Registration ID: 15513, Discipline: MS Civil Engineering, Course Title: Irrigation Engineering and Practices, Course Code: CE-566, Instructor: Dr. Prof. Dr. M.A.Q. Jahnagir Durrani, Date: 26.09.2020

Q4. Write notes on the following: (a) Field Capacity (b) Permanent wilting point (c) Canal Head Regulator (d) Under Sluices.

(a) FIELD CAPACITY (FC):

When all gravity water has drained down to water table, a certain amount of water is retained by surface soil. This water which cannot be easily drained under the action of gravity and is called Field Capacity.

Period of drainage = 2-5 days

FC is measured after 2 or 5 days

Field Capacity:

1. Capillary water

2. Hygroscopic water.

1. Capillary water is the water attached to soil by surface tension, which can easily be extracted by plants by capillary action.
2. Hygroscopic water is the water attached to soil by chemical bonds, which cannot be extracted by plants by capillary action.

Field capacity = (weight of water retained in a certain volume of soil) / Wt. of same volume of soil) X 100.

Consider 1 sq.m area of soil, d m depth of root zone.

Volume of soil = d X 1 Cu.m

If ɣ Kg/cu.m = density of soil = specific wt. of soil,

Then wt. of d cu.m of soil = ɣ d kg., If F is Field capacity

F = Wt. of water retained in unit area of soil / ɣ d

Wt of water retained in unit area of soil =F ɣ d Kg/ Cu.m

Wt of water retained in unit area or volume= wd1 = ɣ d. F

d1= depth of water stored in root zone

= ɣ d. F/w

= kg/Sq.m/kg/cu.m

= m., w

= Specific Wt. of water

= Kg/cu.m.

(b) PERMANENT WILTING POINT (P.W.P):

A plant can extract water from soil till a permanent wilting is reached. P.W.P is that water content at which a plant can no longer extract sufficient water for its growth and wilts up.

Water Available to plant = Field capacity- P.W.P water

Readily Available Moisture

It is that portion of available moisture which is most easily extracted by plants and is approximately 75 to 80% available moisture.

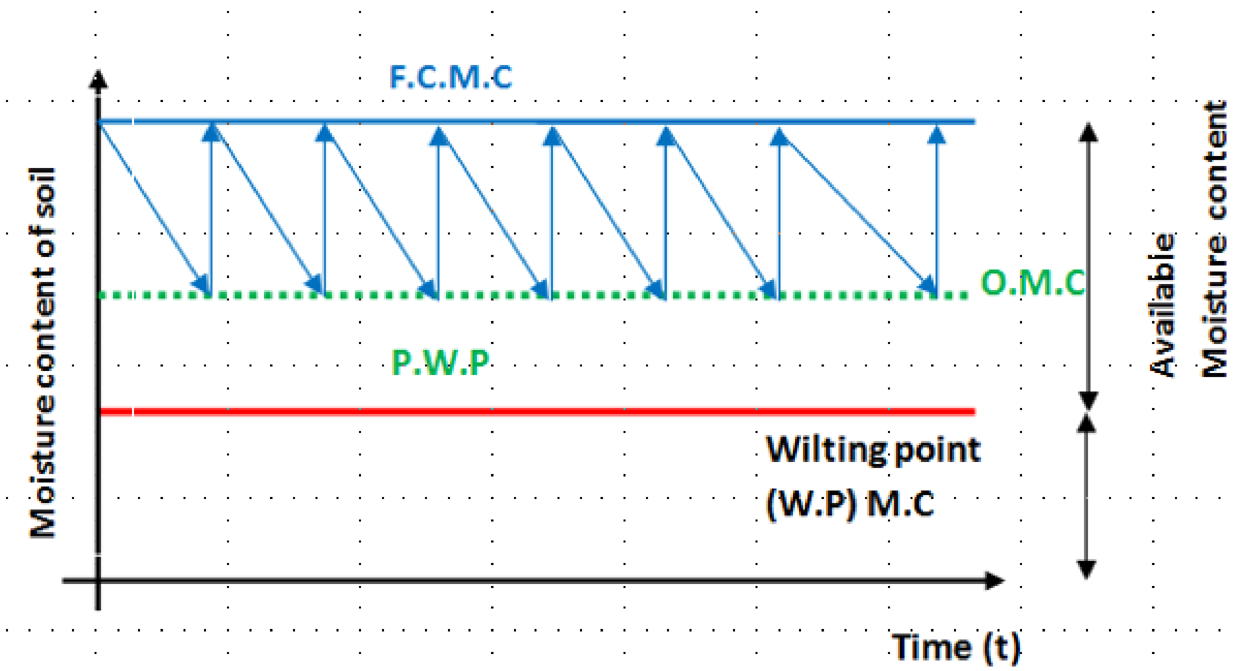
Soil Moisture deficiency (S.M.D)

The water required to bring the soil moisture content of given soil to field capacity is called S.M.D.

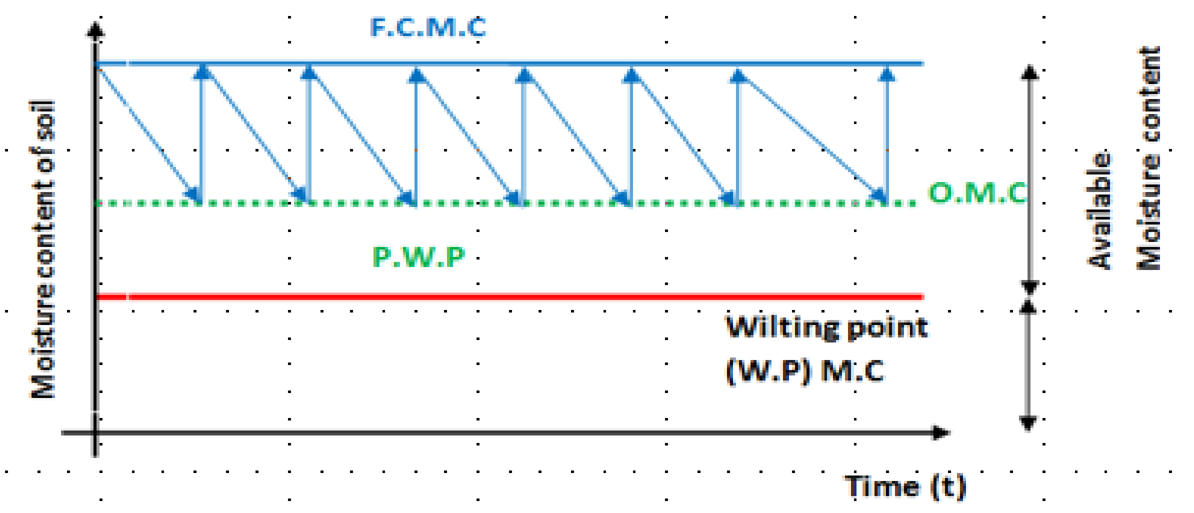
Equivalent Moisture (E.M)

