INTERNATIONAL INSTITUTE OF TECHNOLOGY & MANAGEMENT, MURTHAL SONEPAT

E-NOTES

SUBJECT: IRRIGATION **SUBJECT CODE: -**

COURSE- DIPLOMA **BRANCH: CIVIL ENGINEERING**

SEMESTER 4TH **CHAPTER NAME: INTRODUCTION**

(PREPARED BY: Mr. ANKUR CHAUHAN, LECTURER, CE)

1.1 DEFINATION:

IRRIGATION IS DEFINED AS THE NATURAL OR ARTIFICIALLY SUPPLYING WATER TO THE SOIL FOR PROPER GROWTH OF THE PLANTS, CROPS ETC.

The application of water to soil is essential for plant growth and it serves the following functions:

(i) It supplies moisture to the soil essential for the germination of seeds, and chemical and bacterial processes during plant growth.

(ii) It cools the soil and the surroundings thus making the environment more favourable for plant growth.

(iii) It washes out or dilutes salts in the soil.

(iv) It softens clods and thus helps in tillage operations.

(v) It enables application of fertilisers.

(vi) It reduces the adverse effects of frost on crops.

(vii) It ensures crop success against short-duration droughts.

1.2 METHODS OF IRRIGATION:

THERE ARE THREE METHODS OF IRRIGATION:

a) SURFACE IRRIGATION
b) SUB-SURFACE IRRIGATION
c) SPRINKLER IRRIGATION

1.2.1 SURFACE IRRIGATION: Surface irrigation is where water is applied and distributed over the soil **surface** by gravity. It is by far the most common form of **irrigation** throughout the world and has been practiced in many areas virtually unchanged for thousands of years.

There are various ways of application of surface irrigation are:

a) Wild Flooding
b) Free Flooding
c) Check Flooding
d) Border Strip Method
e) Zig-Zag Method
f) Basin Method
g) Furrow Method

1.2.2 SUB-SURFACE IRRIGATION: Subsurface irrigation, also designated as **sub irrigation**, involve **irrigation** to crops by applying water from beneath the soil **surface** either by constructing trenches or installing underground perforated pipe lines or tile lines. Pipelines remain filled with water during the period of **irrigation**.

1.2.3 SPRINKLER IRRIGATION: Sprinkler irrigation is a method of applying **irrigation** water which is similar to natural rainfall. Water is distributed through a **system** of pipes usually by pumping. It is then sprayed into the air through **sprinklers** so that it breaks up into small water drops which fall to the ground.

1.3 Need for Irrigation:

1. Nature of Rainfall:

Due to irregular, uncertain and limited rainfall, scarcity of water is caused. Consequently, the need for irrigation arises. Sometimes, it can rain heavily and for a long duration, whereas sometimes it can be light and for a short duration. If there is torrential rain, it is harmful for agriculture whereas at other places it might rain at short intervals in a balanced way.

2. Nature of Soil:

There is greater need of irrigation in sandy soil whereas in clay or alluvial soil the need for irrigation is lower.

3. Probability of Drought:

At places having irregular rainfall, since there is probability of drought, irrigation is needed.

4. Need of Irrigation in Dry Areas:

In dry areas, where rainfall ranges between 40 to 50 cm per year, the need arises for irrigation.

5. More Need of Water for Special Crops:

Crops like rice, jute, sugarcane, etc. need more water, which can be fulfilled only through irrigation.

6. More Need of Water for Improved Seed Varieties:

New and high- yielding seeds need additional water through irrigation for higher productivity. This was felt after the green revolution.

7. For Pasture Development:

Along with agriculture, it is essential to develop pastures for cattle development and dairy development, which also need water.

8. Population Increase:

Population of the world is multiplying fast, and it needs additional food production. This can be possible only through irrigation.

1.4 Advantages of Irrigation:

1. For proper nourishment of crops certain amount of water is required. If rainfall is insufficient there will be deficiency in fulfillment of water requirement. Irrigation tries to remove this deficiency caused due to inadequate rainfall. Thus, irrigation comes to rescue in dry years.

2. Irrigation improves the yield of crops and makes people prosperous. The living standards of the people is thereby improved.

3. Irrigation also adds to the wealth of the country in two ways. Firstly as bumper crops are produced due to irrigation it makes country self-sufficient in food requirements. Secondly as the irrigation water is taxed when it is supplied to the cultivators, it adds to the revenue.

4. Irrigation makes it possible to grow cash crops which give good returns to the cultivators than the ordinary crops they might have grown in absence of irrigation. Fruit gardens, sugarcane, potato, tobacco etc., are the cash crops.

5. Sometimes large irrigation channels can be used as a means of communication.

6. The falls which come across the irrigation channels can be utilised for producing hydroelectric power.

7. Domestic advantages should not be overlooked. Irrigation facilitates bathing, cattle watering etc., and improves freshwater circulation.

8. Irrigation improves the groundwater storage as water lost due to seepage adds to the groundwater storage.

9. Along the banks of large irrigation channels plantation can be successfully done which not only helps introducing social forestry but also improves environmental status of the region.

10. New irrigation works are started at the time of famines to provide employment to a large number of population. These works are called famine works or relief works.

11. When watering facility is provided to a barren land, the value of this land gets appreciated.

1.5 Disadvantages of Irrigation:

1. Excessive seepage and leakage of water forms marshes and ponds all along the channels. The marshes and the ponds in course of time become the colonies of the mosquito, which gives rise to a disease like malaria.

2. Excessive seepage into the ground raises the water-table and this in turn completely saturates the crop root-zone. It causes waterlogging of that area.

3. It lowers the temperature and makes the locality damp due to the presence of irrigation water.

4. Under irrigation canal system valuable residential and industrial land is lost.

5. Initial cost of irrigation project is very high and thereby the cultivators have to pay more taxes in the form of levy.

6. Irrigation works become obstacles in the way of free drainage of water during rainy season and thus results in submerging standing crops and even villages.

1.6 HISTORY OF IRRIGATION:

(i) Irrigation is a very ancient science. Irrigation has been practiced in India from time immemorial and so has been the construction of canals.

(ii) The Vedas are replete with references to wells, tanks, canals and dams. Samritis too contain evidence of early irrigation works.

(iii) The ancient rulers of India took keen interest in the provision of irrigation facilities. The early irrigation works were not primitive but had scientific basis. The most outstanding example of engineering talent in ancient time is manifest in the bold conception and construction of grand anicut across river Cauvery in the second century A.D.

(iv) The British started irrigation development in the nineteenth century. They constructed dams such as Periyar and Mettur; the Nizamsagar and Krishnarajasagar were constructed by the princes in their native states.

(v) Further, the British introduced a definite irrigation policy in 1854 with the setting up of Public Works Department and instituting a separate fund for irrigation works.

(vi) Two categories of irrigation works, namely Minor works and Major works came into existence. Minor works which were undertaken in principle more for the sake of protecting the existing cultivation and revenue from retrogression than as revenue producing works continued to be financed out of the general revenues. Later minor irrigation works generally included private works (particularly their renovation) and private irrigation works formed a major constituent of Grow More Food Campaign.

(vii) Public tube wells were also included in the category of minor irrigation works when the department of agriculture was constituted in 1845. Major works were henceforth financed by raising public loans. Each major work was required to satisfy the productivity criterion.

(viii) Later the Famine Commission (1880) and the First Irrigation Commission (1928) laid great stress on encouraging private works (wells, tanks, etc.,) to overcome recurrent famines.

(ix) During the last 150 years, eight severe famines have occurred; the last one was in Bengal as late as in 1943. In tropical and subtropical countries like India, famines occurred due to drought conditions.

1.7 Major irrigation Scheme:

Major irrigation schemes are those schemes which have a Culturable Command Areas of More than 10,000 hectares.

1.8 Medium irrigation Schemes:

The Medium Irrigation Schemes have a CCA of 2,000-10,000 hectares.

1.9 Minor Schemes:

Those with Culturable command areas up to 2000 hectares.

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SEMESTER 4TH **CHAPTER NAME: WATER REQIREMENTS OF CROPS**

(PREPARED BY: Mr. ANKUR CHAUHAN, LECTURER, CE)

2.1 Crop Seasons

Activities relating to crops go on continuously throughout the year in India. In north India, there are two main crop seasons. These are '*Kharif*' (July to October) and '*Rabi*' (October to March). Crops grown between March and June are known as '*Zaid*'. In other parts of the country there are no such distinct seasons but some kind of classification of crop seasons exists everywhere. The Kharif season is characterised by a gradual fall in temperature, larger number of rainy days, low light intensity, a gradual shortening of the photoperiod, high relative humidity, and cyclonic weather. On the other hand, bright sunshine, near absence of cloudy days, and lower relative humidity are the characteristics of the Rabi season. The Kharif season starts earlier in the eastern part of the country because of the earlier arrival of the monsoon and continues until the withdrawal of the monsoon. On the other hand, the Rabi season starts earlier in the western part and continues until the sun attains equatorial position. Thus, Kharif is longer in the eastern part and Rabi is longer in the western part.

