Department of Civil Engineering

B.TECH – 6TH SEM

WATER RESOURCES AND IRRIGATION ENGINEERING (WRE)

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UNIT-1

IRRIGATION ENGINEERING

Benefits of irrigation

With the introduction of irrigation, there have been many advantages, as compared to the total dependence on rainfall. These may be enumerated as under:

1. ***Increase in crop yield***: the production of almost all types of crops can be increased by providing the right amount of later at the right time, depending on its shape of growth. Such a controlled supply of water is possible only through irrigation.

2. ***Protection from famine***: the availability of irrigation facilities in any region ensures protection against failure of crops or famine due to drought. In regions without irrigation, farmers have to depend only on rains for growing crops and since the rains may not provide enough rainfall required for crop growing every year, the farmers are always faced with a risk.

3. ***Cultivation of superior crops***: with assured supply of water for irrigation, farmers may think of cultivating superior variety of crops or even other crops which yield high return. Production of these crops in rain-fed areas is not possible because even with the slight unavailability of timely water, these crops would die and all the money invested would be wasted.

4. ***Elimination of mixed cropping***: in rain-fed areas, farmers have a tendency to cultivate more than one type of crop in the same field such that even if one dies without the required amount of water, at least he would get the yield of the other. However, this reduces the overall production of the field. With assured water by irrigation, the farmer would go for only a single variety of crop in one field at anytime, which would increase the yield.

5. ***Economic development***: with assured irrigation, the farmers get higher returns by way of crop production throughout the year, the government in turn, benefits from the tax collected from the farmers in base of the irrigation facilities extended.

6. ***Hydro power generation***: usually, in canal system of irrigation, there are drops or differences in elevation of canal bed level at certain places. Although the drop may not be very high, this difference in elevation can be used successfully to generate electricity. Such small hydro electric generation projects, using ***bulb-turbines*** have been established in many canals, like Ganga canal, Sarada canal, Yamuna canal etc.

7. ***Domestic and industrial water supply***: some water from the irrigation canals may be utilized for domestic and industrial water supply for nearby areas. Compared to the irrigation water need, the water requirement for domestic and industrial uses is

rather small and does not affect the total flow much. For example, the town of Siliguri in the Darjeeling district of West Bengal, supplies its residents with the water from Teesta Mahananda link canal.

Classification of irrigation schemes

Irrigation projects in India are classified into three categories –major medium & minor according to the area cultivated the classification criteria is as follows:-

1) Major irrigation projects: projects which have a ***culturable command area*** (CCA) of more than 10,000 ha but more than 2,000 ha utilize mostly surface water resources.

2) Medium irrigation projects: projects which have CCA less than 10,000 ha. But more than 2,000 ha utilizes mostly surface water resources.

3) Minor irrigation projects: projects with CCA less than or equal to 2,000 ha. utilizes both ground water and local surface water resources. Ground water development is primarily done through individual and cooperative effort of farmers with the help of institutional finance and their own savings. Surface water minor irrigation schemes are generally funded from the public sector only. The ultimate irrigation potential from minor irrigation schemes have been assessed as 75.84 million ha of which partly would be ground water based (58.46 million ha) and covers about two thirds. By the end of the ninth plan, the total potential created by minor irrigation was 60.41 million ha.

The ultimate irrigation potential of the country from major and medium irrigation projects has been assessed as about 64 M-ha. By the end of the ninth plan period, the total potential created from major and medium projects was about 35 M-ha.

Command Area Development Programme (CADP)

This scheme, sponsored by the central government was launched in 1974-75 with the objective of bridging the gap between irrigation potential created and that utilized for ensuring efficient utilization of created irrigation potential and increasing the agricultural productivity from irrigated lands on a sustainable basis. The programme envisages integrating various activities relating to irrigated agriculture through a multi-disciplinary team under an area development authority in a coordinated manner. The existing components of the CADP are as follows:-

1. On farm development works, that is, development of field channels and field drains within the command of each ***outlet***, land leveling on an outlet command basis; reclamation of ***water logged*** areas; enforcement of a proper system of rotational water supply (like the ***warabandi***) and fair distribution of water to individual fields; realignment of field boundaries, wherever necessary (where possible, consolidation of holding are also combined)supply of all inputs and service including credit; strengthening of extension services; and encouraging farmers for participatory irrigation management.

2. Selection and introduction of suitable cropping patterns.

3. Development of ground water to supplement surface irrigation (conjunctive use under minor irrigation sector)

4. Development and maintenance of the main and intermediate drainage system.

5. Modernization, maintenance and efficient operation of the irrigation system up to the outlet of one cusec ($1 ft^3/sec$) capacity.

For an overall appreciation of an entire irrigation project it is essential that the objectives of the CAD be kept in mind by the water resources engineer.

Participatory irrigation management (PIM)

Any irrigation project cannot be successful unless it is linked to the stakeholders, that is, the farmers themselves. In fact, people's participation in renovation and maintenance of field channels was the established practice during the pre independence days. However, the bureaucracy encroached on this function in the post independence period and a realization has dawned that without the participation of farmers, the full potential of an irrigation scheme may not be realized. Though a water resources engineer is not directly involved in such a scheme, it is nevertheless wise to appreciate the motive behind PIM and keep that in mind while designing an irrigation system.

Management of water for irrigation

Of the two resources –land and water, management of the former is largely in the domain of agricultural engineers. Management of water, on the other hand, is mostly the purview of the water resources engineer who has to decide the following:

- How much water is available at a point of a surface water source, like a river (based on hydrological studies)

- How much ground water is available for utilization in irrigation system without adversely lowering the ground water table?

- For the surface water source, is there a need for construction of a reservoir for storing the monsoon runoff to be used in the lean seasons?

- What kind of diversion system can be constructed across the river for diverting part of the river flow into a system of canal network for irrigating the fields?

- How efficient a canal network system may be designed such that there is minimum loss of water and maximum agricultural production?

- How can excess water of an irrigated agricultural fields be removed which would otherwise cause water logging of the fields?

In order to find proper solution to these and other related issues, the water resources engineer should be aware of a number of components essential for proper management of water in an irrigation system. These are:-

1. ***Watershed development:*** since the water flowing into a river is from a watershed, it is essential that the movement of water over ground has to be delayed. This would ensure that the rain water falling within the catchment recharges the ground water, which in turn replenishes the water inflow to the reservoir even during the lean season. Small check dams constructed across small streams within the catchment can help to delay the surface water movement in the watershed and recharge the ground water. Measures for the water shed development also includes aforestation within the catchment area which is helpful in preventing the valuable top-soil from getting eroded and thus is helpful also in preventing siltation of reservoirs. Other soil conservation methods like regrassing and grass land cultivation process, galley plugging, nullah bunding, contour bunding etc. also come under watershed development.