It is the water retained by a saturated soil after being configured for 30 minutes by centrifugal force of 1000 times that of gravity

E.M = field capacity



- Water is consumed by plants through roots
- Sufficient moisture should be available in root zone
- Soil moisture in root zone varies from F.C.M.C to wilting point M.C
- Soil M.C is not allowed to deplete up to W.P
- The optimum level up to which the soil moisture content is allowed to deplete is called Optimum Moisture Content (O.M.C)



The irrigation water should be supplied as soon as the moisture falls up to optimum level (i.e. fixing irrigation frequency) and its quantity should be just sufficient to bring the moisture to the field capacity, making allowance for application losses (thus fixing water depth).

(c) CANAL HEAD REGULATOR:

- A structure which is constructed at the head of the canal to regulate flow of water is known as canal head regulator.
- Itconsists of a number of piers which divide the total width of the canal into a number of spans which are known as bays.
- Thepiers consist of number tiers on which the adjustable gates are placed.
- The gates are operated form the top by suitable mechanical device.
- A platform is provided on the top of the piers for the facility of operating the gates.
- Again some piers are constructed on the downstream side of the canal head to support the roadway.

Functions of Canal Head Regulator:

- It regulates the supply of water entering the canal
- It controls the entry of silt in the canal
- It prevents the river-floods from entering the canal

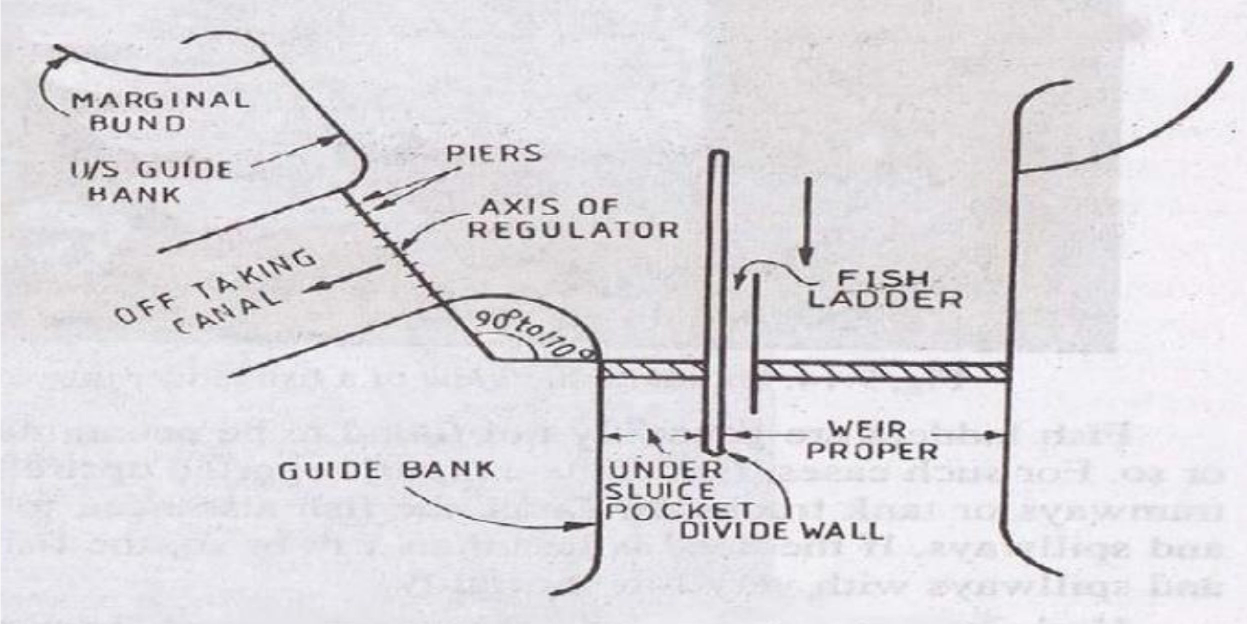


Fig: Alignment of a canal head regulator

(d) UNDER SLUICES:

- Also known as scouring sluices.
- The under sluices are the openings provided at the base of the weir or barrage.
- These openings are provided with adjustable gates. Normally, the gates are kept closed.

- The suspended silt goes on depositing in front of the canal head regulator.
- When the silt deposition becomes appreciable the gates are opened and the deposited silt is loosened with an agitator mounting on a boat.
- The muddy water flows towards the downstream through the scouring sluices.
- The gates are then closed. But, at the period of flood, the gates are kept opened.

UNDER SLUICES

Q.3.

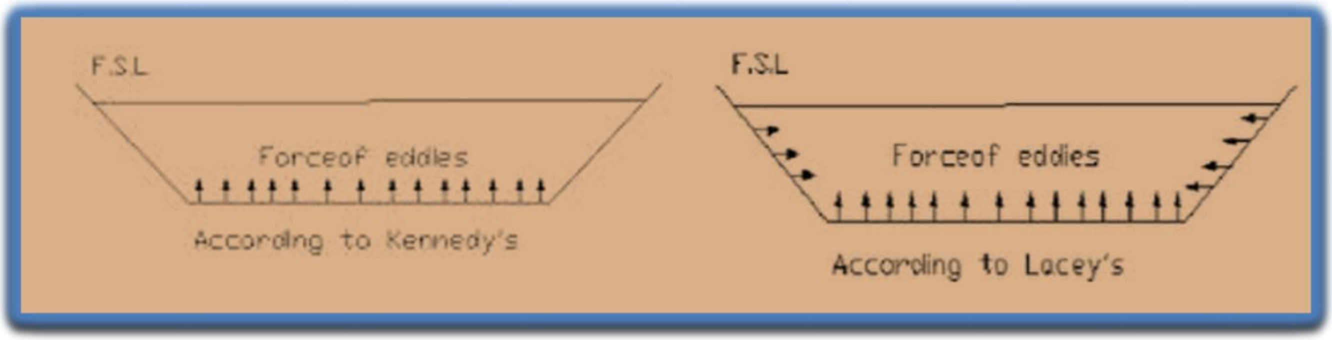
(a) How does Kennedy's theory differ from Lacey's theory for the design of irrigation canals?