There are several cropping patterns which are followed in India depending upon the climatic, edaphic, socio-economic conditions of the region. With a geographic area of about 329 Mha, stretching between 8°N and 36°N latitude and between 68°E and 98°E longitude, and its altitude varying from the mean sea level to the highest mountain ranges of the world, India hosts a variety of flora and fauna in its soil with few parallels in the world. The country has an average annual rainfall of 1,143 mm which varies from 11,489 mm around Cherrapunji in Assam to 217 mm around Jaisalmer in Rajasthan. Just as rainfall and temperature vary over a wide range, there is considerable difference in the socio-economic conditions of peasants of different parts of the country. Due to the variation in soil-climatic conditions there exists considerable variation in crop genotypes. Considering the potential of food grain production in different parts of India, the country has been divided into the following five agricultural regions (13):

(i) The eastern part including larger part of the north-eastern and south-eastern India, and another strip along the western coast form the rice region of India.

(ii) The wheat region occupies most of northern, western, and central India.

(iii) The millet (*bajra*)–sorghum (*jawar*) region comprising Rajasthan, Madhya Pradesh, and the Deccan plateau.

(iv) The Himalayan region of Jammu and Kashmir, Himachal Pradesh, Uttar Pradesh, and some adjoining areas in which potatoes, cereal crops (mainly maize and rice), and fruits are grown.

(v) The plantation crops (*e.g.* tea, coffee, rubber, and spices) are grown in Assam, hills of south India and peninsular region of India which form the plantation region.

2.2 Ideal Weather for Kharif and Rabi Seasons

At the end of May or beginning of June, there should be some rainfall so that the fields can be ploughed. Towards the end of June, heavy rainfall is required for thorough wetting of the land. This must be followed by a period of clear sky for tillage and sowing operations. In the months of July and August, there should be periods of bright sunshine (not exceeding ten days) between two spells of rain. The weather in the month of September should be similar to that in July and August, but with less rainfall. A few showers at the end of September are needed to prepare the land for Rabi crops.

The first requirement for a good Rabi crop is that the soil temperature should fall rapidly to germination temperature. During November and early December, clear days and cool weather are beneficial. Towards the end of December, a light rainfall is useful. The winter rain must be broken by clear weather as continuous cloudy weather results in widespread plant diseases. The rest of the Rabi season should be dry and free from hailstorms.

2.2.1 Crops of Kharif Season

Kharif (or south-westerly monsoon) crops include rice, maize, *jawar*, *bajra*, groundnut, cotton and other crops.

Rice

Rice cultivation in India stretches from 8°N latitude to 34°N latitude. Rice is also grown in areas below the sea level (as in the Kuttanad region of Kerala) as well as at altitudes of about 2000 m (as in parts of Jammu and Kashmir). High rainfall or assured irrigation is essential for areas of rice cultivation. Rice crop requires about 30 cm of water per month during the growing period stretching from about 3 to 8 months. Rice is grown on about 40 Mha in the country. This area also includes about 7 Mha which is saline, alkaline or flood-prone. Twenty-five per cent of the rice growing area has assured irrigation and about 55 per cent of the rice growing area is ill-drained or waterlogged. The rest of the rice-growing area is rainfed uplands where the rainfall is marginal to moderate and its distribution is erratic.

Rice cultivation in India is either upland cultivation or lowland cultivation. The upland system of cultivation is confined to such areas which do not have assured irrigation facilities. In this system, fields are ploughed in summer, farmyard manure is uniformly distributed 2–3 weeks before sowing, and the rain water is impounded in the field until the crop is about 45–60 days old.

In the lowland system of rice cultivation, the land is ploughed when 5–10 cm of water is standing in the field. Seeds may be sown after sprouting. Alternatively, seedling which are 25– 30 days old are transplanted. The nursery area required to provide seedlings for transplanting on one hectare is roughtly one-twentieth of a hectare. The water requirement of lowland rice cultivation is much higher than that of other cereal crops with similar duration.

Maize

Maize is one of the main cereals of the world and ranks first in the average yield. Its world average yield of 27.8 quintals/hectare (q/ha)

Maize requires deep and well-drained fertile soils, but can be grown on any type of soil ranging from heavy clays to light sands provided that the pH does not deviate from the range
7.5 to 8.5. Maize plants, particularly in the seedling stage, are highly susceptible to salinity and waterlogging, and hence, proper drainage of the land is essential for the successful cultivation of maize. Over 85 per cent of the crop area in India is rainfed during the monsoon.

Maize is essentially a warm weather crop grown in different regions of the world ranging from tropical to temperate ones. It cannot withstand frost at any stage of its growth. In India, its cultivation extends from the hot arid plains of Rajasthan and Gujarat to the wet regions of Assam and West Bengal.

Maize is a short-duration (80–95 days) crop and, hence, can conveniently fit into a wide range of crop rotations. It is usually grown as a pure crop, but sometimes legumes (*e.g.*, *moong*, *arhar* or beans), and quick-growing vegetables (*e.g.*, pumkins, gourds) are grown as mixed crops with it.

The sowing of maize starts 7–10 days before the usual date of the onset of monsoon. One irrigation at the initial stage is useful for the establishment of seedlings and the crop yield is increased by about 15–20 per cent. The maize crop is harvested when the grains are nearly dry and do not contain more than 20 per cent moisture. Maize is grown for grains as well as fodder.

Sorghum (Jawar)

Sorghum (popularly known as *jawar*) is the main food and fodder crop of dryland agriculture. It is grown over an area of about 18 Mha with the average yield of about 600 kg/ha. *Jawar* cultivation is concentrated mainly in the peninsular and central India. Andhra Pradesh, Gujarat, Karnataka, Madhya Pradesh, Maharashtra, Rajasthan, Tamil Nadu, and Uttar Pradesh are the major *jawar*-growing states. *Jawar* is mainly grown where rainfall distribution ranges from 10–20 cm per month for at least 3 to 4 months of the south-westerly monsoon.

Sorghum is grown during both Kharif (July–October) and Rabi (October–February) seasons. The Rabi cultivation of *jawar* constitutes about

37 per cent of the total *jawar*-growing area. Sorghum cultivation still remains predominantly traditional in most parts of the country. Mixed cropping of *jawar* and *arhar* (*tur*) is very common. Harvesting and threshing are still carried out manually or with bullock power. The national average yields are still low and around 500 kg/ha. However, the high-yielding hybrid varieties can yield 2000–3000 kg/ha under average growing conditions.

Spiked Millet (Bajra)

Bajra is a drought-resistant crop which is generally preferred in low rainfall areas and lighter soils. It is grown in Rajasthan, Maharashtra, Gujarat, and Uttar Pradesh. Over 66 per cent of this crop is grown in areas receiving 10–20 cm per month of rainfall, extending over 1 to 4 months of the south-westerly monsoons. It should be noted that *jawar* and *bajra* are grown mostly under identical environmental conditions and both have a wide range of adaptability to drought, temperature, and soil.

Groundnut

Groundnut is grown over an area of about 7 Mha concentrated in the states of Gujarat (24 percent), Andhra Pradesh (20 per cent), Karnataka (12 per cent), Maharashtra (12 per cent), and Tamil Nadu (13 per cent). Madhya Pradesh, Orissa, Punjab, Rajasthan, and Uttar Pradesh together have about 20 per cent of the total groundnut producing area in the country. Groundnut is generally grown as a rainfed Kharif crop. Groundnut is sown during May and June in the subtropics. In the tropics, however, it is sown during either January and February or June and July. Under rainfed conditions the average yield is 1200–1400 kg per hectare.

Cotton

Cotton occupies about 7.5 Mha in India. Maharashtra (36 per cent), Gujarat (21 per cent), Karnataka (13 per cent), and Madhya Pradesh (9 per cent) are the leading states which together grow cotton over an area of about 6 Mha. Other cotton growing states are Punjab (5 per cent), Andhra Pradesh (4 per cent), Tami Nadu (4 per cent), Haryana (3 per cent), and Rajasthan (3 per cent). Most of the cotton-growing areas in the country are in the high to medium rainfall zones.

Cotton requires a well-drained soil. It is grown as a rainfed crop in the black cotton and medium black soils and as an irrigated crop in alluvial soils. The sowing season varies from region to region and starts early (April-May) in north India.

2.2.2Crops of Rabi Season

Main crops of Rabi (Post-monsoon) season are wheat, barley and gram.

Wheat

In terms of production, wheat occupies the first place among the food crops in the world. In India, it is the second most important food crop, next only to rice. The Indo-Gangetic plains form the most important wheat area. The cool winters and hot summers are conducive to a good crop of wheat. Well-drained loams and clayey loams are considered good soils for the cultivation of wheat. However, good crops of wheat can be raised in sandy loams and black soils also.

Wheat crop requires a well-pulverized but compact seedbed for good and uniform germination. Under irrigated conditions, the first fortnight of November is considered the optimum time for sowing the medium to long-duration wheats (*e.g.* the 'Kalyanasona' variety). For short-duration wheats (*e.g.* the 'Sonalika' variety) the second fortnight of November is the optimum time of sowing. In eastern India, wheat is sown in the third week of December due to the late harvesting of paddy. In north-western India also, wheat sowings get delayed due to the late harvesitng of paddy, sugarcane or potato.

For wheat sown under irrigated conditions, four to six irrigations are required. The first irrigation should be given at the stage of initiation of the crown root, *i.e.*, about 20–25 days after sowing. Two or three extra irrigations may be required in case of very light or sandy soils.

The crop is harvested when the grains harden and the straw becomes dry and brittle. The harvesting time varies in different regions. In the peninsular region, harvesting starts in the latter half of February and is over in the first week of March. In the central zone, the peak season for harvesting is in the month of March. In the north-western zone, the peak harvesting period is the latter half of April. In the eastern zone, harvesting is over by mid–April. However, in the hills, the wheat crop is harvested in the months of May and June.

