1

Irrigation Techniques and Quality of Irrigation Water

1.1. Definition of Irrigation

Plants are living beings and do require water and air for their survival, as do human beings require. Their requirement of water varies with their type. Different types of plants require different quantities of water, and at different times, till they grow up completely. Water is normally supplied to these plants by nature through direct rain or through the flood waters of rivers which inundate large land areas during floods. The flood water may saturate the land before the flood is subsided. The water absorbed by the land during floods, supplements the water requirement of the crop during dry season. These natural processes, whereby, the water is supplied to the crops for their growth, are dependent upon 'nature' or 'God', whatever we may call it. Sometimes, there may be very heavy rains creating serious floods and damaging the crops, and sometimes, there may not be any rains at all, creating scarcity of water for the crops. Thus, famine and scarcity conditions are created. In his bid to control the nature, man discovered various methods by which the water can be stored during the periods of excess rainfall, and to use that stored water during periods of 'less rainfall' or 'no rainfall'. The art or the science by which it is accomplished, is generally, termed, as irrigation. *Irrigation may, therefore, be defined as the science of artificial application of water to the land, in accordance with the 'crop requirements' throughout the 'crop period'* for full-fledged nourishment of the crops.

1.2. Necessity of Irrigation in India

India is a tropical country with a vast diversity of climate, topography and vegetation. Rainfall in India, varies considerably in its place of occurrence, as well as in its amount. Even at a particular place, the rainfall is highly erratic and irregular, as it occurs only during a few particular months of the year. Crops cannot, therefore, be raised successfully, over the entire land, without providing artificial irrigation of fields.

More than seventy percent of our population, directly depends on agriculture, and the remaining depends indirectly on agriculture. Out of a total geographical area of about 328 million hectares, about 184 million hectares is the cultivable area. In order to save this area from the complete wishes and vagaries of nature, and to ensure full growth of crops, it is necessary to provide adequate artificial irrigation facilities. In order to achieve this, the Indian Government is trying hard and spending enormously to provide irrigation facilities for the entire cultivable land. So far developed irrigation facilities in India have been shown under "Introduction" in the previous pages.

1.3. Advantages of Irrigation

Every irrigation project is designed, keeping in view of its economics, *i.e.* the expenditure likely to be incurred and the benefit likely to occur. There is a capital investment on the project and the future recurring charges for maintenance and operation. The project estimate is generally sanctioned when the benefit gives at least about 8% interest on the capital outlay. Sometimes, unproductive projects are also sanctioned in view of their *general public benefits.*

There is hardly any point in emphasizing the importance and advantages of irrigation during the times of acute food shortages and growing population of our country.

Even then, some of the advantages of irrigation are summarised below:

(1) **Increase in Food Production.** Irrigation helps in increasing crop yields, and hence, to attain self-sufficiency in food.

(2) **Optimum Benefits.** Optimum utilisation of water is made possible by irrigation. By optimum utilisation, we generally mean, obtaining maximum crop yield with required amount of water. In other words, yield will be smaller for any quantity lesser than or in excess of this optimum quantity.

(3) **Elimination of Mixed Cropping.** In the areas, where irrigation is not assured, generally mixed cropping is adopted. *By mixed cropping, we mean, sowing together of two or more crops in the same field.* If the weather conditions are not favourable to one of the crops, they may be better suitable for the other; and thus, the farmer may get at least some yield. Mixed cropping, is thus, found necessary and also economical when irrigation facilities are lacking, and especially during periods of *Crash programmes* in under-developed countries. But if irrigation is assured, mixed cropping can be eliminated.

Mixed cropping is generally not acceptable, because different crops require different types of field preparations and different types of waterings, manurings, etc. If two crops are mixed together, the field preparations, waterings, manurings, etc. cannot be made to suit the special needs of either. Moreover, during the time of harvesting, the crops get intermixed with each other, reducing the purity of each other. But, when regular and permanent water supply is assured, a single superior crop can be sown, depending upon the conditions of the soil and the needs of the country.

(4) **General Prosperity.** Revenue returns with well developed irrigation, are sometimes, quite high, and helps in all round development of the country and prosperity of the entire nation and community.

(5) **Generation of Hydro-electric power.** Cheaper power generation can be obtained from water development projects, primarily designed for irrigation alone. Canal outlets from dams and Canal falls on irrigation canals can be used for power generation. For example, Ganga and Sarda Canals, constructed for irrigation, are now generating hydro-electric power as a side product, up to about 80,000 kilo-watts.

(6) **Domestic Water Supply.** Development of irrigation facilities in an area helps in augmenting the water supply in nearby villages and towns, where other sources of water are not available or are scarcely available. It also helps in providing drinking water for animals, and water for swimming, bathing, etc.

(7) **Facilities of Communications.** Irrigation channels are generally provided with embankments and inspection roads. These inspection paths provide good roadways to the villagers for walking, cycling or sometimes even for motoring.

(8) **Inland Navigation.** Sometimes, larger irrigation canals can be used and developed for navigation purposes.

(9) **Afforestation.** Trees are generally grown along the banks of the channels, which increase the timber wealth of the country and also help in reducing soil erosion and air polluition.

1.4. Disadvantages and Ill-Effects of Irrigation

(1) Irrigation may contribute in various ways to the problem of water pollution. One of these is the seepage into the ground water of the nitrates, that have been applied to the soil as fertilizer. Sometimes, up to 50% of nitrates applied to the soil, sinks into the underground reservoir. The underground water may thus get polluted, and if consumed by people through wells, etc., it is likely to cause diseases such as anemia. Whether it will ultimately affect the fishing on way to the sea, or as the tides carry the polluted water ahead into the ocean, is yet a matter of research.

(2) Irrigation may result in colder and damper climate, resulting in marshy lands and breeding of mosquitoes, causing outbreak of diseases like malaria & dengu.

(3) Over-irrigation may lead to water-logging* and may reduce crop yields.

(4) Procuring and supplying irrigation water is complex and expensive in itself. Sometimes, subsidised cheaper water has to be provided at the cost of the government, which raduces revenue returns.

1.5. Types of Irrigation

Irrigation may broadly be classified into :

1. *Surface irrigation* ; and 2. *Sub-surface irrigation*

(1) **Surface irrigation** can be further classified into :

(*a*) Flow irrigation ; and (*b*) Lift irrigation.

When the water is available at a higher level, and it is supplied to lower level, by the mere action of gravity, then it is called *Flow Irrigation.* But, if the water is lifted up by some mechanical or manual means, such as by pumps, etc. and then supplied for irrigation, then it is called *Lift Irrigation.* Use of wells and tubewells for supplying irrigation water fall under this category of irrigation.