2. ***Water management:*** surface water reservoirs are common in irrigation systems and these are designed and operated to cater to crop water requirement throughout the year. It is essential, therefore, to check loss of water in reservoir due to
    - Evaporation from the water surface
    - Seepage from the base
    - Reduction of storage capacity due to sedimentation

3. ***Water management in conveyance system:*** In India the water loss due to evaporation, seepage and mismanagement in the conveyance channels (for canals and its distributaries) is exceptionally high-nearly 60%. Some countries like Israel have reduced this loss tremendously by taking several measures like lining of water courses, lining not only reduces seepage, but also minimizes weed infestation and reduces overall maintenance cost though the initial cost of providing lining could be high depending on the material selected.

4. ***On farm water management:*** Though this work essentially is tackled by agricultural engineers, the water resources engineers must also be aware of the problem so that a proper integrated management strategy for conveyance-delivery-distribution of irrigation water is achieved. It has been observed from field that the water delivered from the canal system to the agricultural fields are utilized better in the head reaches and by the time it reaches the tail end, its quantity reduces. Often, there are land holding belonging to different farmers along the route of the water course and there is a tendency of excess withdrawal by the farmers at the upper reaches. In order to

tackle this kind of mismanagement a proper water distribution roster has to be implemented with the help of farmers' cooperatives or water user's associations. At times farmers are of the opinion that more the water applied more would be the crop production which is generally not true beyond a certain optimum water application rate. Education of farmers in this regard would also ensure better on-farm water management.

5. ***Choice of irrigation method:*** Though irrigation has been practiced in India from about the time of the Harappa civilization, scientific irrigation based on time variant crop water need within the constraints of water and land availability is rather recent. It is important to select the right kind of irrigation method to suit the particular crop and soil. For example, following is a short list of available methods corresponding to the kind of crop.

Method of irrigation	Suitable for crops
Border strip method	Wheat, Leafy vegetables, Fodders
Furrow method	Cotton, Sugarcane, Potatoes
Basin method	Orchard trees

Other methods like sprinkler and drip irrigation systems are adapted where water is scarce and priority for its conservation is more than the consideration for cost. Although most advanced countries are adopting these measures, they have not picked up as much in India mainly due to financial constraints. However, as time passes and land and water resources get scarce, it would be essential to adopt these practices in India, too.

6. ***Choice of cropping pattern:*** Scientific choice of cropping pattern should be evolved on the basis of water availability, soil type, and regional agro-climate conditions. Crop varieties which give equivalent yield with less water requirement and take less time to mature should be popularized. Scientific contribution in the form of double or multiple cropping can be achieved if the sowing of crops such as paddy, groundnut, arhar etc. is advanced, if necessary, by raising the nurseries with the help of ground-water. Selection of crops planting sequence per unit weight of water applied.

7. ***Scheduling of irrigation water:*** Traditional farmers engaged in crop production are aware of some kind of scheduling of water to the crops, but their knowledge is based mostly on intuition and traditional wisdom rather than on any scientific basis. Modern scientific study on crop growth has shown that a correlation can be established between the climatic parameters, crop water requirement and the moisture stored in the soil especially in the root zone. It has now been established by scientific

research that the application of irrigation should be such that the available water in the soil above the ***permanent wilting point*** is fully utilized by the crop before requiring application of water to replenish the depleted moisture in the soil. Since any canal would be delivering water at the same time to different fields growing different crops, the demand of the various fields have to be calculated at any point of time or a certain period of time(days, weeks),and the water distributed accordingly through the canal network.

8. ***Development of land drainage:*** Due to improper application of water and inadequate facilities for drainage of excess water from irrigated lands, large tracks of land near irrigated areas have been affected with water logging and excess salt concentration in soils. Adequate drainage measures like surface and subsurface drainage systems, vertical drainage, bio-drainage etc. should be developed as an integral part of the irrigation system.

9. ***Command area development:*** We have already seen that the government has initiated the command area development programme (CADP) which would ensure efficient water utilization and integrated area developments in the irrigation command.

10. ***Canal automation:*** At present, the water entering the canal network through the ***headworks*** as well as the water getting distributed into the various branches and finally reaching the fields through the outlets are controlled manually. However, if these operations are carried out through automated electro-mechanical systems which can communicate to a central computer, then the whole process can be made more efficient. This would also help to save water and provide optimal utilization of the availability water.

Classification of irrigation schemes

The classification of the irrigation systems can also be based on the way the water is applied to the agricultural land as:

1. ***Flow irrigation system*:** where the irrigation water is conveyed by growing to the irrigated land. This may again be classified into the following.

   - **Direct irrigation*:*** Where the irrigation water is obtained directly from the river, without any intermediate storage. This type of irrigation is possible by constructing a weir or a barrage across a river to raise the level of the river water and thus divert some portion of the river flow through an adjacent canal, where the flow takes place by gravity.

   - **Reservoir/tank/storage irrigation:** The irrigation water is obtained from a river, where storage has been created by construction an obstruction across the river, like a dam. This ensures that even when there is no inflow into the river from the catchment, there is enough stored water which can continue to irrigate fields through a system of canals.

2. ***Lift irrigation system:*** Where the irrigation water is available at a level lower than that of the land to be irrigated and hence the water is lifted up by pumps or by other mechanical devices for lifting water and conveyed to the agricultural land through channels flowing under gravity.

Classification of irrigation systems may also be made on the basis of duration of the applied water, like:

1. **Inundation/flooding type irrigation system:** In which large quantities of water flowing in a river during floods is allowed to inundate the land to be cultivated, thereby saturating the soil. The excess water is then drained off and the land is used for cultivation. This type of irrigation uses the flood water of rivers and therefore is limited to a certain time of the year. It is also common in the areas near river deltas, where the slope of the river and land is small. Unfortunately, many of the rivers, which were earlier used for flood inundation along their banks, have been embanked in the past century and thus this practice of irrigation has dwindled.