Punjab, Haryana, Delhi, Uttar Pradesh, Madhya Pradesh, Rajasthan, Gujarat, Bihar, and West Bengal together grow wheat over an area exceeding 70 per cent of the total area of wheat crop for the country. These states also produce 76 percent of the total what production of India and have extensive irrigation systems covering from 85 per cent of the area in Punjab to 51 per cent in Bihar.

Barley

Barley (*Jau*) is an important rabi crop ranking next only to wheat. The total area under this crop is about 3.0 Mha, producing nearly 3 million tonnes of grain. Main barley growing states are Rajasthan, Uttar Pradesh, and Bihar which together grow barley over an area which is about 80 per cent of total barley growing area.

This crop can be grown successfully on all soils which are suitable for wheat cultivation. Barley crop needs less water and is tolerant to salinity. Recent experiments indicate that this crop can be grown on coastal saline soils of Sunderbans in West Bengal and on saline soils in areas of north Karnataka irrigated by canals.

The normal sowing season for barley extends from middle of October to the middle of November, but it can be sown as late as the first week of January. Barley is grown either on conserved moisture or under restricted irrigation. Generally, it needs two to three irrigations. On highly alkaline or saline soils, frequent light irrigations are given.

Harvesting period for barley is between mid-March to mid-April. Harvesting starts in the month of February in Maharashtra, Gujarat, and Karnataka. In the foothills of the Himalayas, harvesting time varies from the end of April to the end of May. The average grain yield of the 'dry' crop is about 700–1000 kg/ha whereas that of the irrigated crop is about twice as much.

Gram

Gram (*Chana*) is the most important pulse which accounts for more than a third of the pulse growing area and about 40 per cent of the production of pulses in India. The average annual area and production of gram are about 7–8 Mha and about 4–5 million tonnes of grain respectively. Haryana, Himachal Pradesh, Rajasthan, and Uttar Pradesh together grow gram over an area exceeding 6 Mha.

In North India, gram is grown on light alluvial soils which are less suitable for wheat. In south India, gram is cultivated on clay loams and black cotton soils. 'Kabuli gram', however, requires soil better than light alluvial soils. Gram is generally grown as a dry crop in the Rabi season.

2.2.3 Other Major Crops

Sugarcane

Sugarcane is the main source of sugar and is an important cash crop. It occupies about 1.8 per cent of the total cultivated area in the country. In the past, the area under sugarcane has been fluctuating between 2 and 2.7 Mha. Uttar Pradesh alone accounts for about 47 per cent of annual production in terms of raw sugar. However, the production per hectare is the highest in Karnataka followed by Maharashtra and Andhra Pradesh.

Tea

Tea is an important beverage and its consumption in the world is more than that of any other beverage. India and Sri Lanka are the important tea growing countries. In India, tea is grown in Assam, West Bengal, Kerala, Karnataka, and Tamil Nadu. Tea is grown over an area of about 358,000 hectares and about 470 million kilograms of the product is obtained annually. The tea crop is the most important plantation crop of India.

Potato

Amongst vegetables, potato is grown over the largest area (for any single vegetable) in the world. In the plains of north India, potato is sown from the middle of September to the beginning of January. Two successive crops can be raised on the same land. Potato needs frequent irrigation depending upon the soil and climatic conditions. Generally, six irrigations are sufficient.

Crop	*Sowing time*	*Harvesting time*	*Seed requirement (kg/ha)*	*Average yield under normal condtions (q/ha)*	*Average water depth (mm)*
Rice	June–July	October–November	40–50	20–40	1500–2000
Maize	June–July Jan.–Feb.	September–October	40–50	15–30	150–200
Sorghum (*Jawar*)	June–July	October–November	20–30	15–30	150–200
Spiked Millet (*Bajra*)	July	October–November	5–10	15–30	150–200
Groundnut	June–July	November–December	100–120	20–25	200–250
Cotton	April–May	November–January	15–20	2–5 (with seeds)	500–700
Wheat	November–December	April–May	100–120	20–40	300–400
Barley	October–November	March–April	80–100	20–40	250–300
Gram	October–November	March–April	30–40	15–30	250–300
Sugarcane	October–November and February–March	October–April	3000–4000	8000–10000	1500–2000
Potatoes	September–December	November–February	1500–2500	25000–30000	400–500

2.3 SOILS

Soil mainly consists of finely divided organic matter and minerals (formed due to disintegration of rocks). It holds the plants upright, stores water for plant use, supplies nutrients to the plants and helps in aeration. Soils can be classified in many ways, such as on the basis of size (gravel, sand, silt, clay, *etc.*), geological process of formation, and so on. Based on their process of formation (or origin), they can be classified into the following categories:

(i) *Residual soils:* Disintegration of natural rocks due to the action of air, moisture, frost, and vegetation results in residual soils.

(ii) *Alluvial soils:* Sediment material deposited in bodies of water, deltas, and along the banks of the overflowing streams forms alluvial soils.

(iii) *Aeolian soils:* These soils are deposited by wind action.

(iv) *Glacial soils:* These soils are the products of glacial erosion.

(v) *Colluvial soils:* These are formed by deposition at foothills due to rain wash.

(vi) *Volcanic soil:* These are formed due to volcanic eruptions and are commonly called as volcanic wash.

The soils commonly found in India can be classified as follows:

(i) ***Alluvial Soils:*** Alluvial soils include the deltaic alluvium, calcareous alluvial soils, coastal alluvium, and coastal sands. This is the largest and most important soil group of India.

The main features of the alluvial soils of India are derived from the deposition caused by rivers of the Indus, the Ganges, and the Brahmaputra systems. These rivers bring with them the products of weathering of rocks constituting the mountains in various degrees of fineness and deposit them as they traverse the plains. These soils vary from drift sand to loams and from fine silts to stiff clays. Such soils are very fertile and, hence, large irrigation schemes in areas of such soils are feasible. However, the irrigation structures themselves would require strong foundation.

Black Soils: The black soils vary in depth from a thin layer to a thick stratum. The typical soil derived from the Deccan trap is black cotton soil. It is common in Maharashtra, western parts of Madhya Pradesh, parts of Andhra Pradesh, parts of Gujarat, and some parts of Tamil Nadu. These soils may vary from clay to loam and are also called heavy soils. Many black soil areas have a high degree of fertility but some, especially in the uplands, are rather poor. These are suitable for the cultivation of rice and sugarcane. Drainage is poor in such soils.

(ii) ***Red Soils:*** These are crystalline soils formed due to meteoric weathering of the an- cient crystalline rocks. Such soils are found in Tamil Nadu, Karnataka, Goa, south-eastern Maharashtra, eastern Andhra Pradesh, Madhya Pradesh, Orissa, Bihar, and some districts of West Bengal and Uttar Pradesh. Many of the so-called red soils of south India are not red. Red soils have also been found under forest vegetation.

(iii) ***Lateritic Soils:*** Laterite is a formation peculiar to India and some other tropical countries. Laterite rock is composed of a mixture of the hydrated oxides of aluminium and iron with small amounts of manganese oxides. Under the monsoon conditions, the siliceous matter of the rocks is leached away almost completely during weathering. Laterites are found on the hills of Karnataka, Kerala, Madhya Pradesh, the estern Ghats of Orissa. Maharashtra, West Bengal, Tamil Nadu, and Assam.

(iv) ***Desert Soils:*** A large part of the arid region belonging to western Rajasthan, Haryana, and Punjab lying between the Indus river and the Aravalli range is affected by desert and conditions of geologically recent origin. This part is covered with a mantle of the blown sand which, combined with the arid climate, results in poor soil development. The Rajasthan desert is a vast sandy plain including isolated hills or rock outcrops at places. The soil in Rajasthan improves in fertility from west and north-west to east and north-east.

(v) ***Forest Soils:*** These soils contain high percentage of organic and vegetable matter and are also called humus. These are found in forests and foothills.

Soils suitable for agriculture are called arable soils and other soils are non-arable.

Depending upon their degree of arability, these soils are further subdivided as follows:

(i) *Class I:* The soils in class I have only a few limitations which restrict their use for cultivation. These soils are nearly level, deep, well-drained, and possess good water-holding capacity. They are fertile and suitable for intensive cropping.

(ii) *Class II:* These soils have some limitations which reduce the choice of crops and require moderate soil conservation practices to prevent deterioration, when cultivated.

(iii) *Class III:* These soils have severe limitations which reduce the choice of crops and require special soil conservation measures, when cultivated.

(iv) *Class IV:* These soils have very severe limitations which restrict the choice of crops to only a few and require very careful management. The cultivation may be restricted to once in three or four years.

Soils of type class *I* to class *IV* are called arable soils. Soils inferior to class *IV* are grouped as non-arable soils. Irrigation practices are greatly influenced by the soil characteristics. From agricultural considerations, the following soil characteristics are of particular significance.

(i) Physical properties of soil,

(ii) Chemical properties of soil, and

(iii) Soil-water relationships.

2.4 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.

2.5 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***.

2.6 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. As such, the projects with a CCA of more than 2000 hectare are grouped as ***major*** and ***medium*** irrigation projects. The ultimate irrigation potential of our country from major and medium projects has been assessed as 58.46 M-hectare.

2.7 Crop Period and Base Period

Crop Period

The time period from the sowing of the crop to the instant of its harvesting is called a crop period.