ANS.3 (a):

Lacey states that as the shape of an irrigation canal is fixed to particular geometrical figure, it cannot achieve final regime conditions and hence may be said to achieve initial regime only. **Kennedy** assumes that when there is neither silting nor scouring the channel is in its regime condition.

1- Both (K & L) considered that the vertical eddies are responsible for holding silt in suspension. But Kennedy neglected the eddies generated by sides.

Lacey considered the sides (so he included R instead of D).



2- Kennedy: All channels which are not silting or scouring are in regime. But Lacey differentiated between initial and final regime.
3- Lacey: Grain size is important.
   - Silt factor $F = 1.76 * M^{0.5}$

Designing of non-erodible (lined) channels:
The initial dimensions of a channel are determined by uniform flow or Manning's Formula. But final dimensions are determined on the basis of

a. Hydraulic efficiency
b. Empirical rule of the best section
c. Practicability & economy

Factors considered in the design:

1. Kind of material to find n.
2. Minimum velocity.
3. Maximum velocity:
4. Bed Slopes
5. Side Slopes
6. Free board

1. Kind of material is important to find the roughness coefficient of channel.
2. Minimum velocity: It is 2-3 ft/sec, non-silting velocity to prevent aquatic growth.
3. Maximum velocity: Up to 8 ft/sec, more than the above value, the lining blocks are pulled away by moving water.

4. Bed slopes: It depends upon topography and energy head required for flow of water.
5. Side slopes: It depends upon the material forming the channel section

	H: V
e.g. Earth with lime stone	1 : 1
Earth with concrete lining	**½ : 1**

6. Free Board: Distance between top of channel to maximum water surface. It should prevent waves. It should be 5-13 % of depth.

U.S.B.R $F = \sqrt{cy}$

F= free board in ft

y=depth in ft

C = 1.5----20 cft

C = 2.5----300 cft

Best section: Max Q for Min P

Best Section of Hexagon	A	P	R	T	Z=sectional factor
Trapezoid	$\sqrt{3}y^2$	$\sqrt{3}y$	$\frac{y}{2}$	$\frac{4}{3}\sqrt{2}y$	$\frac{3}{2}y^{2.5}$
Rectangle	$2y^2$	$4y$	$\frac{y}{2}$	$2y$	$2y^{2.5}$

Design steps for non-erodible channel

1. Collect all the information and estimate n & s.
2. Compute section factor $AR^{\frac{2}{3}} = \frac{nQ}{1.486s^{0.5}}$
3. Substitute the values of A & R

From

$$A = (b + zy)y$$

$$P = b + 2y\sqrt{1 + z^2}$$

$$R = \frac{(b + zy)y}{b + 2y\sqrt{1 + z^2}}$$

& solve for y (depth) by assuming b & z.

- Assume different values for b and z and different dimensions of y are obtained.
- Final dimension is based on hydraulic efficiency and practicability.

4. If best hydraulic section is required, directly substitute for A and R for best section.
    - e.g. Trapezoid
    - $R = \frac{y}{2}$
    - $A = (3)^{0.5} y^2$
5. Check for minimum permissible velocity
6. Add proper free board to depth

Balancing depth:

- For a given cross-section of channel, there can be only one depth, for which a balance between cutting and filling will occur. This depth is known as balancing depth.
- This can be computed by equating the areas of cutting and filling.
- Types of lining:

1- Hard surface type lining
   a. Cement concrete lining
   b. Pre-cast concrete lining
   c. Brick- burn clay lining
   d. Shot-crete lining
   e. Asphalt concrete lining
   f. Stone masonry lining

2- Buried and protected type membrane lining
   a. Sprayed in place asphalt membrane lining
   b. Pre- fabricated
   c. Synthetic rubber and plastic film membrane lining
   d. Bentonite-clay membrane lining
3- Earth type lining
   a. Compacted earth lining
   b. Soil cement lining
4- Porous type lining, Boulder and brick lining

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Q.3. (b) Design a regime channel for a discharge of 30 cumecs and mean diameter of the particle of 0.56 mm using Lacey's theory.

Given data:
Discharge = Q = 30 cumecs
Mean diameter of particle = M = 0.56 mm

SOLUTION:

Step 1: Calculate velocity

$$Vm = \left[\frac{Qf^2}{140}\right]^{1/6}$$

$f = 1.76xM^{.5}$

$f = 1.76x0.56^{.5}$ = 1.32

$$Vm = \left[\frac{30x1.32^2}{140}\right]^{1/6}$$

$$Vm = \left[\frac{52.27}{140}\right]^{1/6}$$

$Vm = [0.373]^{1/6}$

$Vm = 0.849\ m/sec$

$A = \frac{Q}{Vm}$ = 30/0.849 = 35.33 m2

Step 2: Work out R

$$R = \frac{5}{2} * \frac{V^2}{f}$$

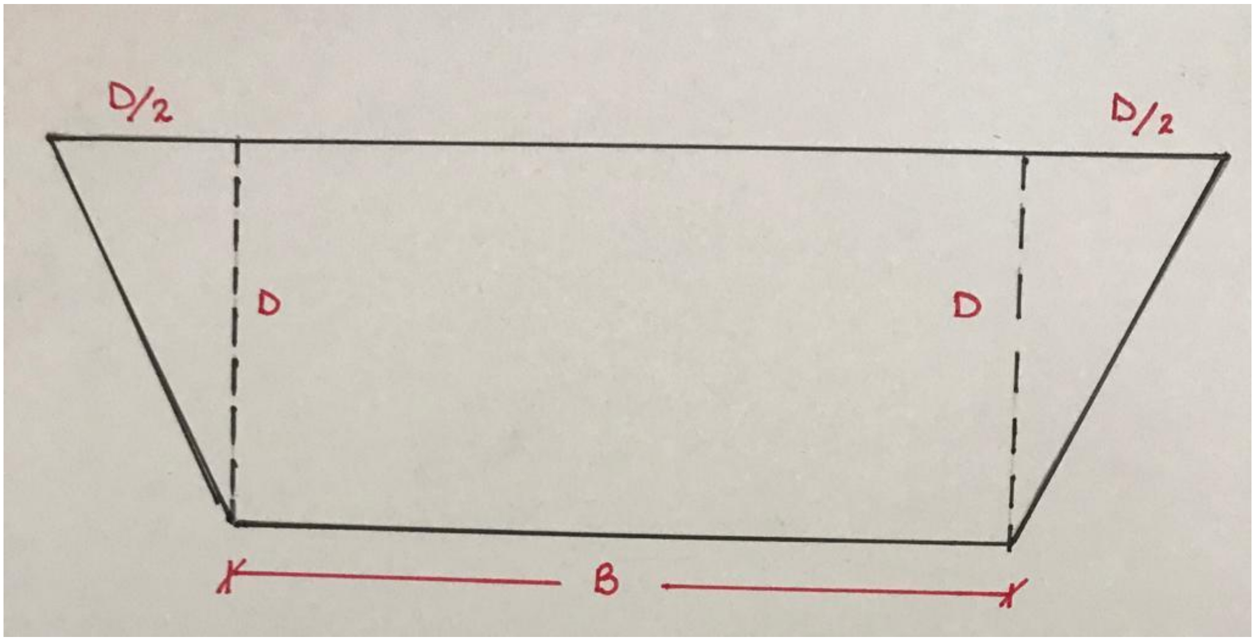
$$R = \frac{5}{2} * \frac{0.849^2}{1.32}$$

$$R = 2.5 * \frac{0.721}{1.32}$$

$R = 2.5 * 0.546$

R = 1.36 m

Consider a trapezoidal section having Bed Slope H:V = 1/2:1



Step 3: Compute P

$P = 4.75\sqrt{Q}$

$P = 4.75\sqrt{30}$

$P = 4.75\ x\ 5.48$

$P = 26.03\ m$

A = BD + D2/2 = D(B+D/2)

P = B+D√5

35.33 = D(B+D/2) .... (i)

26.03 = B+D√5

26.03 = B+2.236D ....(ii)

B= 26.03 - 2.236D

Putting the value in equation (i)

35.33 = D(26.02 - 2.236D +D/2)

35.33 = D(26.02 – 1.74D)

35.33 = 26.02D – 1.74D2

1.74D2-26.02D + 35.33 = 0

D2 – 14.95D + 20.30 = 0

$$D = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$$D = \frac{-(-14.95) \pm \sqrt{(-14.95)^2 - 4x1x20.30}}{2x1}$$

$$D = \frac{14.95 \pm \sqrt{223.50 - 81.2}}{2}$$

$$D = \frac{14.95 \pm \sqrt{142.3}}{2}$$

$D = \frac{14.95 \pm 11.93}{2}$ Neglecting unfeasible + ve sign, we get

$D = 3.02/2$ = 1.51m

B= 26.03 - 2.236D

B= 26.03 - 2.236 x 1.51

B = 22.65 m

Step 4: Compute slope of the bed

$$s = \frac{f^{\frac{5}{3}}}{3340 * Q^{\frac{1}{6}}}$$

$$s = \frac{1.32^{\frac{5}{3}}}{3340 * 30^{\frac{1}{6}}}$$

$$s = \frac{1.588}{3340 * 1.764}$$

$$s = \frac{1.588}{5887.5}$$

$$s = 1/3707$$

Therefore the design velocity Vm is 0.849m/sec, channel base width is 22.65 m, depth of water in channel is 1.51 m and bed slope of channel is 1/3707.

Q.NO (01)

(a) Define "Delta" and "Duty" and write the significance of duty of crop.
(b) Wheat requires about 10cm of water after every 35 days and the base period or crop period of wheat is 140 days. Find out the delta for wheat?
(c) Explain the factors affecting consumptive use.

ANS (a):

DELTA:

Delta is defined as the depth of water in cm or inches required for the crop throughout the base period is called Delta of the crop.

DUTY:

The duty of water is defined as the relationship between the volume of water and the area of crop it matures.
Volume of water is generally expressed by a unit discharge flowing for a time of base period of the crop.

1 cu.m per sec or 1 cu.ft/sec of water for B days matures D hectares or acres of land. Then the Duty of water for that particular crop is D hectare/cumecs or D acres/cusecs.

SIGIFICANCE OF DUTY OF CROP:

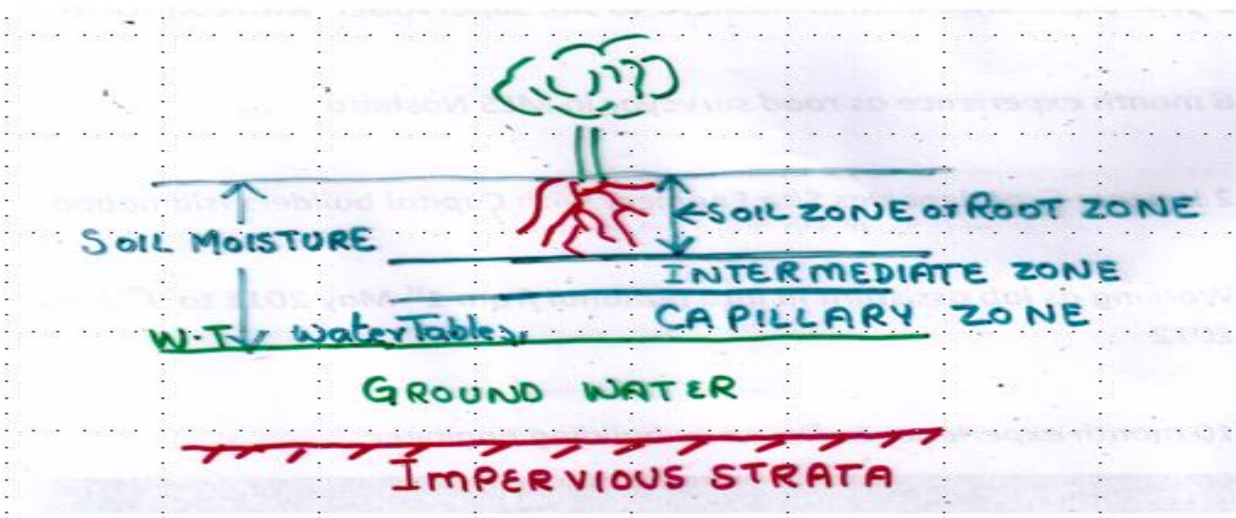
- It helps in designing efficient canal irrigation system. Knowing the total available water at the head of the main canal and the overall duty for all the crops required to be irrigated in different seasons of the year, the area which can be irrigated can be worked out.
- Inversely if we know the crop area required to be irrigated and their duties, we can work out the discharge required for designing the canal.