2. **Perennial irrigation system:** In which irrigation water is supplied according to the crop water requirement at regular intervals, throughout the life cycle of the crop. The water for such irrigation may be obtained from rivers or from walls. Hence, the source may be either surface or ground water and the application of water may be by flow or lift irrigation systems.

Classification of irrigation projects

Irrigation projects are classified in different ways, however, in Indian context it is usually classified as follows:

- **Major project:** This type of project consists of huge surface water, storage reservoirs and flow diversion structures. The area envisaged to be covered under irrigation is of the order over 10000 hectare.

- **Medium project:** These are also surface water projects but with medium size storage and diversion structures with the area under irrigation between 10000 hectare and 2000 hectare.

- **Minor project:** The area proposed under irrigation for these schemes is below 2000Ha and the source of water is either ground water or from wells or tube wells or surface water lifted by pumps or by gravity flow from tanks. It could also be irrigated from through water from tanks.

The major and medium irrigation projects are further classified as

- Direct irrigation method
- Storage irrigation method.

Each of the two classifications is explained in subsequent sections. But before that, it may be worthwhile to discuss here a few terms related to irrigation projects which may also be called irrigation schemes.

IMPORTANT TERMS

Culturable Command Area (CCA): The gross command area contains unfertile barren land, alkaline soil, local ponds, villages and other areas as habitation. These areas are called unculturable areas. The remaining area on which crops can be grown satisfactorily is known as cultivable command area (CCA). Culturable command area can further be divided into 2 categories

1. Culturable cultivated area: It is the area in which crop is grown at a particular time or crop season.
2. Culturable uncultivated area: It is the area in which crop is not sown in a particular season.

Gross command area (GCA): The total area lying between drainage boundaries which can be commanded or irrigated by a canal system.

G.C.A = C.C.A + UNCULTURABLE AREA

Water Tanks: These are dug areas of lands for storing excess rain water.

Outlet: This is a small structure which admits water from the distributing channel to a water course of field channel. Thus an outlet is a sort of head regulator for the field channel delivering water to the irrigation fields.

Water logged area: An agricultural land is said to be waterlogged when its productivity or fertility is affected by high water table. The depth of water-table at which it tends to make the soil water-logged and harmful to the growth and subsistence of plant life

depends upon the height of capillary fringe, which is the height to which water will rise due to capillary action. The height of capillary fringe is more for fine grained soil and less for coarse grained ones.

Permanent wilting point: or the wilting coefficient is that water content at which plants can no longer extract sufficient water from the soil for its growth. A plant is considered to be permanently wilted when it will not regain its turbidity even after being placed in a saturated atmosphere where little or no consumptive water use occurs

Commanded area (CA): is defined as the area that can be irrigated by a canal system, the CA may further be classified as under:

Gross command area (GCA): This is defined as total area that can be irrigated by a canal system on the perception that unlimited quantity of water is available. It is the total area that may theoretically be served by the irrigation system. But this may include inhibited areas, roads, ponds, uncultivable areas etc which would not be irrigated.

Culturable command area (CCA): This is the actually irrigated area within the GCA. However, the entire CCA is never put under cultivation during any crop season due to the following reasons:

- The required quantity of water, fertilizer, etc. may not be available to cultivate the entire CCA at a particular point of time. Thus, this is a physical constraint.
- The land may be kept fallow that is without cultivation for one or more crop seasons to increase the fertility of the soil. This is a cultural decision.
- Due to high water table in some areas of the CCA irrigated water may not be applied as the crops get enough water from the saturation provide to the surface water table.

During any crop season, only a part of the CCA is put under cultivation and this area is termed as ***culturable cultivated area***. The remaining area which is not cultivated during a crop season is conversely termed as ***culturable uncultivated area***.

Intensity of irrigation is defined as the percentage of the irrigation proposed to be irrigated annually. Usually the areas irrigated during each crop season (Rabi, Kharif, etc) is expressed as a percentage of the CCA which represents the intensity of irrigation for the crop season. By adding the intensities of irrigation for all crop seasons the yearly intensity of irrigation to be obtained.

Methods of Field Water Application

Irrigation water conveyed to the head or upstream point of a field must be applied efficiently on the whole area such that the crops growing in the either fields gets water more or less uniformly.

Naturally it may be observed that a lot depends on the topography of the land since a large area with uneven topography would result in the water spreading to the low lying areas. The type of crop grown also immensely matter as some like rice, require standing water depths at almost all stages of its growth. Some, like potato, on the other hand, suffer under excess water conditions and require only the right amount of water to be applied at the right time. Another important factor determining the way water is to apply in the fields is the quantity of water available at any point of time. If water is scarce, as what is actually happening in many parts of the country, then it is to be applied through carefully controlled methods with minimum amount of wastage. Usually these methods employ pressurized flow through pipes which is either sprinkled over the crop or applied carefully near the plant root. On the other hand when water is rather unlimited during the crop growing season as in deltaic regions, the river flood water is allowed to inundate as much area as possible as long the excess water is available. Another important parameter dictating the choice of the irrigation method is the type of soil. Sometimes water is applied not on the surface of the field but is used to moist the root zone of the plants from beneath the soil surface. Thus, in effective the type of irrigation methods can be broadly divided as under:

- Surface irrigation method
- Subsurface irrigation method
- Sprinkler irrigation system
- Drip irrigation system

Surface Irrigation Methods

In this system of field water application the water is applied directly to the soil from a channel located at the upper reach of the field. It is essential in these methods to construct designed water distribution systems to provide adequate control of water to the fields and proper land preparation to permit uniform distribution of water over the field.

One of the surface irrigation method is ***flooding method*** where the water is allowed to cover the surface of land in a continuous sheet of water with the depth of applied water just sufficient to allow the field to absorb the right amount of water needed to raise the soil moisture up to field capacity,. A properly designed size of irrigation stream aims at proper balance against the intake rate of soil, the total depth of water to be stored in the root zone and the area to be covered giving a reasonably uniform saturation of soil over the entire field.

Flooding method has been used in India for generations without any control what so ever and is called uncontrolled flooding. The water is made to enter the fields bordering rivers during folds. When the flood water inundates the flood plane areas, the water distribution is quite uneven, hence not very efficient, as a lot of water is likely to be wasted as well as soils of excessive slopes are prone to erosion. However the adaptation of this method doesn’t cost much.

The flooding method applied in a controlled way is used in two types of irrigation methods as under:

- **Border irrigation method**

- ***Basin irrigation method***

As the names suggest the water applied to the fields by this inundates or floods the land, even if temporarily. On the other hand there are many crops which would try better if water is applied only near their root zone instead of inundating.