Flow irrigation can be further sub-divided into :

(*i*) Perennial irrigation, and

(*ii*) Flood irrigation.

(*i*) *Perennial Irrigation.* In perennial system of irrigation, constant and continuous water supply is assured to the crops in accordance with the requirements of the crop,

* For detailed description of water-logging, please refer Chapter 6.

throughout the 'crop period'. In this system of irrigation, water is supplied through storage canal head works and canal distribution system.

When irrigation is done from the direct runoff of a river, or by diverting the river runoff into some canal by constructing a diversion weir or a barrage across the river, it is called *Direct Irrigation.* Ganga Canal System is an example of this type of irrigation. But, if a dam is constructed across a river to store water during monsoons, so as to supply water in the off-taking channels during periods of low flow, then it is termed as *Storage Irrigation.* Ram-Ganga Dam project in U.P. is an example of storage type of irrigation system. In the regions of peninsula India, where rivers are generally seasonal, storage irrigation is an absolute necessity, whereas, in Indo-gangetic region, direct irrigation is feasible, since the rivers are perennial, getting their supplies from the melting of snow. Direct irrigation is always simple, easy and economical. The perennial system of irrigation, is most important and is mostly practised in India.

(*ii*) *Flood Irrigation.* This kind of irrigation, is sometimes called as *inundation irrigation.* In this method of irrigation, soil is kept submerged and thoroughly flooded with water, so as to cause thorough saturation of the land. The moisture soaked by the soil, when occasionally supplemented by natural rainfall or minor waterings, brings the crop to maturity.

(2) **Sub-surface Irrigation.** It is termed as sub-surface irrigation, because in this type of irrigation, water does not wet the soil surface. The underground water nourishes the plant roots by capillarity. It may be divided into the following two types :

(*a*) Natural sub-irrigation ; and

(*b*) Artificial sub-irrigation.

(*a*) *Natural sub-irrigation.* Leakage water from channels, etc., goes underground, and during passage through the sub-soil, it may irrigate crops, sown on lower lands, by capillarity. Sometimes, leakage causes the water-table to rise up, which helps in irrigation of crops by capillarity. When underground irrigation is achieved, simply by natural processes, without any additional extra efforts, it is called natural sub-irrigation.

(*b*) *Artificial sub-irrigation.* When a system of open jointed drains is artificially laid below the soil, so as to supply water to the crops by capillarity, then it is known as artificial sub-irrigation. It is a very costly process and hence, adopted in India on a very small scale. It may be recommended only in some special cases with favourable soil conditions and for cash crops of very high return. Sometimes, irrigation water may be intentionally collected in some ditches near the fields, the percolation water may then come up to the roots through capillarity.

1.6. Techniques of Water Distribution in the Farms

There are various ways in which the irrigation water can be applied to the fields. Their main classification is as follows :

(1) Free flooding
(2) Border flooding
(3) Check flooding
(4) Basin flooding
(5) Furrow irrigation method
(6) Sprinkler irrigation method
(7) Drip irrigation method.

These methods are briefly discussed below :

(1) **Free flooding or Ordinary flooding.** In this method, ditches are excavated in the field, and they may be either on the contour or up and down the slope. Water from these ditches, flows across the field. After the water leaves the ditches, no attempt is made to control the flow by means of levees, etc. Since the movement of water is not restricted, it is sometimes called **wild flooding.** Although the initial cost of land preparation is low, labour requirements are usually high and water application efficiency is also low. Wild flooding, is most suitable for close growing crops, pastures, etc., particularly where the land is steep. Contour ditches called laterals or subsidiary ditches, are generally spaced at about 20 to 50 metres apart, depending upon the slope, texture of soil, crops to be grown, etc. This method may be used on rolling land (topography irregular) where borders, checks, basins and furrows are not feasible.

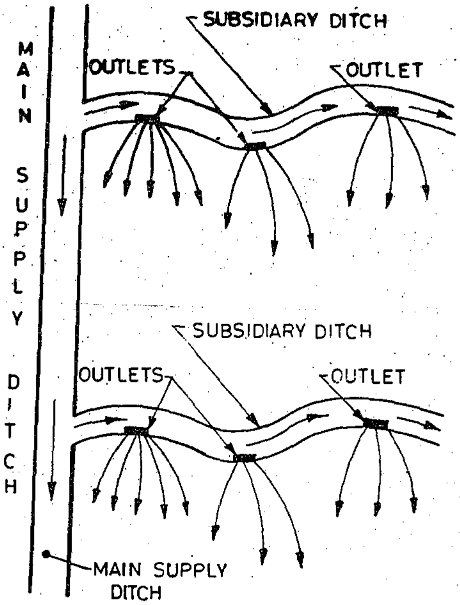


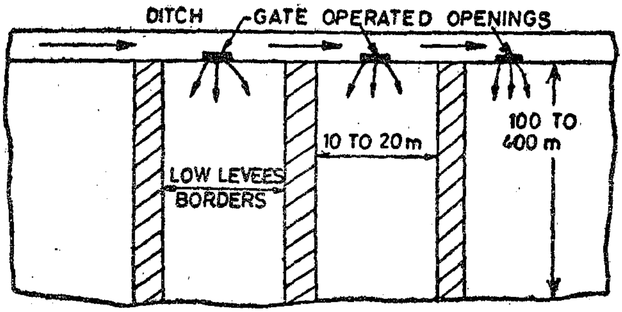
Fig. 1.1. Free flooding (plan view).

(2) **Border flooding.** In this method, the land is divided into a number of strips, separated by low levees called *borders*. The land areas confined in each strip is of the order of 10 to 20 metres in width, and 100 to 400 metres in length, as shown in Fig. 1.2. Ridges between borders should be sufficiently high to prevent overtopping during irrigation.

To prevent water from concentrating on either side of the border, the land should be levelled perpendicular to the flow. Water is made to flow from the supply ditch into each strip. The water flows slowly towards the lower end, and infiltrates into the soil as it advances. When the advancing water reaches the lower end of the strip, the supply of water to the strip is turned off.

The *supply ditch,* also called *irrigation stream,* may either be in the form of an earthen channel or a lined channel or an underground concrete pipe having risers at intervals. The size of the supply ditch depends upon the infiltration rate of the soil, and the width of the border strip. Coarse textured soils with high infiltration rates will require high discharge rate and therefore larger supply ditch, in order to spread water over the entire strip *rapidly,* and to avoid excessive losses due to deep percolation at the upper reaches. On the other hand, fine textured soils with low infiltration rates, require smaller ditches to avoid excessive losses due to run off at the lower reaches.