Q = A/D   => A=QD

Crop	Duty in hectares/cumec
Sugar Cane	730
Rice	775
Other Kharif	1500
Rabi	1800

Perennials	1100
Hot Fodder	2200

Soil –Moisture – Irrigation Relationship



- Above the water Table: Soil moisture
- Below water Table: Ground water
- Root Zone: Depth of soil up to which roots are penetrated. When water falls on ground: Part of the water absorbed by root zone and other part flows downwards by gravity.

(b) Wheat requires about 10cm of water after every 35 days and the base period or crop period of wheat is 140 days. Find out the delta for wheat?

ANS.1 (b)

Solution:

Water requirement = 10 cm

Water requirement interval = 35 days

Base Period = 140 days

Number of watering required = Base Period/Interval = 140/35 = 4

$\Delta = water\ depth\ x\ number\ of\ watering$

$\Delta = 10\ x\ 4$

$\Delta = 40\ cm$

Therefore the Delta for wheat is 40 cm.

ANS (c) Explain the factors affecting consumptive use.

1**. PRECIPITATION**

The amount and rate of precipitation may have some minor effect on the amount of water consumptively used during any summer. Under certain conditions, precipitation may occur as a series of frequent, light showers during the hot summer. Such showers may add little or nothing to the soil moisture for use by the plants through transpiration but do decrease the withdrawal from the stored moisture. Such precipitation may be lost largely by evaporation directly from the surface of the plant foliage and the land surface.

Part of the precipitation from heavy storms may be lost by surface runoff. Other storms may be of such intensity and amount that a large percentage of the moisture will enter the soil and become available for plant transpiration. This available soil moisture may materially reduce the amount of irrigation water needed.

2. TEMPERATURE

The rate of consumptive use of water by crops in any particular locality is probably affected more by temperature, which for long-time periods is a good measure of solar radiation, than by any other factor. Abnormally low temperatures retard plant growth and unusually high temperatures may produce dormancy. Consumptive use may vary widely even in years of equal accumulated temperatures because of deviations from the normal seasonal distribution. Transpiration is influenced not only by temperature but also by the area of leaf surface and the physiologic needs of the plant, both of which are related to stage of maturity.

3. HUMIDITY

Evaporation and transpiration are accelerated on days of low humidity and slowed during periods of high humidity. During periods of low relative humidity, greater rate of use of water by vegetation may be expected.

4. WIND MOVEMENT

Evaporation of water from land and plant surfaces takes place more rapidly when there is moving air than under calm air conditions. Hot, dry winds and other unusual wind conditions during the growing period will affect the amount of water consumptively used. However, there is a limit in the amount of water that can be utilized. As soon as the land surface is dry, evaporation practically stops and transpiration is limited by the ability of the plants to extract and convey the soil moisture through the plants.

5. GROWING SEASON

The growing season, which is tied rather closely to temperature, has a major effect on the seasonal use of water by plants. It is frequently considered to be the period between killing frosts, but for many annual crops, it is shorter than the frost-free period, as such crops are usually planted after frosts are past and mature before they recur.

For most perennial crops, growth starts as soon as the maximum temperature stays well above the freezing point for an extended period of days, and continues throughout the season despite later freezes. Sometimes growth persists after the first so-called killing frost in the fall. In the spring, and to less extent in the fall, daily minimum temperatures may fluctuate several degrees above and below 32° F. for several days before remaining generally above or below the freezing point. The hardier crops survive these fluctuations and continue unharmed during a few hours of subfreezing temperature. In fact, many hardy crops, especially grasses, may mature even though growing season temperatures repeatedly drop below freezing. In southern Arizona and California alfalfa and citrus trees grow throughout the year.

Although the frost-free season may be used as a guide for computing consumptive use, actual dates of planting and harvesting of the crops and average annual dates of the first and last irrigation are important in determining the consumptive irrigation requirements of the crops.

6. LATITUDE AND SUNLIGHT

Although latitude may hardly be called a climatic factor, it does have considerable influence on the rate of consumptive use of water by various plants. Because of the earth's movement and axial inclination, the hours of daylight during the summer are much greater in the northern latitudes than at the Equator. Since the sun is the source of all energy used in crop growth and evaporation of water, this longer day may allow plant transpiration to continue for a longer period each day and to produce an effect similar to that of lengthening the growing season.

7. AVAILABLE IRRIGATION WATER SUPPLY

All the above-mentioned climatic factors influence the amount of water that potentially can be consumed in a given area. However, there are other factors that also cause important differences in the consumptive use-rates. Naturally, unless water is available from some source (precipitation, natural ground water, or irrigation), there can be no consumptive use. In those areas of the arid and semiarid West where the major source is irrigation, both the quantity and seasonal distribution of the available supply will affect consumptive use. Where water is plentiful and cheap, there is a tendency for farmers to overirrigate. If the soil surface is frequently wet and the resulting evaporation is high, the combined evaporation and transpiration or consumptive use may likewise increase. Also, under more optimum soil moisture conditions, yields of crops such as alfalfa may be higher than average and more water consumed. In irrigating some crops, such as potatoes, water is applied to the field not only for the purpose of supplying the consumptive water needs of the crop but also to help maintain a favorable microclimatic condition.