Such an irrigation method is called the Furrow irrigation method. All these methods are discussed in the subsequent sections.

Border irrigation

Borders are usually long uniformly graded strips of land separated by earth bunds (low ridges) as shown in Figure 4.

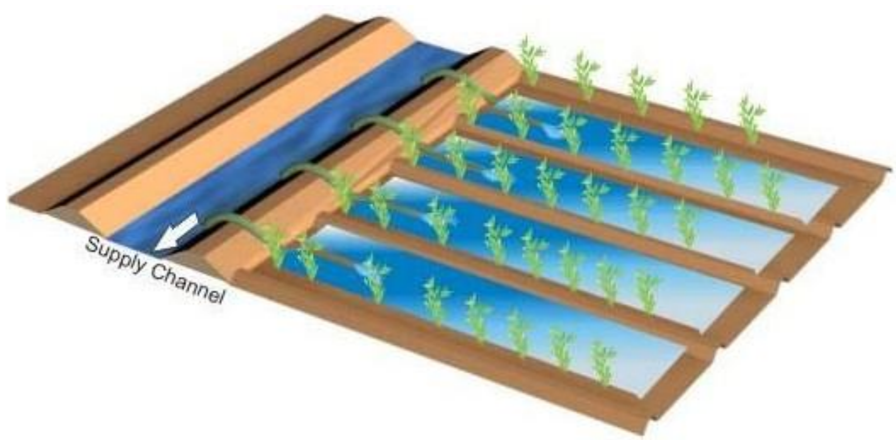


FIGURE 4. Border irrigation with water being applied to the borders with the help of flexible pipes, acting as siphons

The essential feature of the border irrigation is to provide an even surface over which the water can flow down the slope with a nearly uniform depth. Each strip is irrigated independently by turning in a stream of water at the upper end as shown in Figure 5.

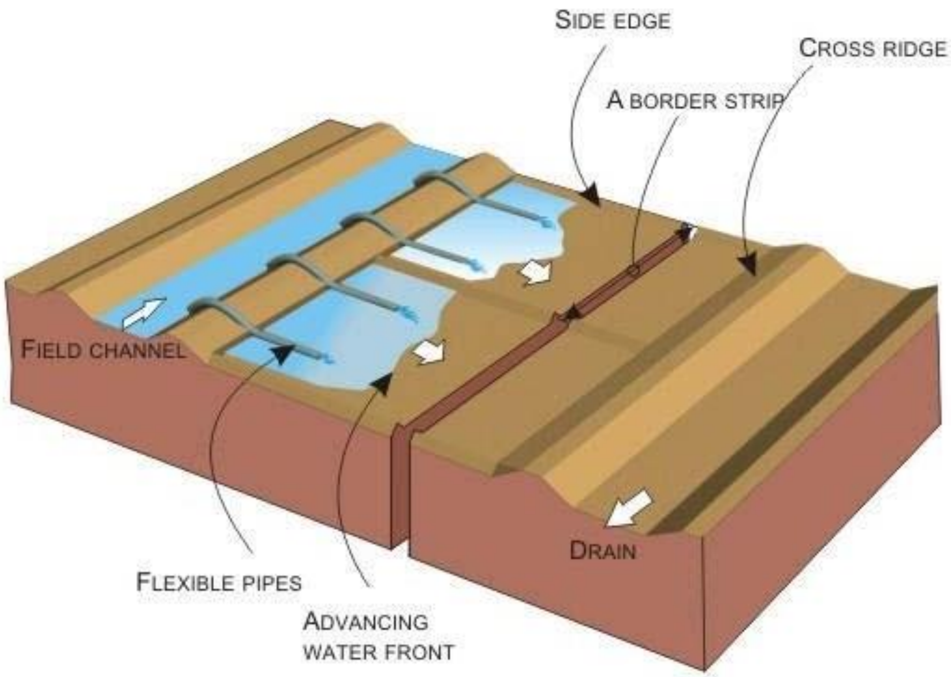


FIGURE 5. Water entering each border strip independently

The water spreads and flow down the strip in a sheet confined by border ridges. When the advancing water reaches the lower end of the border, the stream is turned off.

For uniform advancement of water front the borders must be properly leveled. The border shown in the figures above are called ***straight borders***, in which the border strips are laid along the direction of general slope of the field. The borders are sometimes laid along the elevation contours of the topography when the land slope is excessive. Thos method of border is called ***contour border method*** of irrigation (Figure 6).

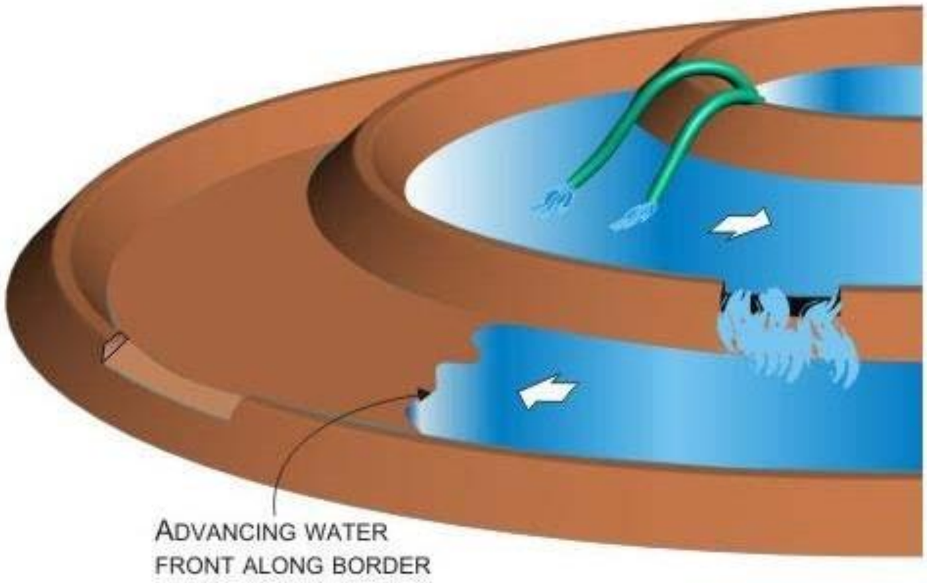


FIGURE 6. Contour border method of irrigation

The straight border irrigation is generally suited to the larger mechanized farms as it is designed to produce long uninterrupted field lengths for ease of machine operations. Borders can be 800m or more in length and 3 – 30 m wide depending on variety of factors. It is less suited to small scale farms involving hand labour or animal powered cultivation methods.