Base Period

The time period from the first watering of the crop during its sowing to the last watering of the crop before its harvesting is called a base period. It is also called a base of the crop.

Mostly, the crop period is greater than the base period. Practically, both terms are considered same and are expressed in days. In the calculation of water requirements of crops, the crop period, base period and the growth period are considered same and represented by ‘B’ in days.

2.8 Duty and Delta of a Crop

Delta

It is defined as the total depth of water required by a particular crop to attain its maturity condition. It is represented by delta in cm.

Every crop requires a certain amount of water at certain intervals throughout its period of growth. The time interval between such consecutive watering is called as “Frequency of irrigation” or “Rotation period”. Every time, the water depth required by the crop varies from 5 to 10cm which again varies with the type of crop. The rotation period can also vary in the range of 6 to 15 days depending on the type of crop.

Hence, the total depth of water required during the crop period represents the total quantity of water required for its complete nourishment. This total quantity of water required by the crop measured in hectare-meter or acre-ft or million cubic meters or million cubic ft.

The concept of the delta can be explained by a small example.

If rice requires about 10cm depth of water at an average interval of 10 days and the crop period of the rice is 120 days, Determine delta?

Crop Period, B = 120 days

Interval of watering = 10days

Number of Intervals demanded by the crop = 120/10 = 12 Intervals

The depth of water at each interval = 10cm

Delta = Total depth of water throughout the crop period = 12 x 10 = 120cm

Duty of Water (D)

Duty is defined as the number of hectares of land that is irrigated for the complete growth of a crop by supplying 1-meter cubes per second of water continuously throughout the crop or base period ‘B’ of the respective crop. Duty gives a relation between the volume of water and the area of the crops that are harvested.

For example, 200 hectares per cumec to the base of B days means that the water flowing at a rate of 1 cubic per meter cube per second running continuously for B days, matures 200 hectares of crop.

2.9 Relation between Duty and Delta

D= duty in hectares/cumec

Δ= total depth of water supplied in metres

B= base period in days

i. If we take a field of area D hectares, water supplied to the field corresponding to the water depth Δ metres will be = Δ x D hectares-metres = D x Δ x104

cubic-metres. .... (1)

ii. Again for the same field of D hectares, one cumec of water is required to flow during the entire base period. Hence, water supplied to this field. = (1) x (B x 24 x 60 x 60) m3

.... (2)

Equating Equations (1) and (2), we get D x Δ x 104

= B x 24 x 60 x 60

Δ = *B*×24×60×60*D*×104=8.64 B/D metres.

1 hectare = 104 sq metres

cumec-day = 8.64 hectare-metres

INTERNATIONAL INSTITUTE OF TECHNOLOGY & MANAGEMENT, MURTHAL SONEPAT

E-NOTES

SUBJECT: IRRIGATION **SUBJECT CODE: -**

COURSE- DIPLOMA **BRANCH: CIVIL ENGINEERING**

SEMESTER 4TH **CHAPTER NAME: RAINFALL AND RUN-OFF**

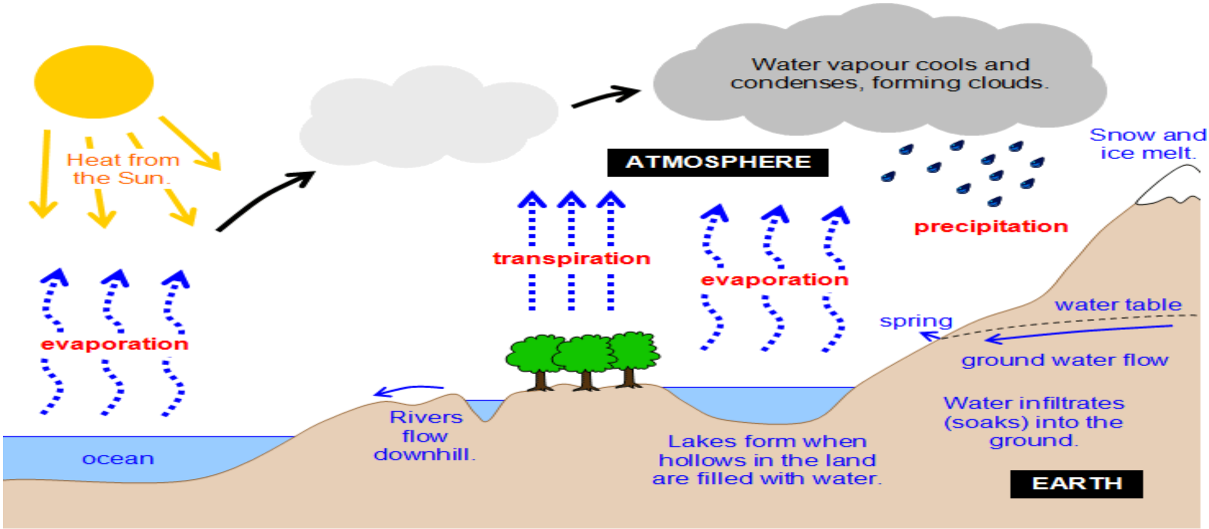
(PREPARED BY: Mr. ANKUR CHAUHAN, LECTURER, CE)

3.1 HYDROLOGY

The word *hydrology* means science of water which deals with the spatial and temporal characteristics of the earth's water in all its aspects such as occurrence, circulation, distribution, physical and chemical properties, and impact on environment and living things. Engineering hydrology deals with all these aspects which are pertinent to planning, design, and operation of hydraulic engineering projects for the control and use of the available water. Hydrology finds its application in the design and operation of water resources projects to estimate the magnitudes of flood flows at different times of a year to decide reservoir capacity, spillway discharge, dimensions of hydraulic structures etc.

3.2 HYDROLOGICAL CYCLE

The total water of earth, excluding deep ground water, is in constant circulation from the earth (including oceans) to atmosphere and back to the earth and oceans. This cycle of water amongst earth, oceans, and atmospheric systems is known as *hydrological cycle.*



3.3 RUNOFF

Runoff can be defined as the portion of the precipitation that makes it's way towards rivers or oceans etc, as surface or subsurface flow. Surface runoff can be generated either by rainfall, snowfall or by the melting of snow, or glaciers.

Precipitation (or rainfall), after satisfying the requirements of evapotranspiration, interception, infiltration into the ground, and detention storage, drains off or flows off from a catchment basin as an overland flow (or surface runoff which includes precipitation falling on the stream system too) into a stream channel. Some part of the infiltrating water moves laterally through the upper layers of the soil and returns to the ground surface as interflow or subsurface runoff at some place away from the point of infiltration into the soil. Part of the infiltrating water percolates deep into the ground and joins the ground water storage. When water table intersects the stream channels of the catchment basin, some ground water may reach the surface or join the stream as ground water runoff, also called base flow or dry-weather flow. Thus, the runoff from a catchment includes surface runoff, subsurface runoff and base flow. The surface runoff starts soon after the precipitation and is the first to join the stream flow. Subsurface runoff is slower and joins the stream later. Depending upon the time taken by the subsurface runoff between the infiltration and joining the stream channel, it may be termed as prompt subsurface runoff or delayed subsurface runoff. The groundwater runoff is the slowest in joining the stream channel but, is responsible in maintaining low flows in the stream during dry season. Based on the time interval between the precipitation and runoff, the runoff is categorized as direct runoff (that enters the stream immediately after precipitation *i.e.*, surface runoff and subsurface runoff) and base flow (*i.e.*, ground water runoff). Runoff, thus is the response of a catchment to the precipitation reflecting the combined effects of the nature of precipitation, other climatic characteristics of the region, and the physiographic characteristics of the catchment basin.

3.4 HYDROGRAPH

HYDROGRAPH IS DEFINED AS A GRAPH SHOWING DISCHARGE OF FLOWING WATER WITH RESPECT TO TIME FOR SPECIFIED TIME.

Consider a concentrated storm producing a short-duration and reasonably uniform rainfall of duration t_r over a watershed. Part of this rainfall is retained on the land surface as detention storage. Yet another part of the rainfall infiltrates into the soil. The remaining part of the rainfall is termed rainfall excess (or effective rainfall) that is neither retained on the land surface nor infiltrated into the soil. This effective rainfall reaches the watershed outlet after flowing over the watershed surface. The flow over the watershed surface builds up some storage both in the overland and channel flow phases. This storage gradually depletes when the rainfall has ceased. There is, thus, a time lag between the occurrence of rainfall over a watershed and the time when the rainfall excess reaches the gauging station at the watershed outlet in the form of direct runoff. The runoff measured at the gauging station would typically vary with time as shown by the curve AMCE in the graph (known as hydrograph) of Fig. The hydrograph is, therefore, the response of a given catchment (or watershed) to a rainfall input and can be regarded as an integral expression of the physiographic and climatic characteristics of the region that decide the rainfall-runoff relationship. It comprises all three phases of runoff, viz., surface runoff, interflow and base flow. Therefore, two different storms over the same watershed would, invariably, produce hydrographs of different shapes (*i.e.*, peak rate of discharge, time base *etc*.) Likewise, identical storms over different watersheds would also produce different hydrographs.