A relationship between the discharge through the supply ditch (Q), the average depth of water flowing over the strip (y), the rate of infiltration of the soil (f), the area



(*a*) Plan view.

(*b*) Photographic view.
Fig. 1.2. Border flooding.

of the land irrigated (A), and the approximate time required to cover the given area with water (t), is given by the equation :

$$t = 2.3 \cdot \frac{y}{f} \cdot \log_{10}\left(\frac{Q}{Q - fA}\right) \qquad ...(1.1)$$

where Q = Discharge through the supply ditch
y = Depth of water flowing over the border strip
f = Rate of infiltration of soil
A = Area of land strip to be irrigated
t = Time required to cover the given area A.

The above equation can be obtained by considering small area (dA) of the border strip of area A, as shown in Fig. 1.3. Let us also assume that in time dt, water advances

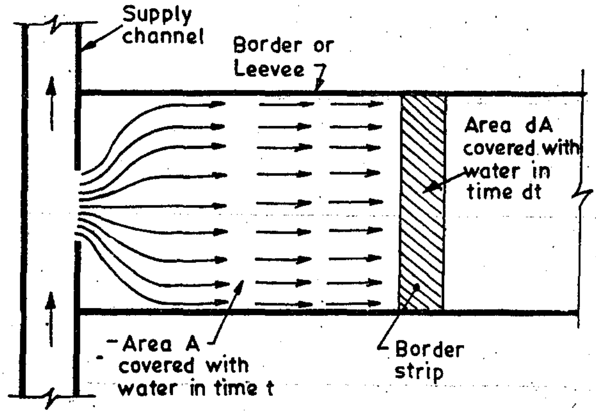


Fig. 1.3.

over this area dA. Now, the volume of water that flows to cover this area would be $y \cdot dA$, because y is the water depth over this area. Also, during the same time dt, the volume of water that percolates into the soil over the area A would be $f \cdot A \cdot dt$. The total quantity of water supplied to the strip during time dt would be $Q \cdot dt$, and also equal to $y{\cdot}dA + f{\cdot}A{\cdot}dt$.

$$\therefore \quad Q{\cdot}dt = y{\cdot}dA + f{\cdot}A{\cdot}dt \quad ...(i)$$

or $$dt = \left(\frac{y{\cdot}dA}{Q - f{\cdot}A}\right) \quad ...(ii)$$

Considering y, f, and Q as constants, and integrating the above equation, we get

$$t = \frac{y}{f}\log_e\left(\frac{Q}{Q - f{\cdot}A}\right) + \text{a constant of integration } (K)$$

But at $t = 0$, $A = 0$

$$\therefore \quad K = \frac{y}{f}\log_e 1 = 0 \quad (\because \ \log_e 1 = 0)$$

$$\therefore \quad t = \frac{y}{f}\log_e\left(\frac{Q}{Q - fA}\right)$$

or $$t = 2.3 \cdot \frac{y}{f}\log_{10}\left(\frac{Q}{Q - fA}\right),$$ which is the above given equation (1).

This equation can be further written as

$$\frac{t{\cdot}f}{2.3y} = \log_{10}\left(\frac{Q}{Q - fA}\right) \quad \text{Now, let } \frac{t{\cdot}f}{2.3y} = x$$

Then, $$x = \log_{10}\left(\frac{Q}{Q - fA}\right)$$

or $$10^x = \frac{Q}{Q - fA}$$

or $$Q \cdot 10^x - f \cdot A \cdot 10^x = Q$$

or $$Q\,(10^x - 1) = f \cdot A \cdot 10^x$$

or $$A = \frac{Q\,(10^x - 1)}{f \cdot 10^x}$$

Further, considering the maximum value of $\frac{10^x - 1}{10^x} \approx 1$,

we get $$A_{max} = \frac{Q}{f} \qquad ...(1.2)$$

This equation enables us to determine the maximum area that can be irrigated with a supply ditch of discharge Q and soil having infiltration capacity, f.

It can also be inferred from this equation that the discharge per unit area of the border strip (Q/A) should be varied according to the infiltration capacity of the soil (f), otherwise loss of water will take place.

This method of field irrigation is becoming very popular among the cultivators. Shorter and narrower strips are found to be more efficient. Entry of water into the strips is generally controlled by placing a jet in the supply ditch, at the head of each strip.

Example 1.1. *Determine the time required to irrigate a strip of land of 0.04 hectares in area from a tube-well with a discharge of 0.02 cumec. The infiltration capacity of the soil may be taken as 5 cm/hr, and the average depth of flow on the field as 10 cm.*

Also determine the maximum area that can be irrigated from this tube well.

Solution. $A = 0.04$ hectares

$$= 0.04 \times 10^4 \text{ m}^2 = 400 \text{ m}^2.$$

$$Q = 0.02 \text{ cumecs} = 0.02 \text{ m}^3/\text{sec} = 0.02 \times 60 \times 60 \text{ m}^3/\text{hr} = 72 \text{ m}^3/\text{hr}.$$

$$f = 5 \text{ cm/hr} = \frac{5}{100} \text{ m/hr} = 0.05 \text{ m/hr.} \;\; ; y = 10 \text{ cm} = 0.1 \text{ m.}$$

Using eqn. (1.1), we have

$$t = 2.3 \frac{y}{f} \log_{10}\left(\frac{Q}{Q - fA}\right)$$

or $$t = 2.3 \; \frac{0.10}{0.05} \; \log_{10}\left(\frac{72}{72 - 0.05 \times 400}\right) \text{hr.}$$

$$= 2.3 \times 2 \log_{10}(72/52) \text{ hr.} = 0.65 \text{ hr} = 39 \text{ minutes.}$$ **Ans.**

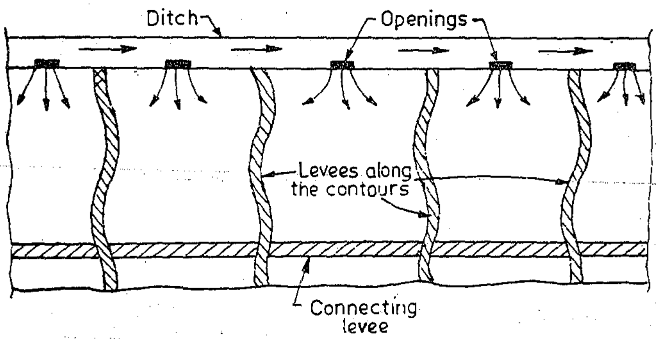
Maximum area that can be irrigated is given by eqn. (1.2) as

$$A_{max} = \frac{Q}{f} = \frac{72}{0.05} \text{ m}^2 = 1440 \text{ m}^2 = \frac{1440}{10^4} \text{ hectares} = 0.144 \text{ hectares.}$$ **Ans.**

Note. After irrigating this much of area, surface flow will stop, and deep percolation will start.