Generally, border slopes should be uniform, with a minimum slope of 0.05% to provide adequate drainage and a maximum slope of 2% to limit problems of soil erosion.

As for the type of soil suitable for border irrigation, deep homogeneous loam or clay soils with medium infiltration rates are preferred. Heavy, clay soils can be difficult to irrigate with border irrigation because of the time needed to infiltrate sufficient water into the soil. Basin irrigation is preferable in such circumstances.

Basin Irrigation

Basins are flat areas of land surrounded by low bunds. The bunds prevent the water from flowing to the adjacent fields. The basins are filled to desired depth and the water is retained until it infiltrates into the soil. Water may be maintained for considerable periods of time.

Basin method of irrigation can be formally divided into two, viz; the c***heck basin method*** and the ***ring basin method***. The check basin method is the most common method of irrigation used in India. In this method, the land to be irrigated is divided into small plots or basins surrounded by checks, levees (low bunds); as shown in Figure 7.

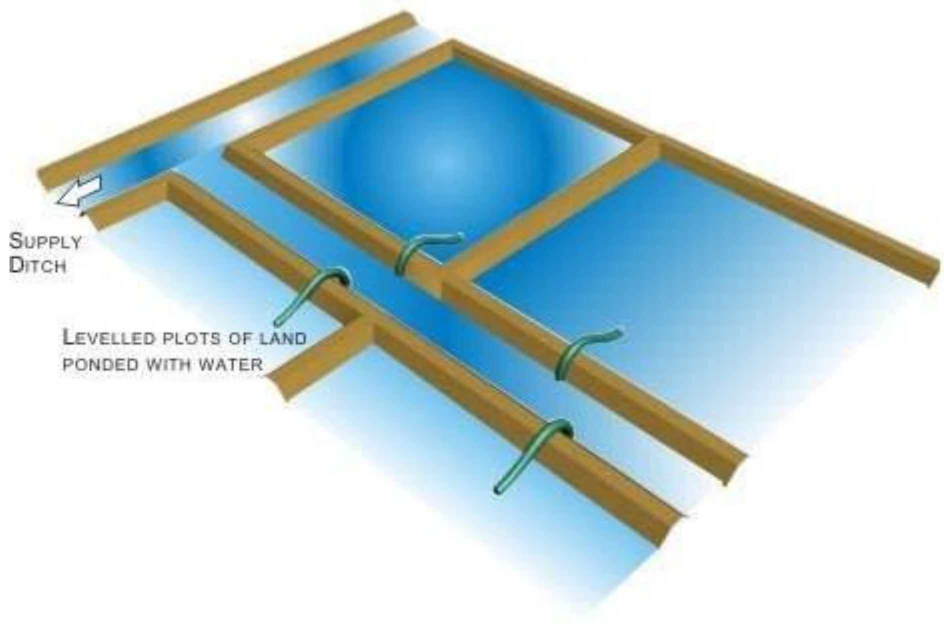


FIGURE 7. Check basin method of irrigation

Each plot or basin has a nearly level surface. The irrigation water is applied by filling the plots with water up to the desired depth without overtopping the levees and the water retained there is allowed to infiltrate into the soil. The levees may be constructed for temporary use or may be semi permanent for repeated use as for paddy cultivation. The size of the levees depends on the depths of water to be impounded as on the stability of the soil when wet.

Water is conveyed to the cluster of check basins by a system of supply channels and lateral field channels or ditches. The supply channel is aligned on the upper side (at a higher elevation) of the field for every two rows of plot as shown in the figure.

The size of basins depends not only on the slope but also on the soil type and the available water flow to the basins. Generally, it is found that the following holds good for basin sizes.

Basin size should be small if the

1. Slope of the land is steep.
2. Soil is sandy.
3. Stream size to basin is small.
4. Required depth of irrigation application is small.
5. Field preparation is done by hand or animal traction

Basin size can be large if the

1. Slope of the land is flat
2. Soil is clay.
3. Stream size to the basin is large
4. Required depth of the irrigation is large.
5. Field preparation is mechanized.

Basin irrigation is suitable for many field crops. Paddy rice grows best when its roots are submerged in water and so basin irrigation is the best method for use with the crop.

The other form of basin irrigation is the ring basin method which is used for growing trees in orchards. In this method, generally for each tree, a separate basin is made which is usually circular in shape, as shown in Figure 8.

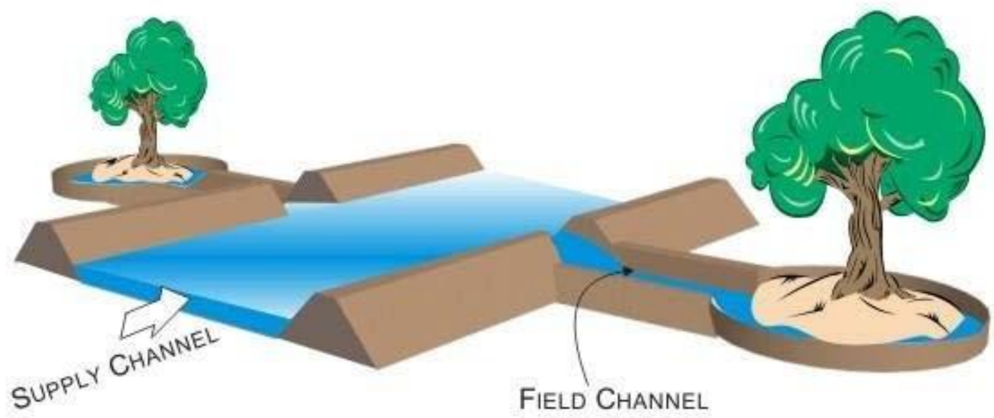


FIGURE 8. Ring basin method of irrigation

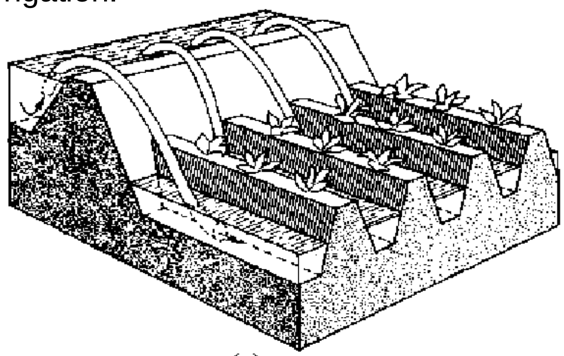
Sometimes, basin sizes are made larger to include two more trees in one basin. Water to the basins is supplied from a supply channel through small field channels conveyed the basins with the supply channel.