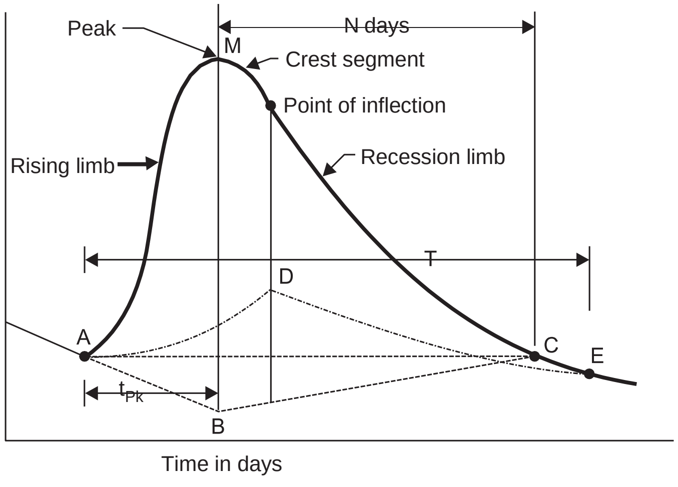


Fig. Base flow separation

The inter-relationship among rainfall, watershed and climatic characteristics is, generally, very complex and so is the shape of the resulting hydrograph (having kinks, multiple peaks *etc*.) much different from the simple single-peaked hydrograph of Fig.

2.5 CATCHMENT AREA

A **catchment area** is a **hydrological** unit. Each drop of precipitation that falls into a **catchment area** eventually ends up in the same river going to the sea if it doesn't evaporate. **Catchment areas** are separated from each other by watersheds. A **watershed** is natural division line along the highest points in an **area**.

2.6 Factors affecting runoff:

Meteorological factors affecting runoff:

- Type of precipitation (rain, snow, sleet, etc.)
- Rainfall intensity
- Rainfall amount
- Rainfall duration
- Distribution of rainfall over the watersheds
- Direction of storm movement
- Antecedent precipitation and resulting soil moisture
- Other meteorological and climatic conditions that affect evapotranspiration, such as temperature, wind, relative humidity, and season.

Physical characteristics affecting runoff:

- Land use
- Vegetation
- Soil type
- Drainage area
- Basin shape
- Elevation
- Slope
- Topography
- Direction of orientation
- Drainage network patterns
- Ponds, lakes, reservoirs, sinks, etc. in the basin, which prevent or alter runoff from continuing downstream

2.7 Unit Hydrograph

A unit hydrograph (or unit-Graph) is the direct runoff hydrograph resulting from one centimeter (or one millimeter or one inch) of excess rainfall generated uniformly over a catchment area at a constant rate for an effective duration (1). The unit hydrograph for a catchment basin is the direct runoff hydrograph produced by a unit (usually 1 cm) rainfall excess from a storm of *D*-hour duration and, therefore, is the lumped response of the basin to the storm. The unit hydrograph is a simple linear model that is most widely used for obtaining the surface runoff hydrograph resulting from any amount of excess rainfall. The physical characteristics of a catchment basin (shape, size, slope *etc*.) remain invariant to a large extent. Therefore, one may expect considerable similarity in the hydrographs of different storms of similar rainfall characteristics. This forms the basis of the unit hydrograph first proposed by Sherman (10). The unit hydrograph is a typical hydrograph for a catchment basin and is so called because the runoff volume under the hydrograph is adjusted to 1 cm (or 1 mm or 1 inch) equivalent depth over the basin. It should, however, be noted that the variable characteristics of storms (such as rainfall duration, time-intensity pattern, areal distribution, magnitude of rainfall) do cause variations in the shape of the resulting hydrographs. Therefore, it would be incorrect to imply that only one typical hydrograph would suffice for any catchment basin. The following basic assumptions are inherent in the unit hydrograph theory (1):

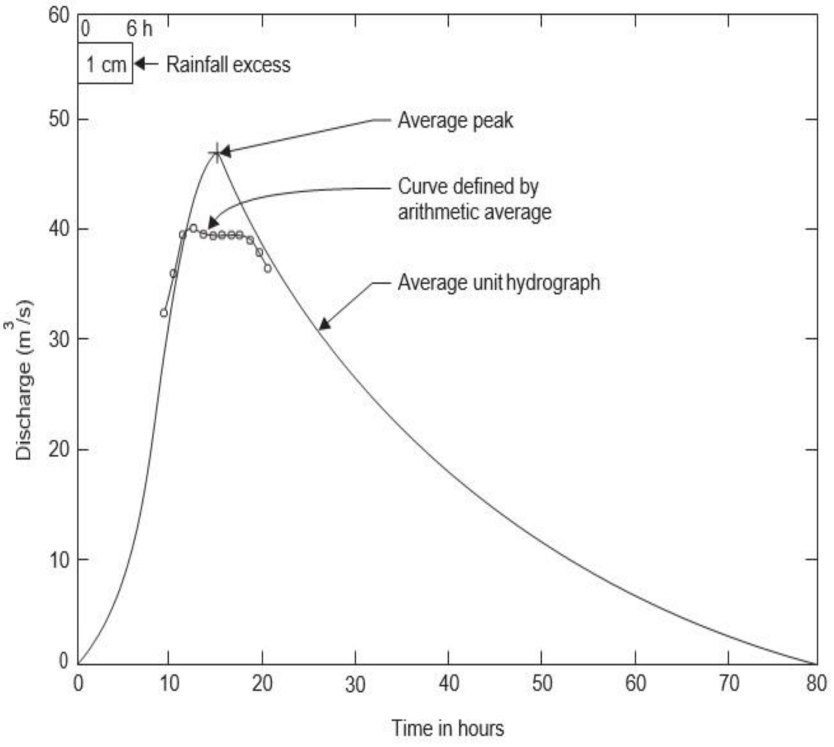
1. The excess rainfall has a constant intensity (1/*D* cm/hr) within effective storm duration of *D* hours.

2. The excess rainfall (giving rise to 1 cm depth of runoff) is uniformly distributed throughout the entire catchment basin.

3. The base time of direct runoff hydrograph (*i.e.*, the duration of the direct runoff) resulting from an excess rainfall of given duration is constant.

4. The ordinates of all direct runoff hydrographs of a common base time are directly proportional to the total amount of direct runoff represented by each hydrograph. This means that a rainfall excess of *r* cm due to a storm of duration *D* hours in a catchment basin will produce a direct runoff hydrograph whose ordinates would be *r* times the corresponding ordinates of a *D*-hour unit hydrograph of the basin.

5. For a given catchment basin, the hydrograph, resulting from a given excess rainfall, reflects the unchanging characteristics of the catchment basin.



Average unit hydrograph

2.7.1 Use and Limitations of Unit Hydrograph

Unit hydrograph is useful for (*i*) the development of flood hydrographs for extreme rainfalls for use in the design of hydraulic structures, (*ii*) extension of flood-flow records based on rainfall data, and (*iii*) development of flood forecasting and warning system based on rainfall.

In very large catchment basins, storms may not meet the conditions of constant intensity within effective storm duration and uniform areal distribution. Therefore, each storm may give different direct runoff hydrograph under, otherwise, identical conditions. Therefore, unit hydrograph is considered applicable for catchments having area less than about 5000 km^2 (9). Very large catchments are usually divided into smaller sub-basins and the hydrographs of these sub-basins are processed to obtain composite hydrograph at the basin outlet.

The application of unit hydrograph also requires that the catchment area should not be smaller than about 200 ha as for such small basins there are other factors which may affect the rainfall-runoff relation and the derived unit hydrograph may not be accurate enough.

2.8 Measurement of Precipitation

One of the most crucial and least known components of the global hydrologic cycle is the precipitation that is the basic data required to estimate any hydrologic quantity (such as runoff, flood discharge *etc*.). Therefore, measurement of precipitation is an important component of all hydrologic studies. Weather and water-balance studies too require information on precipitation.

2.8.1 Precipitation Gauges

Precipitation (of all kinds) is measured in terms of depth of water (in millimeters) that would accumulate on a level surface if the precipitation remained where it fell. A variety of instruments have been developed for measuring precipitation (or precipitation rate) and are known as precipitation gauges or, simply, rain gauges which are classified as either recording or non-recording rain gauges.

Non-recording rain gauges only collect rain water which, when measured suitably, gives the total amount of rainfall at the rain gauge station during the measuring interval. The Indian Meteorological Department has adopted Symon's rain gauge. A glass bottle and funnel with brass rim are put in a metallic cylinder such that the top of the cylinder is 305 mm above the ground level. Rain water falls into the glass bottle through the funnel. The water collected in the bottle is measured with the help of a standard measuring glass jar which is supplied with the rain gauge. The jar measures rainfall in millimeters. At each station, rainfall observations are taken twice daily at 8.30 a.m. and 5.30 p.m.

Recording rain gauges automatically record the intensity of rainfall and the time of its occurrence in the form of a trace (or graph) marked on a graph paper wrapped round a revolving drum. Following three types are the most widely used recording rain gauges:

(i) Tipping bucket rain gauge,
(ii) Weighing bucket rain gauge, and
(iii) Siphon rain gauge.

(i) ***Tipping bucket rain gauge :*** A 300 mm diameter funnel collects rain water and conducts it to one of the two small buckets which are so designed that when 0.25 mm of rainfall is collected in a bucket, it tilts and empties its water into a bigger storage tank and, simultaneously, moves the other bucket below the funnel. When any of the two buckets tilts, it actuates an electric circuit causing a pen to make a mark on a revolving drum. The recording equipment can be remotely located in a building away from the rain gauge. At a scheduled time, the rain water collected in the storage tank can be measured to yield total rainfall in the measuring duration. The rainfall intensity (and also the total rainfall) can be estimated by studying the record sheet on which each mark indicates 0.25 mm of rain in the duration elapsed between the two adjacent marks.