(3) **Check flooding.** Check flooding is similar to ordinary flooding except that the water is controlled by surrounding the *check* area with low and flat levees. Levees are

generally constructed along the contours, having vertical interval of about 5 to 10 cm. These levees are connected with cross-levees at convenient places as shown in Fig. 1.4. The confined plot area varies from 0.2 to 0.8 hectare.



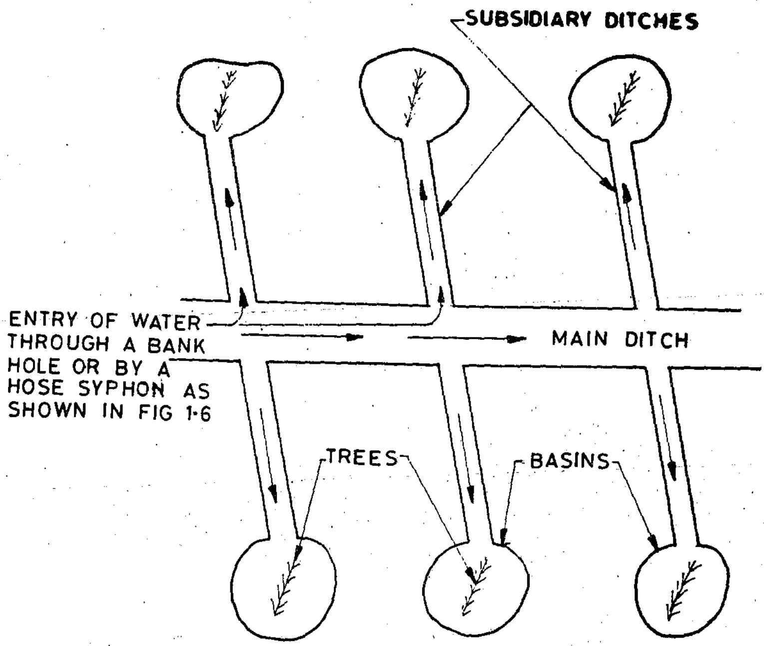
(*a*) Plan view.

(*b*) Photographic view.
Fig. 1.4. Check flooding.

In check flooding, the *check* is filled with water at a fairly high rate and allowed to stand until the water infiltrates.

This method is suitable for more permeable soils as well as for less permeable soils. The water can be quickly spread in case of high permeable soils, thus reducing the percolation losses. The water can also be held on the surface for a longer time in case of less permeable soils, for assuring adequate penetration. These checks, are sometimes used to absorb water, where the stream-flow is diverted during periods of high run off.

(4) **Basin flooding.** This method is a special type of check flooding and is adopted specially for orchard trees. One or more trees are generally placed in the basin, and the surface is flooded as in check method, by ditch water, as shown in Fig. 1.5.

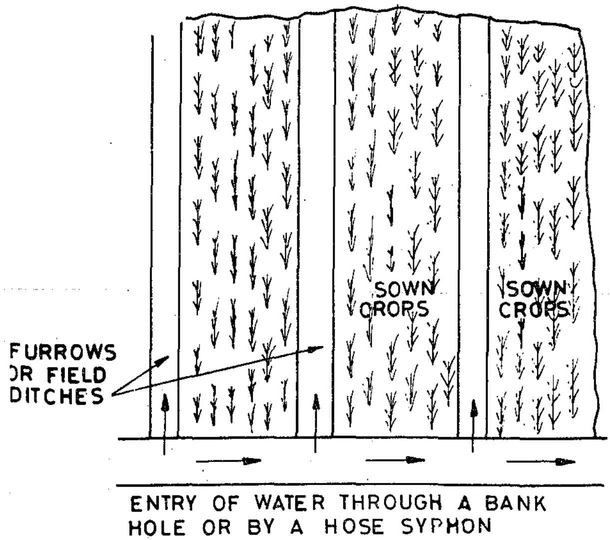


(*a*) Plan view

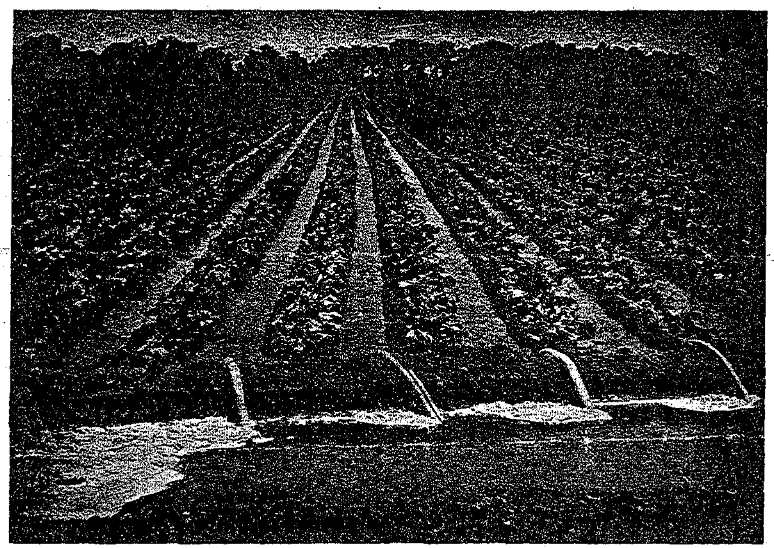
(*b*) Photographic view.
Fig. 1.5. Basin flooding.

(5) **Furrow irrigation method.** In flooding methods, described above, water covers the entire surface; while in furrow irrigation method (Fig. 1.6), only one-fifth to one-half of the land surface is wetted by water. It therefore, results in less evaporation, less pudding of soil, and permits cultivation sooner after irrigation.

Furrows are narrow field ditches, excavated between rows of plants and carry irrigation water through them. Spacing of furrows is determined by the proper spacing of the plants. Furrows vary from 8 to 30 cm deep, and may be as much as 400 metres long.