Trees which can be irrigated successfully using the ring basin method include citrus and banana.

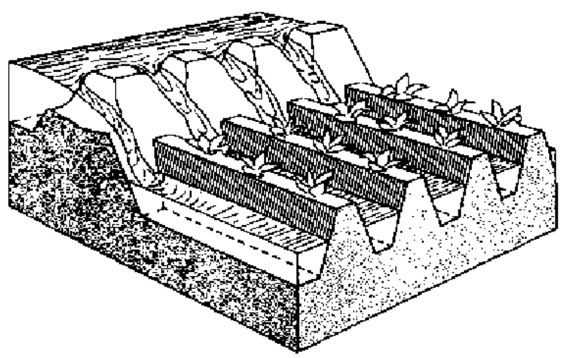
Basins can also be constructed on hillside. Here, the ridges of the basins are constructed as in contour border method thus making the only difference between the two is in the application of water. In the border method, the water is applied once during an irrigation cycle and is allowed to flow along the field and as the water infiltrates, till the supply is cutoff. In the basin method, as in a rice field the water is higher at a desired level on the basin. Basin irrigation is suitable for many field crops. Paddy rice grows best when its roots are submerged in water and so basin irrigation is the best method for use with this crop.

Furrow Irrigation

Furrows are small channels, which carry water down the land slope between the crop rows. Water infiltrates into the soil as it moves along the slope. The crop is usually grown on ridges between the furrows, as shown in Figure 9. This method is suitable for all row crops and for crops that cannot stand water for long periods, like 12 to 24 hours, as is generally encountered in the border or basin methods of irrigation.



(a)



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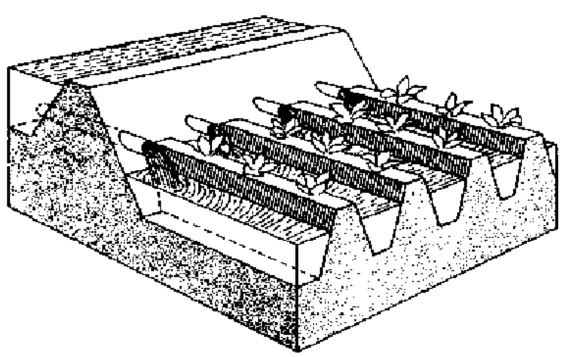

(c)

FIGURE 9. Furow irrigation method of applying water to a field
(a) Using flexible pipes to siphon out water from field channel
(b) Using the breach method to apply water to the furrows
(c) Pipe outlets to deliver water to the furrows

(Image courtesy: Food and Agriculture Organisation, FAO)

Water is applied to the furrows by letting in water from the supply channel, either by pipe siphons or by making temporary breaches in the supply channel embankment. The length of time the water is to flow in the furrows depends on the amount of water required to replenish the root zone and the infiltration rate of the soil and the rate of lateral spread of water in the soil.

Furrow irrigation is suitable to most soils except sandy soils that have very high infiltration water and provide poor lateral distribution water between furrows. As compared to the other methods of surface irrigation, the furrow method is advantageous as:

- Water in the furrows contacts only one half to one-fifth of the land surface, thus reducing puddling and clustering of soils and excessive evaporation of water.
- Earlier cultivation is possible

Furrows may be straight laid along the land slope, if the slope of the land is small (about 5 percent) for lands with larger slopes, the furrows can be laid along the contours.

Subsurface irrigation methods

As suggested by the name, the application of water to fields in this type of irrigation system is below the ground surface so that it is supplied directly to the root zone of the plants. The main advantages of these types of irrigation is reduction of evaporation losses and less hindrance to cultivation works which takes place on the surface.

There may be two ways by which irrigation water may be applied below ground and these are termed as:

- Natural sub-surface irrigation method
- Artificial sub-surface irrigation method

These methods are discussed further below

Natural Sub-surface irrigation method

Under favorable conditions of topography and soil conditions, the water table may be close enough to the root zone of the field of crops which gets its moisture due to the upward capillary movement of water from the water table. The natural presence of the water table may not be able to supply the requisite water throughout the crop growing season. However, it may be done artificially by constructing deep channels in the field which may be filled with water at all times to ensure the presence of water table at a desired elevation below the root zone depth. Though this method of irrigation is excellent from both water distribution and labour saving points of view, it is favorable mostly for the following

- The soil in the root zone should be quite permeable
- There should be an impermeable substratum below the water table to prevent deep percolation of water.
- There must be abundant supply of quality water that is one which is salt free, otherwise there are chances of upward movement of these salts along with the moisture likely to lead the conditions of salt incrustation on the surface.

Artificial subsurface irrigation method

The concept of maintaining a suitable water table just below the root zone is obtained by providing perforated pipes laid in a network pattern below the soil surface at a desired depth. This method of irrigation will function only if the soil in the root zone has high horizontal permeability to permit free lateral movement of water and low vertical permeability to prevent deep percolation of water. For uniform distribution of water percolating into the soil, the pipes are required to be very closely spaced, say at about 0.5m. Further, in order to avoid interference with cultivation the pipes have to be buried not less than about 0.4m below the ground surface. This method of irrigation is not very popular because of the high expenses involved, unsuitable distribution of subsurface moisture in may cases, and possibility of clogging of the perforation of the pipes.

Sprinkler Irrigation System

Sprinkler irrigation is a method of applying water which is similar to natural rainfall but spread uniformly over the land surface just when needed and at a rate less than the infiltration rate of the soil so as to avoid surface runoff from irrigation. This is achieved by distributing water through a system of pipes usually by pumping which is then sprayed into the air through sprinklers so that it breaks up into small water drops which fall to the ground. The system of irrigation is suitable for undulating lands, with poor water availability, sandy or shallow soils, or where uniform application of water is desired. No land leveling is required as with the surface irrigation methods. Sprinklers are, however, not suitable for soils which easily form a crust. The water that is pumped through the pump pipe sprinkler system must be free of suspended sediments. As otherwise there would be chances of blockage of the sprinkler nozzles.