(ii) ***Weighing bucket rain gauge:*** This gauge has a system by which the rain that falls into a bucket set on a platform is weighed by a weighing device suitably attached to the platform. The increasing weight of rain water in the bucket moves the platform. This movement is suitably transmitted to a pen which makes a trace of accumulated amount of rainfall on a suitably graduated chart wrapped round a clock driven revolving drum. The rain- fall record of this gauge is in the form of a mass curve of rainfall. The slope of this curve at any given time gives the intensity of rainfall at that time.

(*iii*) ***Siphon rain gauge:*** This gauge is also called float type rain gauge as this gauge has a chamber which contains a light and hollow float. The vertical movement of float on account of rise in the water level in the chamber (due to rain water falling in it) is transmit- ted by a suitable mechanism to move a pen on a clock-driven revolving chart. The record of rainfall is in the form of a mass curve of rainfall and, hence, the slope of the curve gives the intensity of rainfall.

2.9 Standard rain gauge

The standard United States National Weather Service rain gauge, developed at the start of the 20th century, consists of an 8-inch diameter (203 mm) funnel emptying into a graduated cylinder, 1.17 inches (29.7 mm) in diameter, which fits inside a larger container that is 8 inches in diameter and 20 inches (508 mm) tall. If the rainwater overflows the graduated inner cylinder, the larger outer container will catch it. When measurements are taken, the height of the water in the small graduated cylinder is measured, and the excess overflow in the large container is carefully poured into another graduated cylinder and measured to give the total rainfall. A cone meter is sometimes used to prevent leakage that can result in alteration of the data. In locations using the metric system, the cylinder is usually marked in mm and will measure up to 250 millimetres (9.8 in) of rainfall. Each horizontal line on the cylinder is 0.5 millimetres (0.02 in). In areas still using Imperial units, each horizontal line represents 0.01 inch.

2.10 Floating or Natural Syphon Type Rain Gauge

The working of this type of rain gauge is similar to weighing bucket rain gauge. A funnel receives the water which is collected in a rectangular container. A float is provided at the bottom of container, and this float raises as the water level rises in the container. Its movement being recorded by a pen moving on a recording drum actuated by a clock work.

Fig: Natural Syphon or Float Type Rain Gauge

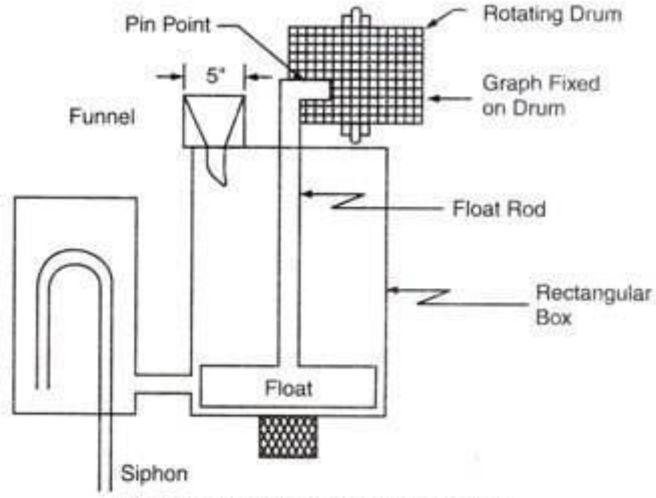


Fig. 2.5. Recording type rain-gauge

Fig: Natural Syphon or Float Type Rain Gauge Details

When water rises, this float reaches to the top floating in water, then syphon comes into operation and releases the water outwards through the connecting pipe, thus all water in box is drained out. This rain gauge is adopted as the standard recording rain gauge in India and the curve drawn using this data is known as mass curve of rain fall.

2.11 METHOD TO ESTIMATE RAINFALL:

1. Arithmetic Mean:

When the area of the basin is less than 500 km^2 this method implies summing up of all the rainfall values from all the rain gauging stations and then dividing it by the number of stations in that basin. The method becomes very clear by the use of a tabular form.

Table 2.3.

Rain gauging station	*Rainfall in cm*
A	5.6
B	4.9
C	5.2
D	5.5
Σ 4	Σ 21.2

$$\text{Now average depth} = \frac{\Sigma \text{ Rainfall values}}{\text{Number of stations}} = \frac{21.2}{4} = 5.3 \text{ cm.}$$

To explain, there are in all four rain-gauging stations A, B, C, D in the basin, whose rainfall values are given in the table 2.3. Sum of the rainfall values comes out to be 21.2 cm. It is divided by number of stations to give average depth of precipitation which comes out to be 5.3 cm.

This method gives accurate results if the stations are uniformly distributed over the area. There should not be much variation in the rainfall values of the stations under consideration. Drawback of this method is the stations just outside of the basin are not considered although these stations might have some influence on the basin under consideration.

2.12 Advantages of recording rain gauges:

1. Necessity of an attendant does not arise
2. Intensity of rainfall at anytime as well as total rainfall is obtained, where as non recording
gauge gives only total rainfall.
3. Data from in accessible places (hilly regions) can be continuously obtained once gauge is
established.
4. Human errors are eliminated.
5. Capacity of gauges is large.
6. Time intervals are also recorded.

2.13 Disadvantages of recording rain gauges:

1. High initial investment cost.
2. Recording is not reliable when faults in gauge arise (mechanical or electrical) till faults are corrected.

INTERNATIONAL INSTITUTE OF TECHNOLOGY & MANAGEMENT, MURTHAL SONEPAT

E-NOTES

SUBJECT: IRRIGATION **SUBJECT CODE: -**

COURSE- DIPLOMA **BRANCH: CIVIL ENGINEERING**

SEMESTER 4TH **CHAPTER NAME: METHODS OF IRRIGATION**

(PREPARED BY: Mr. ANKUR CHAUHAN, LECTURER, CE)

4.1 Surface Irrigation

In all the surface methods of irrigation, water is either ponded on the soil or allowed to flow continuously over the soil surface for the duration of irrigation. Although surface irrigation is the oldest and most common method of irrigation, it does not result in high levels of performance. This is mainly because of uncertain infiltration rates which are affected by year-to-year changes in the cropping pattern, cultivation practices, climatic factors, and many other factors. As a result, correct estimation of irrigation efficiency of surface irrigation is difficult. Application efficiencies for surface methods may range from about 40 to 80 per cent.

(a) Uncontrolled Flooding

When water is applied to the cropland without any preparation of land and without any levees to guide or restrict the flow of water on the field, the method is called 'uncontrolled', wild or 'free' flooding. In this method of flooding, water is brought to field ditches and then admitted at one end of the field thus letting it flood the entire field without any control.

Uncontrolled flooding generally results in excess irrigation at the inlet region of the field and insufficient irrigation at the outlet end. Application efficiency is reduced because of either deep percolation (in case of longer duration of flooding) or flowing away of water (in case of shorter flooding duration) from the field. The application efficiency would also depend on the depth of flooding, the rate of intake of water into the soil, the size of the stream, and topography of the field.

Obviously, this method is suitable when water is available in large quantities, the land surface is irregular, and the crop being grown is unaffected because of excess water. The advantage of this method is the low initial cost of land preparation. This is offset by the disadvantage of greater loss of water due to deep percolation and surface runoff.

(b) Border Strip Method

Border strip irrigation (or simply 'border irrigation') is a controlled surface flooding method of applying irrigation water. In this method, the farm is divided into a number of strips which can be 3-20 metres wide and 100-400 metres long. These strips are separated by low levees (or borders). The strips are level between levees but slope along the length according to natural slope. If possible, the slope should be between 0.2 and 0.4 per cent. But, slopes as flat as 0.1 per cent and as steep as 8 per cent can also be used (1). In case of steep slope, care should be taken to prevent erosion of soil. Clay loam and clayey soils require much flatter slopes (around 0.2%) of the border strips because of low infiltration rate. Medium soils may have slopes ranging from 0.2 to 0.4%. Sandy soils can have slopes ranging from 0.25 to 0.6%.

Water from the supply ditch is diverted to these strips along which it flows slowly towards the downstream end and in the process it wets and irrigates the soil. When the water supply is stopped, it recedes from the upstream end to the downsteam end.

The border strip method is suited to soils of moderately low to moderately high intake rates and low erodibility. This method is suitable for all types of crops except those which require prolonged flooding which, in this case, is difficult to maintain because of the slope. This method, however, requires preparation of land involving high initial cost.

(c) Check Method

The check method of irrigation is based on rapid application of irrigation water to a level or nearly level area completely enclosed by dikes. In this method, the entire field is divided into a number of almost levelled plots (compartments or '*Kiaries*') surrounded by levees. Water is admitted from the farmer's watercourse to these plots turn by turn. This method is suitable for a wide range of soils ranging from very permeable to heavy soils. The farmer has very good control over the distribution of water in different areas of his farm. Loss of water through deep percolation (near the supply ditch) and surface runoff can be minimised and adequate irrigation of the entire farm can be achieved. Thus, application efficiency is higher for this method. However, this method requires constant attendance and work (allowing and closing the supplies to the levelled plots). Besides, there is some loss of cultivable area which is occupied by the levees. Sometimes, levees are made sufficiently wide so that some 'row' crops can be grown over the levee surface.