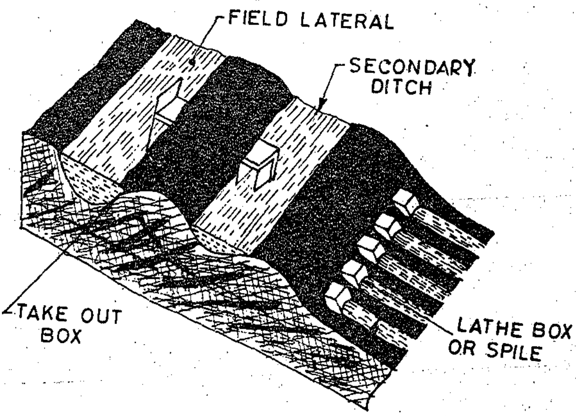
(*a*) Plan view.



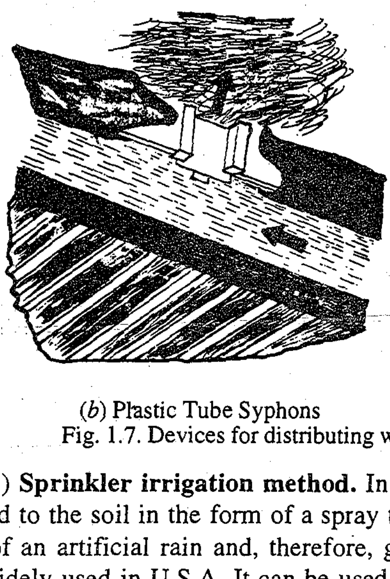
(*b*) Photographic view (using plastic syphons).
Fig. 1.6. Furrow Irrigation.

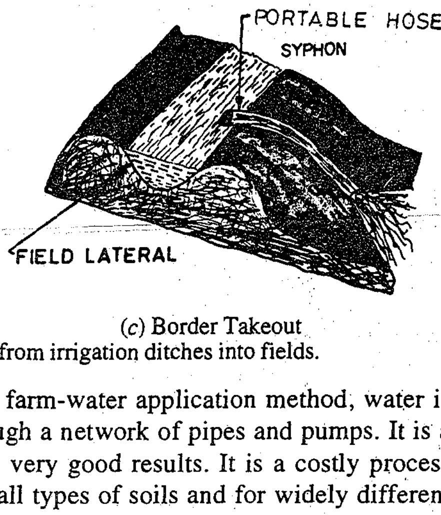
Excessive long furrows may result in too much percolation near the upper end, and too little water near the down-slope end. Deep furrows are widely used for row crops. Small shallow furrows called *corrugations*, are particularly suitable for relatively irregular topography and close growing crops, such as meadows and small grains.

Water may be diverted into the furrows by an opening in the bank of the supply ditch or preferably by using a rubber hose tubing, which can be primed by immersion in the ditch. The use of hose, prevents the necessity of breaking the ditch bank. and provides a uniform flow into the furrow. Fig. 1.7 shows such different devices which are used for distributing water into the fields from the supply ditch.



(*a*) Spiles or Lathe Box.





(*b*) Plastic Tube Syphons (*c*) Border Takeout

Fig. 1.7. Devices for distributing water from irrigation ditches into fields.

(6) **Sprinkler irrigation method.** In this farm-water application method, water is applied to the soil in the form of a spray through a network of pipes and pumps. It is a kind of an artificial rain and, therefore, gives very good results. It is a costly process and widely used in U.S.A. It can be used for all types of soils and for widely different topographies and slopes. It can advantageously be used for many crops, because it fulfils the normal requirement of uniform distribution of water. This method possesses great potentialities for irrigating areas in Rajasthan in India, where other types of surface or sub-surface irrigation are very difficult.

Inspite of the numerous advantages which this method possesses over the other methods, it has not become popular in India for the simple reason that ours is a poor and a developing nation. This method is not only costly but requires a lot of technicalities. The correct design and efficient operation are very important for the success of this method. Special steps have to be taken for preventing entry of silt and debris, which are very harmful for the sprinkler equipment. Debris-choke nozzles, interfere with

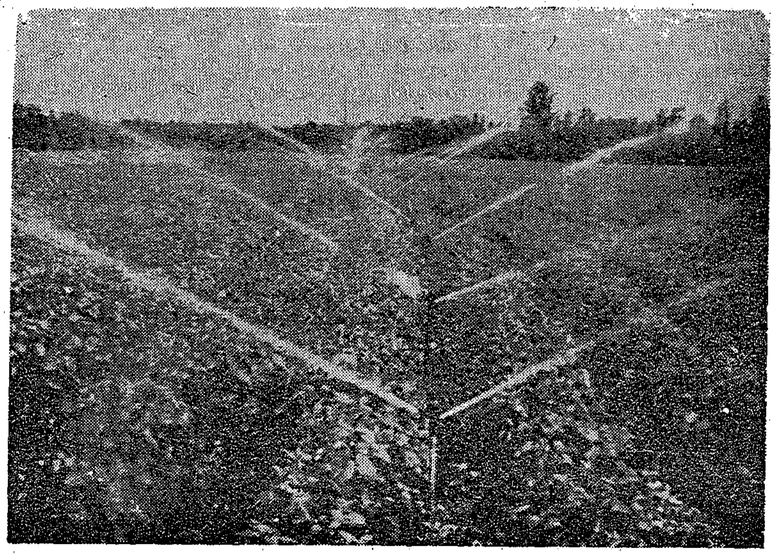


Fig. 1.8. Photoview of a sprinkler system in operation (using a rotary head).

the application of water on the land : while the abrasive action of silt causes excessive wear on pump impellers, sprinkler nozzles, and bearings. The system is to be designed in such a way that the entire sprayed water seeps into the soil, and there is no run off from the irrigated area.

The **conditions favouring the adoption of this method,** are :

(*i*) When the land *topography is irregular,* and hence unsuitable for surface irrigation.

(*ii*) When the land *gradient is steeper,* and soil is easily *erodible.*

(*iii*) When the land soil is *excessively permeable,* so as not to permit good water distribution by surface irrigation ; or when the soil is *highly impermeable.*

(*iv*) When the *watertable* is high.

(*v*) When the area is such that the seasonal water requirement is low, such as *near the coasts.*

(*vi*) When the *crops to be grown are such :*

(*a*) as to require humidity control, as in tobacco ;

(*b*) crops having shallow roots ; or

(*c*) crops requiring high and frequent irrigation.

(*vii*) When the water is available with difficulty and is scarce.

