation rotation (4 and 4 days) has to be followed. While in case of cotton, a three turn irrigation rotation (6 and 12 days) can be followed.

The water duty is first calculated for the field (F.W.D.) according to the kinds of cultivated crops. Then, the water duty for the different grades of canals can be calculated as discussed previously.

Consequently, the discharge (Q) passing through the canals can be determined *using the following relation:*

Q = W.D. x Area Served

Where, Q: The discharge. & W.D.: The water duty.

Example (1-9):

A diversion canal serves an area of 20 km x 21 km and by two main canals A and B.

The main canal A serves 60 % of the total area, and its area served is cultivated *as follows:* 40 % cotton, 50 % sharaki (prepared for cultivating maize), and the rest 10 % is used for the public services.

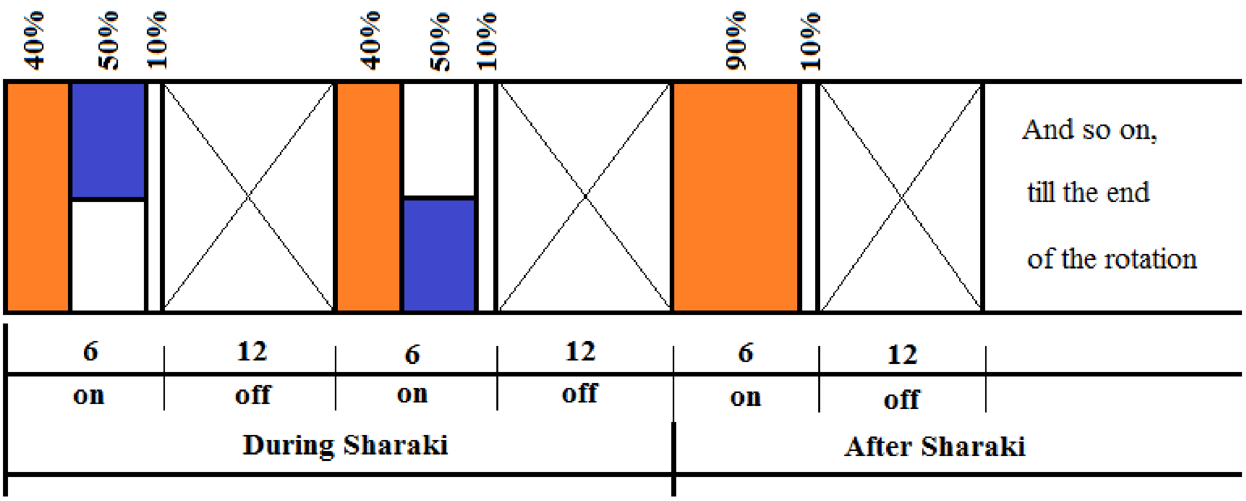
The main canal B serves 40 % of the total area, and its area served is cultivated *as follows:* 25 % rice, 30 % cotton, 35 % sharaki (prepared for cultivating maize), and the rest 10 % is used for the public services.

1) Suggest the suitable irrigation rotations for the two main canals A and B?
2) Sketch a diagram for each main canal showing the details of performing the irrigation rotation?
3) Determine the maximum and the minimum discharges passing in the diversion canal?