(d) Basin Method

This method is frequently used to irrigate orchards. Generally, one basin is made for one tree. However, where conditions are favourable, two or more trees can be included in one basin.

(e) *Furrow Method*

In the surface irrigation methods discussed above, the entire land surface is flooded during each irrigation. An alternative to flooding the entire land surface is to construct small channels along the primary direction of the movement of water and letting the water flow through these channels which are termed 'furrows', 'creases' or 'corrugation'. Furrows are small channels having a continuous and almost uniform slope in the direction of irrigation. Water infiltrates through the wetted perimeter of the furrows and moves vertically and then laterally to saturate the soil. Furrows are used to irrigate crops planted in rows.

Furrow lengths may vary from 10 metres to as much as 500 metres, although, 100 metres to 200 metres are the desirable lengths and more common. Very long furrows may result in excessive deep percolation losses and soil erosion near the upstream end of the field. Preferable slope for furrows ranges between 0.5 and 3.0 per cent. Many different classes of soil have been satisfactorily irrigated with furrow slope ranging from 3 to 6 per cent (1). In case of steep slopes, care should be taken to control erosion. Spacing of furrows for row crops (such as corn, potatoes, sugarbeet, *etc*.) is decided by the required spacing of the plant rows. The furrow stream should be small enough to prevent the flowing water from coming in direct contact with the plant. Furrows of depth 20 to 30 cm are satisfactory for soils of low permeability. For other soils, furrows may be kept 8 to 12 cm deep.

Water is distributed to furrows from earthen ditches through small openings made in earthen banks. Alternatively, a small-diameter pipe of light weight plastic or rubber can be used to siphon water from the ditch to the furrows without disturbing the banks of the earthen ditch.

Furrows necessitate the wetting of only about half to one-fifth of the field surface. This reduces the evaporation loss considerably. Besides, puddling of heavy soils is also lessened and it is possible to start cultivation soon after irrigation. Furrows provide better on-farm water management capabilities for most of the surface irrigation conditions, and variable and severe topographical conditions. For example, with the change in supply conditions, number of simultaneously supplied furrows can be easily changed. In this manner, very high irrigation efficiency can be achieved.

The following are the disadvantages of furrow irrigation:

(i) Possibility of increased salinity between furrows,

(ii) Loss of water at the downstream end unless end dikes are used,

(iii) The necessity of one extra tillage work, *viz.*, furrow construction,

(iv) Possibility of increased erosion, and

(v) Furrow irrigation requires more labour than any other surface irrigation method.

4.2 Subsurface Irrigation

Subsurface irrigation (or simply subirrigation) is the practice of applying water to soils directly under the surface. Moisture reaches the plant roots through capillary action. The conditions which favour subirrigation are as follows (1):

(i) Impervious subsoil at a depth of 2 metres or more,

(ii) A very permeable subsoil,

(iii) A permeable loam or sandy loam surface soil,

(iv) Uniform topographic conditions, and

(v) Moderate ground slopes.

In natural sub irrigation, water is distributed in a series of ditches about 0.6 to 0.9 metre deep and 0.3 metre wide having vertical sides. These ditches are spaced 45 to 90 metres apart.

Sometimes, when soil conditions are favourable for the production of cash crops (*i.e.,* high-priced crops) on small areas, a pipe distribution system is placed in the soil well below the surface. This method of applying water is known as artificial sub irrigation. Soils which permit free lateral movement of water, rapid capillary movement in the root-zone soil, and very slow downward movement of water in the subsoil are very suitable for artificial sub irrigation. The cost of such methods is very high. However, the water consumption is as low as one-third of the surface irrigation methods. The yield also improves. Application efficiency generally varies between 30 and 80 per cent.

4.3 Sprinkler Irrigation

Sprinkling is the method of applying water to the soil surface in the form of a spray which is somewhat similar to rain. In this method, water is sprayed into the air and allowed to fall on the soil surface in a uniform pattern at a rate less than the infiltration rate of the soil. This method started in the beginning of this century and was initially limited to nurseries and orchards. In the beginning, it was used in humid regions as a supplemental method of irrigation. This method is popular in the developed countries and is gaining popularity in the developing countries too.

Rotating sprinkler-head systems are commonly used for sprinkler irrigation. Each rotating sprinkler head applies water to a given area, size of which is governed by the nozzle size and the water pressure. Alternatively, perforated pipe can be used to deliver water through very small holes which are drilled at close intervals along a segment of the circumference of a pipe. The trajectories of these jets provide fairly uniform application of water over a strip of cropland along both sides of the pipe. With the availability of flexible PVC pipes, the sprinkler systems can be made portable too.

Sprinklers have been used on all types of soils on lands of different topography and slopes, and for many crops. The following conditions are favourable for sprinkler irrigation (1):

(i) Very previous soils which do not permit good distribution of water by surface methods,

(ii) Lands which have steep slopes and easily erodible soils,

(iii) Irrigation channels which are too small to distribute water efficiently by surface irrigation, and

(iv) Lands with shallow soils and undulating lands which prevent proper levelling re- quired for surface methods of irrigation.

Besides, the sprinkler system has several features. For example, small amounts of water can be applied easily and frequently by the sprinkler system. Light and frequent irrigations are very useful during the germination of new plants, for shallow-rooted crops and to control soil temperature. Measurement of quantity of water is easier. It causes less interference in cultivation and other farming operations. While sprinkler irrigation reduces percolation losses, it increases evaporation losses. The frequency and intensity of the wind will affect the efficiency of any sprinkler system. Sprinkler application efficiencies should always be more than 75 per cent so that the system is economically viable.

The sprinkler method is replacing the surface/gravity irrigation methods in all developed countries due to its higher water application/use efficiency, less labour requirements, adaptability to hilly terrain, and ability to apply fertilizers in solution. In India too, the gross area under sprinkler irrigation has increased from 3 lakh hectares in 1985 to 5.80 lakh hectares in 1989. The total number of sprinkler sets in India now exceeds one lakh.

4.4 Advantages of Surface Irrigation

Followings are the surface irrigation advantages.

- Management is quite easy, you do not need any modern technology. If you have local traditional knowledge, you can do it.
- You do not need high financial support. You can be beneficial with small lands too.
- If you have short time water supplies, then this is the best process for you.
- If your drainage system is far, then you just need longer tubes.
- This is a nature-friendly system, you can utilize rainwater.
- It also works effectively in a low filtration rate.
- Low capital and no energy cost needed.
- You can use this irrigation process in sloping lands and long fields.

4.5 Disadvantages of Surface Irrigation

Followings are the surface irrigation disadvantages.

- Level lands require high accuracy, you cannot use it there.
- This is a big no-no for big fields.

- Not applicable on soil with a high filtration rate.
- Plants are always covered with water even when they do not need it.
- Sometimes limited space gets more water than required.
- No drainage outlet.

Drip Irrigation is a kind of micro irrigation system that saves water but at the same time ensures that water reaches the roots of the plants. It works to drip slowly. Drip Irrigation can work from both above or under the surface of the soil. It works effectively to ensure that all your plants get what they need.

4.6 Advantages of Drip Irrigation System

- Due to improper water supply, fertilizers and nutrients cannot reach the roots of every plant. Drip Irrigation system helps it to reach effectively.
- If you want to gain efficiency in water application, then installing the Drip Irrigation system is a must.
- Field leveling is done by installing this type of irrigation system. When your field is evenly leveled you can plant properly.
- Whatever your field capacity is, they need moisture. Roots should be hydrated.
- Soil erosion and weed growth are reduced.
- Water distribution can be controlled. According to the necessity, water is produced to every root.
- You do not any helping hand to water your plants anymore. So Drip Irrigation also confirms zero labor cost.
- It is a low-cost process that can also be done in low water pressure.

4.7 Disadvantages of Drip Irrigation System

- The installation process needs time. Sometimes may need court approval in some lands.
- Sun heat affects tubes, sometimes they get broken for excessive heat production.
- Plastic tubes affect soils fertility. Sun degrades plastic sometimes and that affect soil and fertilizers too.
- Tubes get clogged sometimes. Water cannot pass through and roots get dehydrated.
- If Drip Irrigation is not installed properly, then it is a waste of time, water and heat.

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E-NOTES

SUBJECT: IRRIGATION **SUBJECT CODE: -**

COURSE- DIPLOMA **BRANCH: CIVIL ENGINEERING**

SEMESTER 4TH **CHAPTER NAME: DESIGN OF IRRIGATION CANALS**

(PREPARED BY: Mr. ANKUR CHAUHAN, LECTURER, CE)

5.1 CANAL FALLS

5.1.1 INTRODUCTION:

Generally the slope of the natural ground surface is not uniform throughout the alignment. Sometimes the ground surface may be steep and sometimes it may be very irregular with abrupt change of grade. In such cases a vertical drop is proved to step down the canal bed and then it is constituted with permissible slope until another step down is necessary. Such vertical drops are known as canal falls or simply falls.

5.1.2 PURPOSES:

1. To account for the difference in the natural bed slope of the canal.
2. To save us from cutting and filling.
3. To Increase the velocity of the water in the canal.
4. To control the seepage in the canal.