Types of sprinkler systems. A sprinkler system can be classified under three heads, as :

1. Permanent system ;
2. Semi-permanent system ; and
3. Portable system.

Earlier, the *fixed over-head perforated pipe installations* were being used for sprinkler network; but with the advent of light weight steel pipes and quick couplers, portable systems have been designed.

In *permanent system,* pipes are permanently buried in such a way that they do not interfere with the farming operations. In the *semipermanent system,* the main lines are buried in the ground, while the laterals are portable. In the *portable* system, the mains as well as laterals are portable. These portable networks can be moved from farm to farm.

In the sprinkler irrigation network, we have the mains and the sub-mains, through which water under pressure is made to flow. *Revolving sprinkler heads* are then usually mounted on *rising pipes* attached to the laterals. The water jet comes out through the revolving sprinkler heads, with force. When sprinkler heads are not provided, perforations are made in the pipes, and they are provided with nozzles, through which water jets out and falls on the ground. Generally, such a perforated pipe system operates at low heads ; whereas, the revolving head sprinklers operate on high as well as low heads, depending upon the type of rotary head used.

The **advantages** of sprinkler irrigation are enumerated below :

(*i*) Seepage losses, which occur in earthen channels of surface irrigation methods, are completely eliminated. Moreover, only *optimum quantity of water* is used in this method.

(*ii*) Land levelling is not required, and thus avoiding removal of top fertile soil, as happens in other surface irrigation methods.

(*iii*) No cultivation area is lost for making ditches, as happens in surface irrigation methods. It, thus, results in increasing about 16% of the cropped area.

(*iv*) In sprinkler system, the water is to be applied at a rate lesser than the infiltration capacity of the soil, and thus avoiding surface run off, and its bad effects, such as loss of water, washing of top soil, etc.

(*v*) Fertilisers can be uniformly applied, because they are mixed with irrigation water itself.

(*vi*) This method leaches down salts and prevents water-logging or salinity.

(*vii*) It is less labour oriented, and hence useful where labour is costly and scarce.

(*viii*) Upto 80% efficiency can be achieved, *i.e.* upto 80% of applied water can be stored in the root zone of plants.

The **limitations** of sprinkler irrigation are also enumerated below :

(*i*) High winds may distort sprinkler pattern, causing non-uniform spreading of water on the crops.

(*ii*) In areas of high temperature and high wind velocity, considerable evaporation losses of water may take place.

(*iii*) They are not suited to crops requiring frequent and larger depths of irrigation, such as paddy.

(*iv*) Initial cost of the system is very high, and the system requires a high technical skill.

(*v*) Only sand and silt free water can be used, as otherwise pump impellers lifting such waters will get damaged.

(*vi*) It requires larger electrical power.

(*vii*) Heavy soil with poor intake cannot be irrigated efficiently.

(*viii*) A constant water supply is needed for commercial use of equipment.

Note. The widely known Indian Commercial Company which specialises in installing sprinkler irrigation systems, is "Premier Irrigation Equipments (Pvt. Ltd.), Calcutta," with its Delhi office also. This firm and its publications can be referred to, for specialised knowledge in this branch of field irrigation.

(7) **Drip Irrigation Method.** Drip irrigation, also called **trickle irrigation,** is the latest field irrigation technique, and is meant for adoption at places where there exists acute scarcity of irrigation water and other salt problems. In this method, water is *slowly* and directly applied to the root zone of the plants, thereby minimising the losses by evaporation and percolation.

This system involves laying of a system of *head, mains, sub-mains, laterals,* and *drop nozzles.* Water oozes out of these small drip nozzzles uniformly and at a very small rate, directly into the plant roots area.

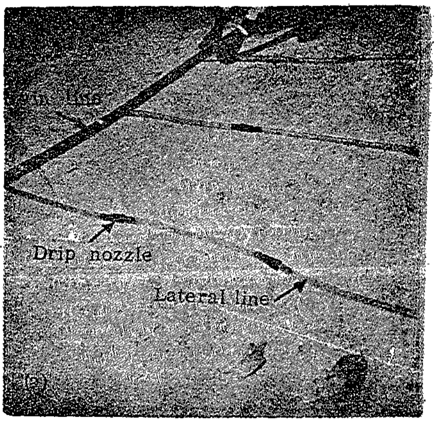
The head consists of a pump to lift water, so as to produce the desired pressure of about 2.5 atmosphere, for ensuring proper flow of water through the system. The lifted irrigation water is passed through a fertiliser tank, so as to mix the fertiliser directly in the irrigation water, and then through a filter, so as to remove the suspended particles from the water, to avoid clogging of drip nozzles.

The *mains and sub-mains* are the specially designed small sized pipes, made of flexible material like black PVC. These are generally buried or laid on the ground, as shown in Fig. 1.9. Their sizes should be sufficient to carry the design discharge of the system.

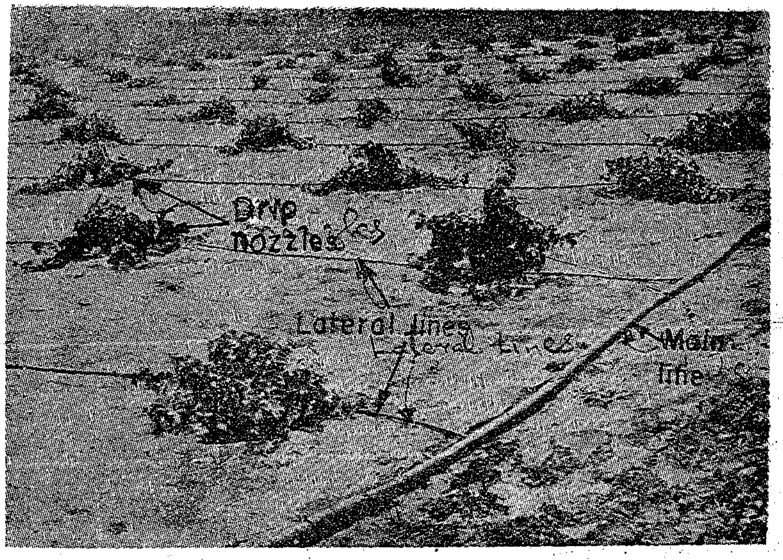
The *laterals* are very small sized (usually 1 to 1.25 cm dia.), specially designed, black PVC pipes, taking off from the mains or sub-mains, Laterals can usually be up to 50 m long, and one lateral line is laid for each row of crop. *Hardie Biwall* is a patented name of a special dual chambered micro tubing, manufactured from a linear low density polyethylene, and is being used these days for laterals.