8. QUALITY OF WATER

Some investigations have shown that the quality of the water supply may have an appreciable effect on consumptive use. Whether or not plants actually transpire more or less if water is highly saline may be debatable. However, if it is necessary to apply additional water to the land to leach the salts down through the soil, more water will probably be lost by evaporation from the soil surface and such loss will be chargeable against the consumptive requirement of the cropped area.

9. SOIL FERTILITY

If a soil is made more fertile through the application of manure or by some other means, the yields may be expected to increase with an accompanying small increase in use of water. However, an increase in fertility of the soil causes a decrease in the amount of water consumed per unit of crop yield.

10. PLANT PESTS AND DISEASES

Where plant pests and diseases seriously affect the natural growth of the plants, it is reasonable to assume that transpiration will likewise decrease. It is recognized that some damage to crops is caused every year by pests and diseases. Ordinarily the losses may not vary greatly from year to year, but in those years when they are unusually severe consumptive use may be lowered materially.

Q.NO (02): (a) what are the principal causes and ill effects of water logging?

ANS:

Land is said to be water logged when its productivity is affected by high water Table (WT). High WT causes saturation of root zone. It leads ill aeration which causes the decay of nitrifying bacteria and thus reduces the crop yield.

Water logging in Pakistan

- **Recharge of Ground water (GW):**

  1. Before canal system- 10 Million acre ft. (MAF).

  2. After canal system- 41.9 MAF.

- WT risen 10 ft in half of canal irrigated area and 5 ft in 16 % of canal irrigated area.

- In Pakistan the total water-logged area is 2 MLN acres.
- GW Reservoirs: 1.Indus plain 2. Bannu basin .3.Warsak- Peshawar area.

Problems due to water-logging

- Delay in cultivation operations such as tilling, ploughing etc.
- Weed growth.
- Salinity.
- If WT has risen up or plant root happens to come up in capillary zone, water continuously evaporated by capillarity thus continuous upward flow of water to land surface is established.
- Salts rise with water & deposits in root zone.
- It reduces osmotic activity of plants and the plant decays.

PRINCIPLE CAUSES OF WATER-LOGGING:-

1. Intensive Irrigation:

If max. area of land is irrigated, percolation of water takes place. This causes the rise of WT.Extensive irrigation (irrigation spread over wider regions) to be followed to avoid water logging.

2. Seepage of water from adjoining high lands.

3. Seepage of water through canal reservoirs.

4. Impervious obstruction:

Water seeping below the soil moves horizontally. It may find obstruction & WT may rise.

5. Inadequate surface Drainage:

Storm water & excess of irrigation water should be removed. If proper drainage is not provided water percolates to rise water table.

6. Excessive Rains:

-Causes temporary water logging.

- No drainage causes permanent.

7. Submergence due to floods:

Continued floods causes the growth of water-loving plants which obstruct natural surface drainage & increase the water-logging.

8. Irregular & flat topography:

In depressions, the drainage is poor, water detention is more. The percolation increases the water table.

Q.NO 2(b) Describe the anti-water logging measures.

ANS: The following are the anti-logging measures:

1. Lining of canals and water courses: It reduces seepage of water.

2. Reducing intensity of irrigation: Only small portion of land should receive canal water in one particular season. Remaining areas can receive water in next season by rotation.

3. By introducing crop rotation: High water requiring crop should be followed by one requiring less water, and then by one requiring almost no water. Example: Rice followed by wheat and then by cotton.

4. Optimum use of water: Certain amount of water gives the best result. Less or more water reduce the yield. Cultivators should be educated so that not to use more water. Revenue should be charged on the basis of quantity of water rather than the area of land.

5. Improving natural drainage of area: water should not be allowed to stay in one area. Natural flow is provided by bush and jungle cutting.

6. Pumping or Tube wells or Vertical Drainage: Lift irrigation should be introduced to use Ground water. Canal irrigation may be substituted by tube well irrigation.

7. Economical use of water according to need: Economical use of irrigation water should be ensured.

8. Adoption of sprinkler method of irrigation: Only predetermined amount of water is supplied to land. No percolation losses from water courses.

Q.NO 2(c) Explain the methods adopted to reclaim saline soils.

ANS:

Alkali salts (Sodium chloride, Sodium Sulphate, and Sodium Carbonate) are injurious to agriculture. NaCl is least harmful, Na2SO4 is medium harmful while Na2CO3is the most harmful. These salts are soluble in water. When water table rises up or roots are in capillary zone, the ground water moves upwards and salts are deposited in root zone and surface of soil.The phenomena of salts coming up in solution and forming a thin crust (5-7.5cm) on the surface after evaporation of water is called Efflorescence. Land affected by efflorescence is called saline soil Salts surrounding the roots reduce the osmotic activity of plants.

Methods adopted to reclaim saline soils are as follow:

1. **Avoid efflorescence**: By maintaining the water table sufficiently below the roots.

- Hence all the measures which were suggested for preventing water logging hold good for preventing salinity of lands
- An efficient drainage (surface and subsurface) must be provided to lower the water table in saline soils.

2. **LEACHING:**

In this process, the following steps are involued.

1) Land is flooded with water

2) Alkaline salts will be dissolved in water

3) Percolation to the ground water

4) Drained by sub surface drains

- High Salt resistant crops like rice are grown on leached land for 1 or 2 seasons
- Then ordinary crops like wheat or cotton are grown
- Then the land is said to have reclaimed.
- When Sodium carbonate is present in the soil, gypsum is added before leaching
- Sodium sulphate is formed which is leached out easily

$Na_2CO_3+CaSO_4$--------->>$Na_2SO_4+CaCO_3$

3. Surface Drainage

- Removal of excess of water using open ditches, field drains, land grading etc.
- Open drain which remove excess of irrigation and storm water are broad and shallow are called shallow surface drains.
- Shallow surface drains carry runoff to point of entrance to outlet-ditches. These Large and deep outlet ditches are called deep surface drains.