A typical sprinkler irrigation system consists of the following components:

- **Pump unit**
- ***Mainline and sometimes sub mainlines***
- ***Laterals***

- ***Sprinklers***

Figure 10 shows a typical layout of a sprinkler irrigation system.

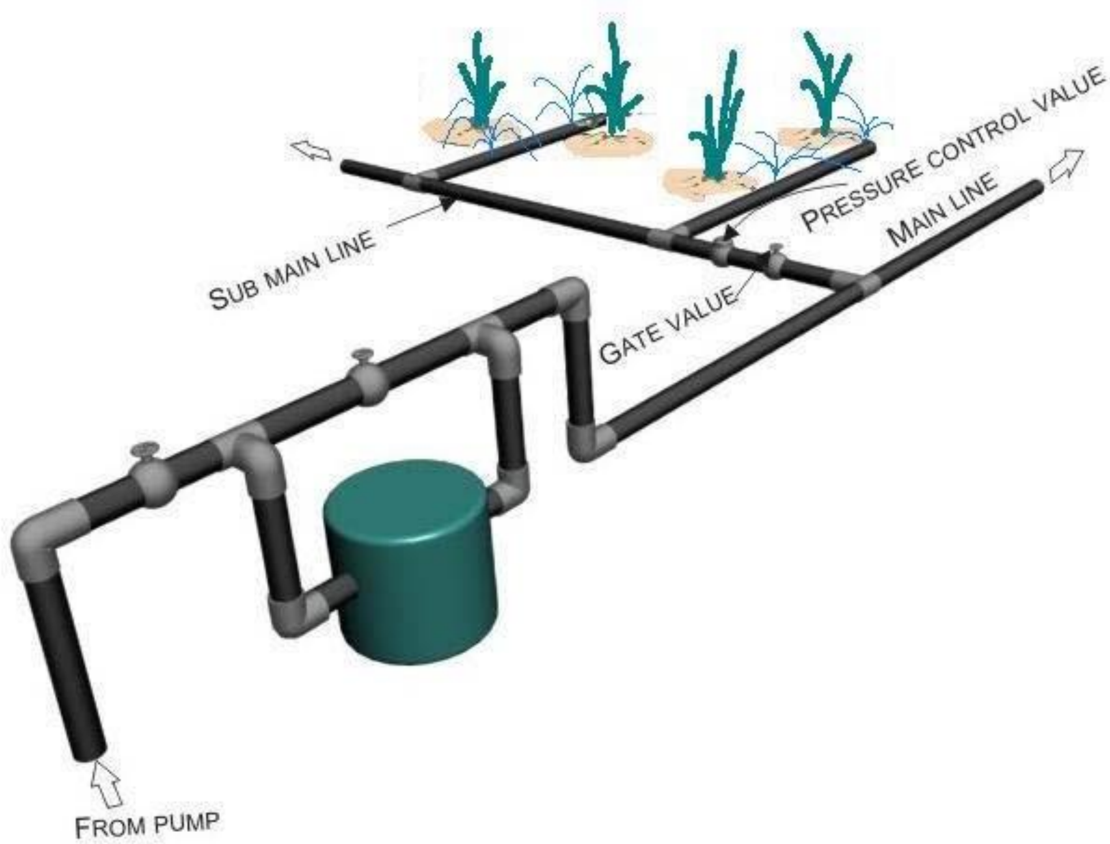

FIGURE 10. The sprinkler irrigation system

The pump unit is usually a centrifugal pump which takes water from a source and provides adequate pressure for delivery into the pipe system.

The mainline and sub mainlines are pipes which deliver water from the pump to the laterals. In some cases, these pipelines are permanent and are laid on the soil surface or buried below ground. In other cases, they are temporary, and can be moved from field to field. The main pipe materials include asbestos cement, plastic or aluminum alloy.

The laterals deliver water from the mainlines or sub mainlines to the sprinklers. They can be permanent but more often they are portable and made of aluminium alloy or plastic so that they can be moved easily.

The most common types of sprinklers that are used are:

- **Perforated pipe system:** This consists of holes perforated in the lateral irrigation pipes in specially designed pattern to distribute water fairly uniformly (Figure 11). The sprays emanating from the perforations are directed in both sided of the pipe and can cover a strip of land 6 m to 15m wide.

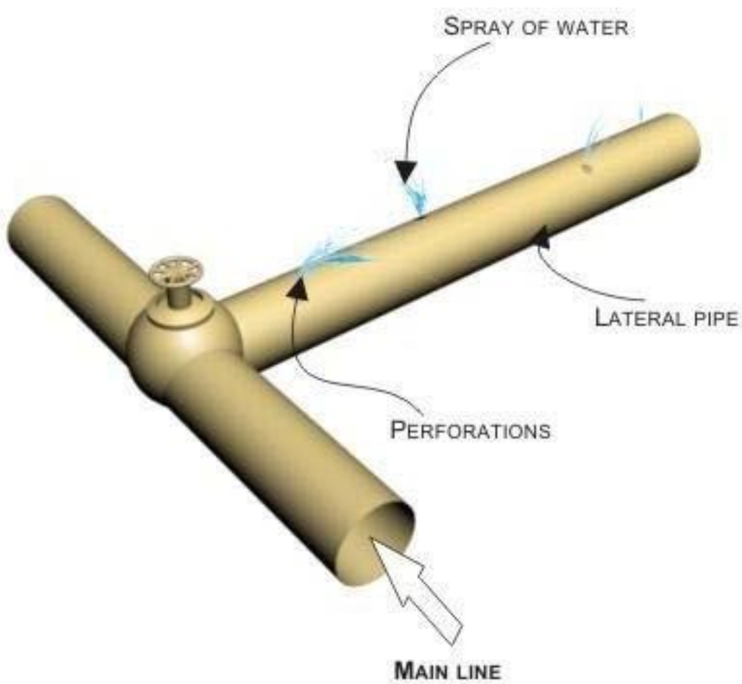

FIGURE 11. Perforated pipe type of sprinkler system

- **Rotating head system:** Here small sized nozzles are placed on riser pipes fixed at uniform intervals along the length of the lateral pipe (Figure 12). The lateral pipes are usually laid on the ground surface. The nozzle of the sprinkler rotates due to a small mechanical arrangement which utilizes the thrust of the issuing water.