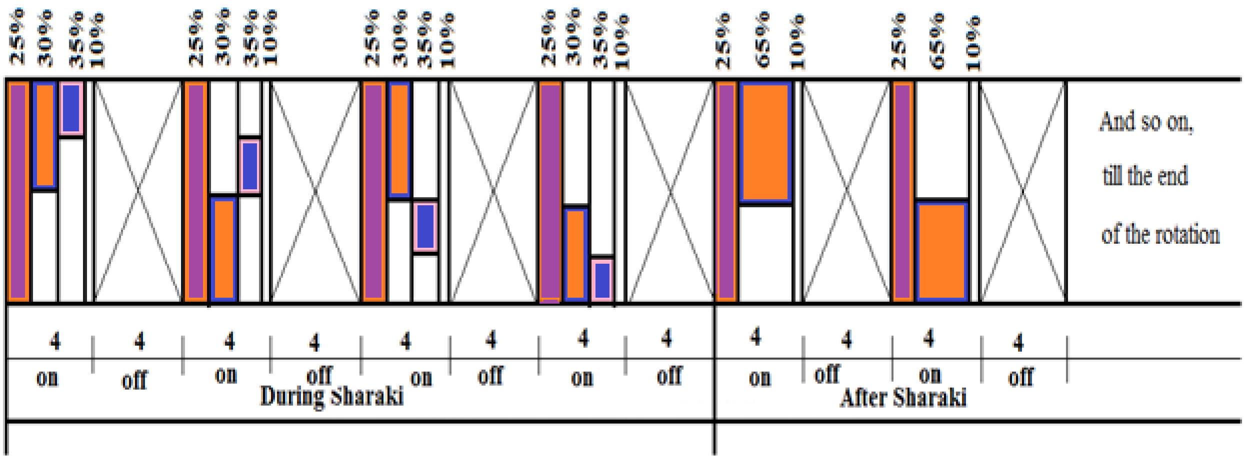
Solution

1) For the main canal A, use a three turn irrigation rotation (6 and 12 days).
For the main canal B, use a two turn irrigation rotation (4 and 4 days).

2) **For the main canal A:**



For the main canal B:



3) The total area served = $(20 \times 21 \times 10^6) / 4200$ = 100,000 Fed

$\therefore$ The area served for M.C.$_A$ = (60 / 100) x 100,000 = 60,000 Fed

& The area served for M.C.$_B$ = 40,000 Fed

For the main canal A:

F.W.D. $_{DSh}$ ={(40/100)x(350/6)}+{(50/100)x(760/6)x(1/2)}=55 m^3/Fed/day

F.W.D. $_{Ash}$ = {(90/100)x(350/6)} = 52.5 m^3/Fed/day

Max M.C.W.D.$_A$ = 55 x 1.2 = 66 m^3/Fed/day

Min M.C.W.D.$_A$ = 52.5 x 1.2 = 63 m^3/Fed/day

Assume the main canal A distributes the irrigation water into 3 equal areas.

Q_{Amax} = 66 x (60,000 / 3) = 1,320,000 m^3/day

$\therefore Q_{Amax}$ = 1,320,000 / (24 x 60 x 60) = 15.28 m^3/sec

Q_{Amin} = 63 x (60,000 / 3) = 1,260,000 m^3/day

$\therefore Q_{Amin}$ = 1,260,000 / (24 x 60 x 60) = 14.58 m^3/sec

For the main canal B:

F.W.D.$_{DSh}$ = {(25/100)x(420/4)} + {(30/100)x(350/4)x(1/2)}
+ {(35/100)x(760/4)x(1/4)}
= 56 m^3/Fed/day

$F.W.D._{Ash}$ = {(25/100)x(420/4)}+{(65/100)x(350/4)x(1/2)}
= 54.7 m^3/Fed/day

Max $M.C.W.D._B$ = 56 x 1.2 = 67.2 m^3/Fed/day
Min $M.C.W.D._B$ = 54.7 x 1.2 = 65.3 m^3/Fed/day

Assume the main canal B distributes the irrigation water into 2 equal areas.

Q_{Bmax} = 67.2 x (40,000 / 2) = 1,344,000 m^3/day
= 1,344,000 / (24 x 60 x 60) = 15.56 m^3/sec

Q_{Bmin} = 65.3 x (40,000 / 2) = 1,306,000 m^3/day
= 1,306,000 / (24 x 60 x 60) = 15.12 m^3/sec

For the diversion canal:

$Q_{max} = Q_{Amax} + Q_{Bmax}$ = 15.28 + 15.56 = 30.84 m^3/sec

$Q_{min} = Q_{Amin} + Q_{Bmin}$ = 14.58 + 15.12 = 29.70 m^3/sec

1-12 Drainage Factor:

The drainage factor (D.F.) can be defined as the quantity of excess water that has to be disposed in order to maintain the air - water balance in the root zone of the plant.

The drainage factor may be a ratio of the field water duty.
It can be assumed to be:

50 % of the field water duty for Lower Egypt,
40 % of the field water duty for Middle Egypt,
30 % of the field water duty for Upper Egypt.

The discharge (Q) passing through the drains can be determined *using the following relation:*

Q = D.F. x Area Served