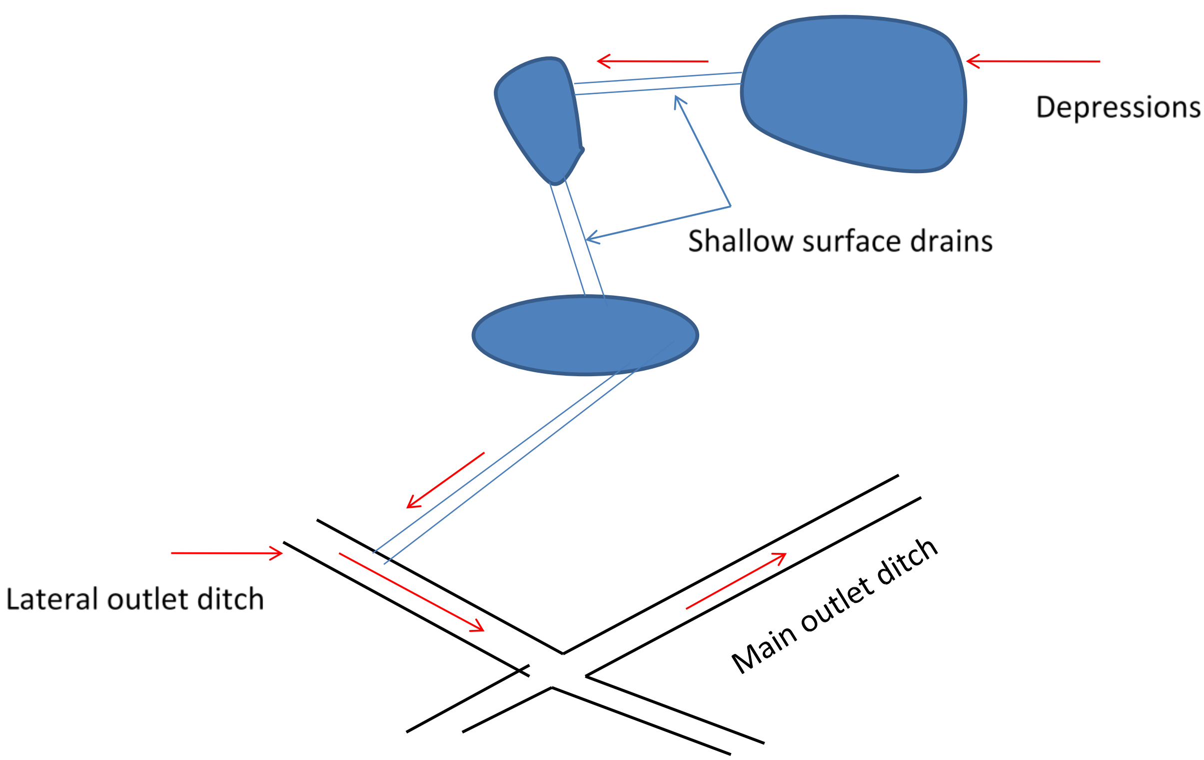
4. Land Grading:

- It is a continuous land slope towards field drains.
- It is necessary for surface irrigation.

5. **DEEP SURFACE DRAINS OR OUTLET DITCHES**: They carry the seepage water from tile drainage. They carry storm water and excess of irrigation water. They are designed for combined discharge.
6. **SURFACE INLET**

- A surface inlet is a structure constructed to carry the pit water into subsurface drain. The surface water from pot hole depressions, road ditches may be removed by:

1. Random field drain or 2. Inlet surface inlet.



Random Field Drain (diagram)