The *drip nozzles,* also called *emitters,* or *valves,* are fixed on laterals, at regular intervals of about 0.5 to 1 m or so, discharging water at very small rates of the order of 2 to 10 litres per hour.

Like the sprinkler system, this method also involves specialised knowledge, and is not being adopted by our ordinary farmers. This method, is however, being used for small nurseries, orchards, or gardens. The widely known Commercial Indian Company, which specialises in this field irrigation method, is known as "Jain Irrigation Systems Ltd., Jalgaon" (Post Box No. 20), Pin Code : 425001. This firm can be contacted in special needs for layout of such an irrigation system.



(*a*) Layout of mains, laterals and drip nozzles.



(*b*) Field irrigated by drip system laid on the ground.
Fig. 1.9. Two photoviews of Drip irrigation system.

1.7. Quality of Irrigation Water

Just as every water is not suitable for human beings, in the same way, every water is not suitable for plant life. Water containing impurities, which are injurious to plant growth, is not satisfactory for irrigation, and is called the unsatisfactory water.

The quality of suitable irrigation water is very much influenced by the constituents of the soil which is to be irrigated. A particular water may be harmful for irrigation on a particular soil, but the same water may be tolerable or even useful for irrigation on some other soil. The various types of impurities, which make the water unfit for irrigation, are classified as :

(*i*) Sediment concentration in water

(*ii*) Total concentration of soluble salts in water

(*iii*) Proportion of sodium ions to other cations

(*iv*) Concentration of potentially toxic elements present in water

(*v*) Bicarbonate concentration as related to the concentration of calcium plus magnesium

(*vi*) Bacterial contamination.

The effects of these impurities are discussed below :

(1) **Sediment.** The effect of sediment present in the irrigation water depends upon the type of irrigated land. When fine sediment from water is deposited on sandy soils, the fertility is improved. On the other hand, if the sediment has been derived from the eroded areas, it may reduce the fertility or decrease the soil permeability. Sedimented water creates troubles in irrigation canals, as it increases their siltation and maintenance costs. In general, ground water or surface water from reservoirs, etc. does not have sufficient sediment to cause any serious problems in irrigation.

(2) **Total concentration of soluble salts.** Salts of calcium, magnesium sodium and potassium, present in the irrigation water may prove injurious to plants. When present in excessive quantities, they reduce the osmotic activities of the plants, and may prevent adequate aeration, causing injuries to plant growth. The injurious effects of salts on the plant growth depend upon the concentration of salts left in the soil.

The concentration of salts in water, may not appear to be harmful to the plants, but the concentration of salts which remain in the soil after the saline water is used up by the plants is much more than the first, and may prove to be harmful. In other words, at the beginning of irrigation with undesirable water, no harm may be evident, but with the passage of time, the salt concentration in the soil may increase to a harmful level, as the soil solution gets concentrated by evaporation.

Hence, the effects of salts on plant growth depend largely upon the total amount of salts present in the soil solution. The salinity concentration of the soil solution (C_s) after the consumptive water (C_u) has been extracted from the soil, is given by

$$C_s = \frac{C \cdot Q}{[Q - (C_u - P_{eff})]} \quad ...(1.3)$$

where Q = The quantity of water applied

C_u = Consumptive use of water, *i.e.* the total amount of water used by the plant for its growth

P_{eff} = Useful rainfall

$C_u - P_{eff}$ = Used up irrigation water

C = Concentration of salt in irrigation water

CQ = Total salt applied to soil with Q amount of irrigation water.

The salt concentration is generally expressed by ppm (parts per million) or by mg/l (milligram per litre), both units being equal. The critical salt concentration in the irrigation water depends upon many factors, yet however, amounts in excess of 700 ppm are harmful to some plants, and more than 2000 ppm are injurious to all crops.

The salt concentration is generally measured by determining the electrical conductivity of water. They are directly proportional to each other. Electrical conductivity is expressed in micro mhos per centimetre. When its value is up to 250 micro mhos/cm at 25°C, it is called low conductivity water (Cl) ; when its value is between 250 to 750, it is called *Medium Conductivity water* (C2) ; when its value is between 750 to 2250, it is called *High Conductivity water* (C3) ; and the values above 2250, are classified as very *High Conductivity water* (C4). The suitabilities of these four types of waters for irrigation supplies are discussed in Table 1.1. This classification which is shown in Table 1.1 was given by U.S.D.A. Handbook No. 60 (1954).

Table 1.1

S. No.	*Type of water*	*Use in irrigation*
1.	Low salinity water (C1). Conductivity between 100 to 250 micro mhos/cm at 25°.	Can be used for irrigation for almost all crops and for almost all kinds of soils. Very little salinity may develop, which may require slight leaching; but it is permissible under normal irrigation practices except in soils of extremely low permeabilities.
2.	Medium salinity water (C2). Conduc- tivity between 250 to 750 micro mhos/cm at 25°C.	Can be used, if a moderate amount of leaching occurs. Normal salt-tolerant plants can be grown without much salinity control.
3.	High salinity water (C3). Conductivity between 750 to 2250 micro mhos/cm at 25°C.	Cannot be used on soils with restricted drainage. Special precautions and measures are undertaken for salinity control and only high-salt tolerant plants can be grown.
4.	Very high salinity water (C4). Conductivity more than 2250 micro mhos/cm at 25°C.	Generally not suitable for irrigation.

(3) **Proportion of sodium ions to other cations.** Most of the soils contain calcium and magnesium ions and small quantities of sodium ions. *The percentage of the sodium ions is generally less than 5% of the total exchangeable cations.* If this percentage increases to about 10% or more, the aggregation of soil grains breaks down. The soil becomes less permeable and of poorer tilth. It starts crusting when dry and its pH increases towards that of an alkaline soil. High sodium soils are, therefore, plastic, sticky when wet, and are prone to form clods, and they crust on drying.

The proportion of sodium ions present in the soils, is generally measured by a factor called *Sodium-Absorption Ratio* (SAR) and represents the sodium hazards of water. SAR is defined as :

$$SAR = \frac{Na^+}{\sqrt{\frac{Ca^{++} + Mg^{++}}{2}}} \quad ...(1.4)$$

where, the concentration of the ions is expressed in equivalent per million (epm) ; epm is obtained by dividing the concentration of salt in mg/l or ppm by its combining weight (*i.e.* Atomic wt. ÷ Valence.)