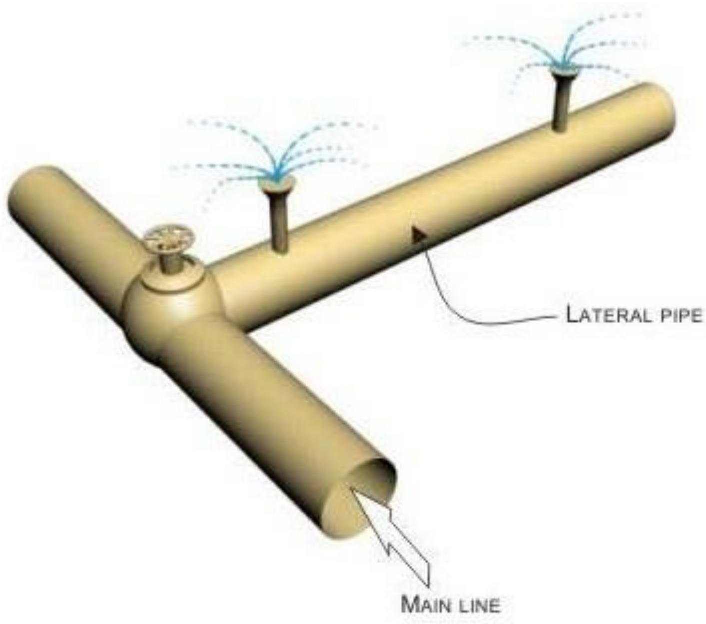

FIGURE 12. Rotating head system of sprinkler irrigation

As such, sprinkler irrigation is suited for most rows, field as tree crops and water can be sprayed over or under the crop canopy. However, large sprinklers are not recommended for irrigation of delicate crops such as lettuce because the large water drops produced by the sprinklers may damage the crop.

Sprinkler irrigation has high efficiency. It however, varies according to climatic conditions; 60% in warm climate; 70% in moderate climate and 80% in humid or cool climate.

Sprinkler irrigation was not widely used in India before the 1980. Although no statistics are available on the total area under sprinkler irrigation, more than 200000 sprinkler sets were sold between 1985 and 1996(with 65000 for 1995-96) according to the National Committee on the use of plastics in agriculture. The average growth rate of sprinkler irrigated area in India is about 25 percent. The cost of installation of sprinkler irrigation depends on a number of factors such as type of crop, the distance from water source.

Drip Irrigation System

Drip Irrigation system is sometimes called trickle irrigation and involves dripping water onto the soil at very low rates (2-20 litres per hour) from a system of small diameter plastic pipes filled with outlets called emitters or drippers. Water is applied close to the plants so that only part of the soil in which the roots grow is wetted, unlike surface and sprinkler irrigation, which involves wetting the whole soil profile. With drip irrigation water, applications are more frequent than with other methods and this provides a very favourable high moisture level in the soil in which plants can flourish. Figure 13 shows a typical layout of the drip irrigation system.

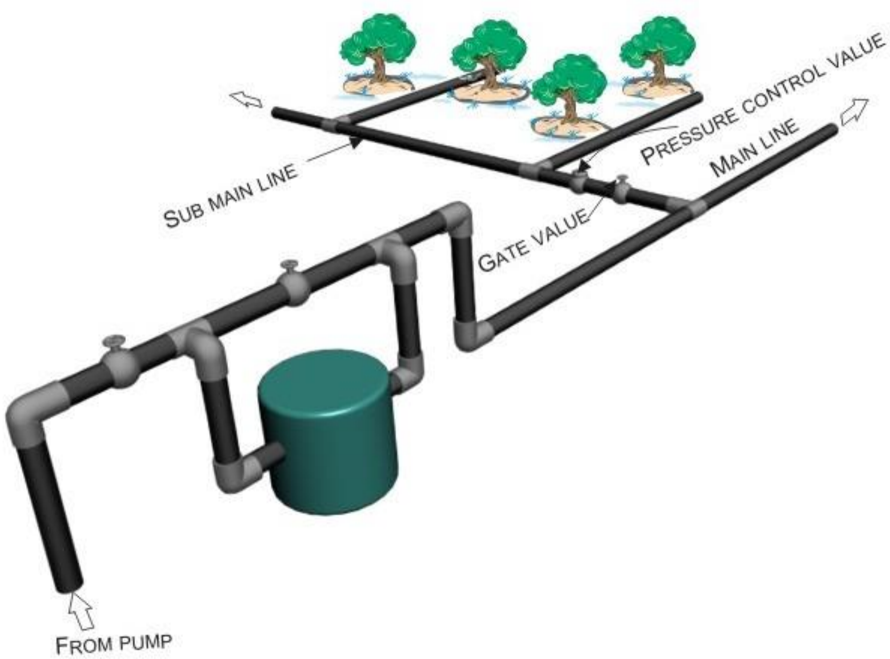

FIGURE 13. The typical layout of the drip irrigation system

A typical drip irrigation system consists of the following components:

- **Pump unit**
- ***Control Head***
- ***Main and sub main lines***
- ***Laterals***
- ***Emitters and drippers***

The drip irrigation system is particularly suited to areas where water quality is marginal, land is steeply sloping or undulating and of poor quality, where water or labour are expensive, or where high value crops require frequent water applications. It is more economical for orchard crops than for other crops and vegetables since in the orchards plants as well as rows are widely spaced. Drip irrigation limits the water supplied for consumptive use of plants. By maintaining a minimum soil moisture in the root zone, thereby maximizing the water saving. A unique feature of drip irrigation is its excellent adaptability to saline water. Since the frequency of irrigation is quite high, the plant base always remains wet which keeps the salt concentration in the plant zone below the critical. Irrigation efficiency of a drip irrigation system is more than 90 percent.

Drip irrigation usage in India is expanding rapidly. There is even some Government subsidy to encourage its use. From about 1000 hectare in 1985, the area under drip irrigation increased to 70860 hectare in 1991, with the maximum developments taking place in the following states:

- Maharashtra (32924 hectare)
- Andhra Pradesh (11585 hectare)
- Karnataka (11412 hectare)

The drip irrigated crops are mainly used to irrigate orchards of which the following crops are important ones (according to a 1991 survey):

- Grapes (12000 hectare)
- Bananas (6500 hectare)
- Pomegranates (5440 hectare)
- Mangoes

Drip irrigation was also used to irrigate sugarcane (3900 hectare) and coconut (2600 hectare).