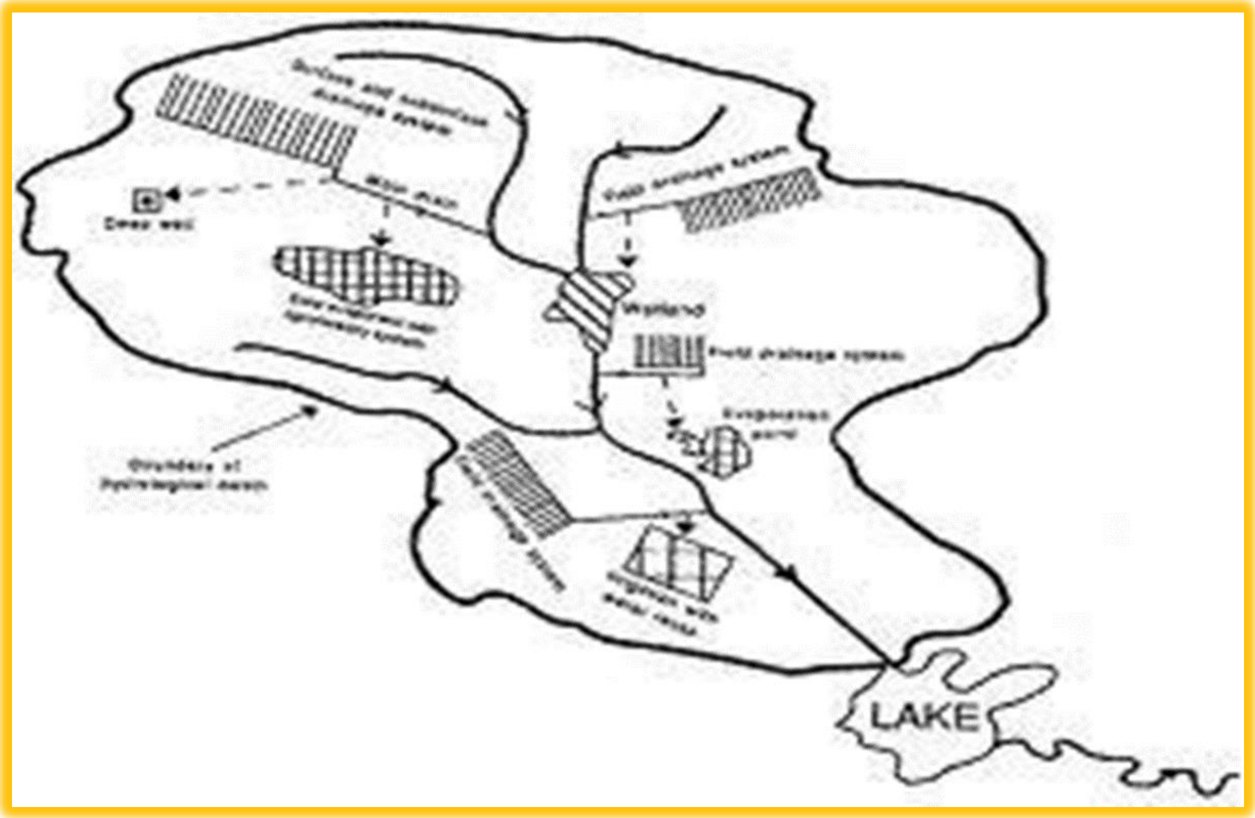


FIGURE 1 Drainage water disposal options within a watershed

7. Surface Drainage

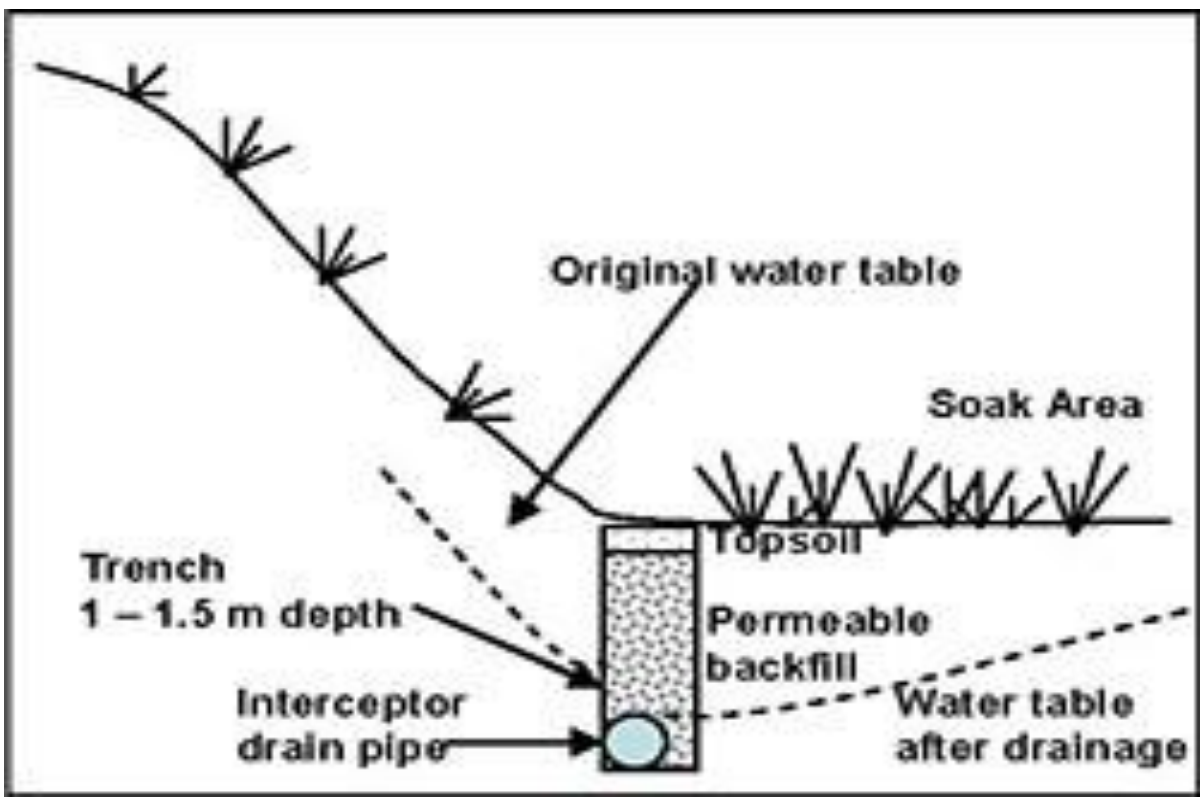
• Surface drainage is often achieved by land forming and smoothing to remove isolated depressions, or by constructing parallel ditches. Ditches and furrow bottoms are gently graded and discharge into main drains at the field boundary. Although the ditches or furrows are intended primarily to convey excess surface runoff, there is some seepage through the soil to the ditches, depending on the water table position. This could be regarded as a form of shallow subsurface drainage. Surface drainage is especially important in humid regions on flat lands with limited hydraulic gradients to nearby rivers or other disposal points. There is also a need for good surface drainage in semi-arid regions which are affected by monsoons.

8. Subsurface drainage

• Surface drainage alone is seldom sufficient to remove excess water from the crop root zone. Deep ditches or subsurface pipe drainage systems enable a more rapid water table drawdown. The downstream ends of the laterals are normally connected to a collector drain. The required diameter of the pipe collectors increases with the area drained. Drain spacing is usually dependent on soil hydraulic conductivity and a design drainage rate coefficient. Depending on topography, land formation and proximity of a water receiving body, the collector may outlet by gravity to an open main drain or into a sump. In the latter case, the discharge is then pumped to another drain, or ultimately to a lake or stream.

• Horizontal subsurface drainage systems are used in irrigated arid and semi-arid regions to reclaim saline and waterlogged lands, and to maintain favourable long-term salt and water balances in the crop root zone. Salinity and waterlogging are caused by a buildup of the water table due to deep percolation of normal excess water and canal seepage. Buried pipe drains are generally installed deeper in arid regions than in humid regions in order to control salinity. Water in excess of plant evapotranspiration (ET) needs is always unavoidably applied during irrigation. This additional quantity of water applied is known as the leaching fraction. Naturally occurring as well as applied salts are then leached from the root zone by this water, and removed from the field via the pipe drains. Deeper drain installation ensures that salts do not rise too rapidly to the soil surface due to capillary action. Drainage also prevents waterlogging of the root zone. The amount of irrigation water to be removed is generally less in arid than in humid regions

• . Vertical drainage by means of tube-wells is also used to control waterlogging and salinity in some parts of the world, e.g., India, Pakistan and central Asian republics. The primary purposes of tube wells are the same as those of horizontal drains, and at the same time to extract groundwater for irrigation. As a result of pumping, the water table is lowered, and salinization due to capillarity is minimized. This situation is ideal where the groundwater is not very brackish or saline, and is therefore suitable for irrigation. In areas where the groundwater is highly saline, the pumped water may be too saline for irrigation, unless mixed with fresher or less saline water. Where the groundwater is too saline for crop production, it must be disposed of. Drainage does not have a direct impact on groundwater quality. It only serves to collect and transport excess.



Subsurface drainage (diagram)