When the value of SAR lies between 0 to 10, it is called *Low Sodium Water* (S1) ; when between 10 to 18, it is called *Medium Sodium Water* (S2) ; between 18 to 26 ; it is called *High Sodium Water* (S3) ; and when values of SAR are more than 26,it is called

Very High Sodium Water (S4). The suitabilities of these four kinds of water for irrigation are discussed in Table 1.2. The SAR value can be reduced by adding gypsum ($CaSO_4$) to the water or to the soil.

Table 1.2

S. No.	*Type of water*	*Use in irrigation*
1.	Low sodium water (S1). SAR value lying between 0 to 10.	Can be used for irrigation on almost all soils and for almost all crops except those which are highly sensitive to sodium, such as stone-fruit trees and adocados, etc.
2.	Medium sodium water (S2). SAR value lying between 10 to 18.	Appreciably hazardous in fine textured soils, which may require gypsum, etc.; but may be used on course-textured or organic soils with good permeability.
3.	High sodium water (S3). SAR value lying between 18 to 26.	May prove harmful on almost all the soils, and do require good drainage, high leaching, gypsum addition etc. for proper irrigation.
4.	Very high sodium water (S4). SAR value above 26.	Generally, not suitable for irrigation.

Depending upon the *Electrical conductivity EC* (representing salt content) of water, the *exchangeable sodium percentage ESP* (representing percentage of sodium w.r.to total exchangeable cations), and the pH value of the soil, the soils are classified as *saline, alkaline*, or *saline- alkali*, as shown in table 1.3 below :

Table 1.3. The Classification of Saline and Alkaline Soils

Sl. No.	*Classification*	*Electrical Conductivity (EC) in micro-mho/cm*	*Exchangeable Sodium Percentage (ESP)*	*pH value*
1.	**Saline soil** or *white alkali*	> 4000	< 15	≤ 8.5
2.	**Alkaline soil** or *Non-saline alkali* or *Sodic soil* or *Black alkali*	< 4000	> 15	8.5 to 10.0
3.	*Saline-alkali soil*	> 4000	> 15	< 8.5

(4) **Concentration of potentially toxic elements.** A large number of elements such as boron, selenium, etc. may be toxic to plants. Traces of *Boron* are essential to plant growth, but its concentrations above 0.3 ppm may prove toxic to certain plants. The concentration above 0.5 ppm is dangerous to nuts, citrus fruits and *deciduous* fruits. Cotton, Cereals and certain truck crops are moderately tolerant to boron, while Dates, Beets, Asparagus etc. are quite tolerant. Even for the most tolerant crops, the boron concentration should not exceed 4 ppm. Boron is generally present in various soaps. The waste water containing soap, etc. should, therefore, be used with great care in irrigation.

Selenium, even in low concentration, is toxic, and must be avoided.

(5) **Bicarbonate concentration as related to concentration of calcium plus magneisum.** High concentration of bi-carbonate ions may result in precipitation of calcium and magnesium bicarbonates from the soil-solution, increasing the relative proportion of sodium ions and causing sodium hazards.

(6) **Bacterial contamination.** Bacterial contamination of irrigation water is not a serious problem, unless the crops irrigated with highly contaminated water are directly

eaten, without being cooked. Cash crops like cotton, nursery stock, etc. which are processed after harvesting, can, therefore, use contaminated waste waters, without any trouble.

Example 1.1. *(a) What is the classification of irrigation water having the following characteristics : Concentration of Na, Ca and Mg are 22, 3 and 1.5 milli-equiavalents per litre respectively, and the electrical conductivity is 200 micro mhos per cm at 25°C ? (b) What problems might arise in using this water on fine textured soils ? (c) What remedies do you suggest to overcome this trouble ?*

Solution.

$$SAR = \frac{Na^+}{\sqrt{\frac{Ca^{++} + Mg^{++}}{2}}} = \frac{22}{\sqrt{\frac{3+1.5}{2}}} = \frac{22}{\sqrt{2.25}} = \frac{22}{1.5} = 14.67.$$

If SAR is between 10 to 18, then it is classified as medium Sodium water and is represented by S2 (See Table 1.2).

Electrical conductivity is 200 micro-mhos per cm at 25°C.

According to Table 1.1, the water is called of Low conductivity (C1) if the value of electrical conductivity is between 100 to 250 micro mhos per cm at 25°C. It is, therefore, C1 water.

Hence, the given water is classified as C1-S2 *water.* **Ans.**

(*b*) In fine-textured soils, the medium sodium (S2) water may create the following problems :

(*i*) Soil becomes less permeable.

(*ii*) It starts crusting when dry.

(*iii*) It becomes plastic and sticky when wet.

(*iv*) Its pH increases towards that of alkaline soil.

(*c*) Gypsum ($CaSO_4$) addition, either to soil or to water is suggested to overcome sodium hazards posed by the given water.

PROBLEMS

1. Define irrigation and explain its necessity in a tropical country like India. What are the advantages and ill-effects of assured irrigation ?

2. What is meant by surface and sub-surface irrigation ; and what are their types ? Discuss briefly the various techniques used for distributing water in the farms.

3. What is meant by 'Furrow Irrigation" and 'Sprinkler Irrigation' ? Which one is preferred in India and why ?

4. 'The sprinkler system of irrigation is an excellent method but not used in India'. Discuss critically and briefly.

5. What is meant by 'Border flooding', and how does it differ from 'Check flooding' and 'Free flooding'?

6. Describe briefly the necessity and importance of irrigation works in our country? What are different types of irrigation ? Write brief notes on each of them.

7. (*a*) What are the benefits that can be accrued from Irrigation projects ?

(*b*) What is 'flood irrigation' ? Where is it practised ?

(*c*) How is the Flow irrigation different from the Lift irrigation ? Give the names of districts in Tamil Nadu where they are practised mostly ?

8. Discuss critically the quality standards required for irrigation water.

9. 'All the waters are not fit for irrigating crops'. Discuss briefly and critically the above statement.

10. What is meant by C2—S2 water ? Discuss its usefulness for irrigating fine textured soils.

11. Write short notes on :

(*i*) Lift irrigation.

(*ii*) Mixed cropping.

(*iii*) Ill-effects of irrigation.

(*iv*) Border strip and Sprinkler methods of irrigating fields.

(*v*) Sodium-Absorption-Ratio (SAR).

(*vi*) Salt concentration of irrigation waters and their utility in irrigation.

(*vii*) Sodium hazards of irrigation waters.

(*viii*) Boron concentration in irrigation waters.

(*ix*) Drip irrigation method.