5.2 NECESSITY OF CANAL FALLS:

The canal falls are necessary in case the following conditions occur:

(a) When the slope of the ground suddenly changes to steeper slope, the permissible bed slope cannot be maintained. In such cases canal falls are provided to avoid excessive earth work in filling. (Fig)

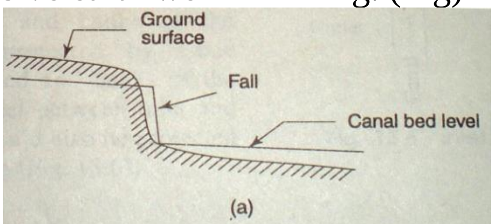
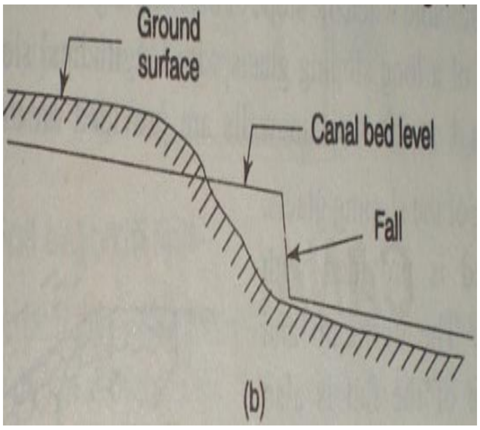
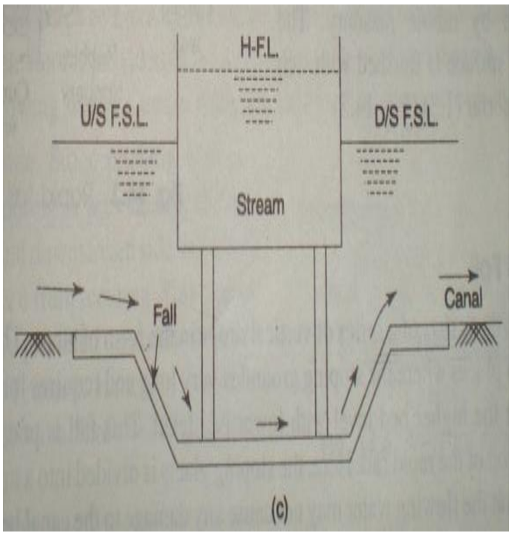


Fig. 14.1(a)

(b) When the slope of the ground is more or less uniform and the slope is greater than the permissible slope of the canal. In such case also the canal falls are necessary (Fig.)



(c) In cross drainage works when the difference between bed level of canal and that of drainage is same or when flood surface level of the canal is above the bed level of drainage then the canal fall is necessary to carry the canal water below the stream or drainage (i.e. in case of siphon super passage) (Fig.)



5.3 TYPES OF CANAL FALLS:

The different types of canal falls are,
1. Ogee fall
2. Rapid fall
3. Stepped Fall
4. Trapezoidal Notch Fall
5. Vertical Drop or Sarda Fall
6. Glacis Fall

1. Ogee fall:

In this type fall an ogee (a combination of convex curve and concave curve) is provided for carrying the canal water from higher level to the lower level. This fall is recommended when the natural ground surface suddenly changes to a steeper slope along the alignment of the canal.

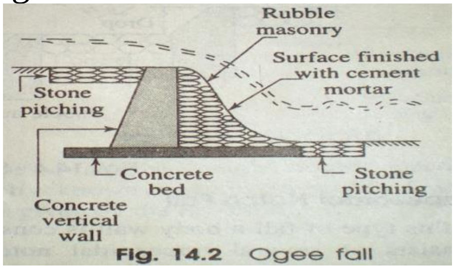


Fig. 14.2 Ogee fall

2. Rapid fall:

The rapid fall is suitable when the slope of the natural ground surface is even and long. It consists of a long sloping glacis with longitudinal slope which varies from 1 in 10 to 1 in 20.

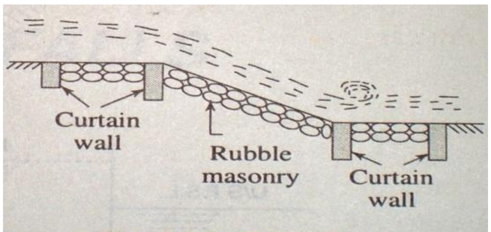


Fig. 14.3 Rapid fall

3. Stepped Fall:

Stepped fall consists of vertical drops in the form of steps. This fall is suitable in places where the sloping ground is very long and requires long glacis to connect the higher bed with the lower bed level. This fall is practically a modification of the rapid fall. Here the sloping glacis is divided into a number of drops so that the flowing water may not cause any damage to the canal bed.

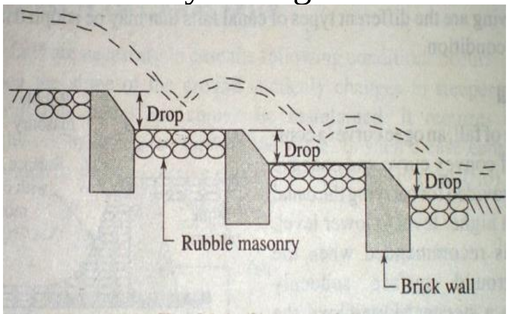


Fig. 14.4 Stepped fall

4. Trapezoidal Notch Fall:

In this type of fall a body wall is constructed across the canal. The body wall consists of several trapezoidal notches between the side piers and the intermediate pier or piers. The sills of the notches are kept at the upstream bed level of the canal. The size and number of notches depends upon the full supply discharge of the canal. (Fig. 14.5)

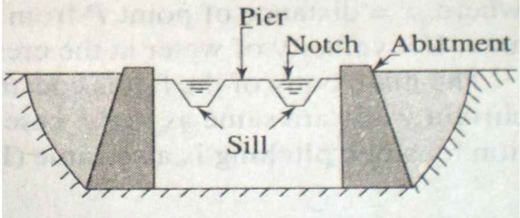


Fig. 14.5 Trapezoidal notch fall

5. Vertical Drop or Sarda Fall:

It consists of a vertical drop wall which is constructed with masonry work. The water flows over the crest of the wall. A water cistern is provided on the downstream side which acts as a water cushion to dissipate the energy of falling water.Hence it is sometimes known as sarda fall.(Fig.14.6)

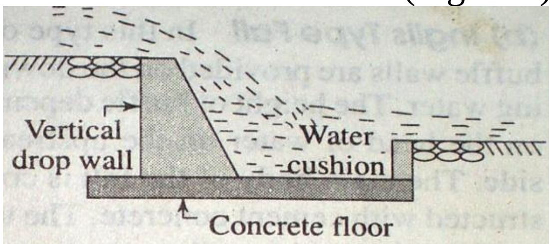


Fig. 14.6 Vertical drop fall

6. Glacis Fall:

It consists of a straight sloping glacis provided with a crest. A water cushion is provided on the downstream side to dissipate the energy of flowing water. Curtain walls and toe walls are provided on the upstream and downstream side. This type of fall is suitable for drops up to 1.5 m (Fig.14.7).

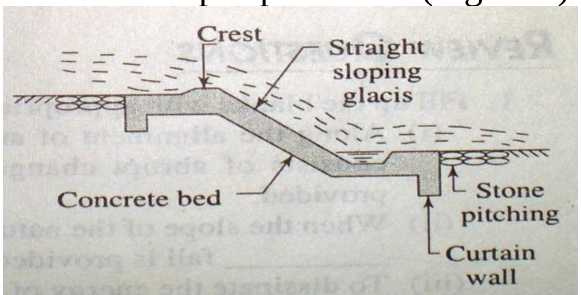


Fig. 14.7 Glacis fall

This type of fall may be of the two types,
(i) Montague type
(ii) Inglis type fall
(i) Montague type:

In this type of fall the straight sloping glacis is modified by giving parabolic shape which is known as Montague profile.

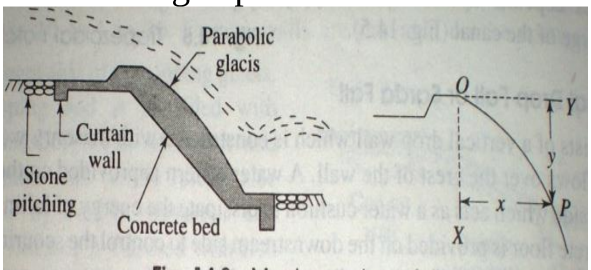


Fig. 14.8 Montague type fall

(ii) Inglis type fall:

In this type of fall the glacis is straight and sloping but baffle walls are provided on the downstream floor to dissipate the energy of flowing water . The height of baffle depends on the head of water on the upstream side.

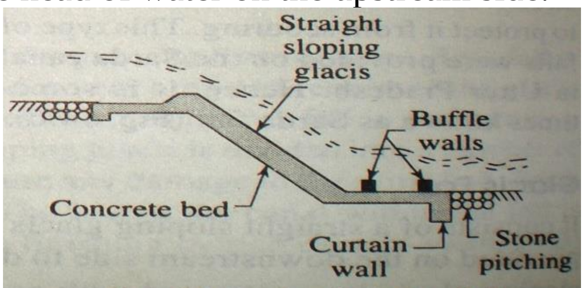


Fig. 14.9 Inglis type fall

5.4 SITE SELECTION / LOCATION OF CANAL FALLS:

The location of falls is decided from the following considerations,
(i) For the canals which do not irrigate the area directly the fall should be located from the considerations of economy in cost and excavation of the channel with regard to balancing the depth and the cost of fall itself.
(ii)For a canal irrigating the area directly a fall may be provided at a location where F.S.L outstrips the ground level, but before the bed of the canal comes into filling.
(iii)The location of the fall may also be decided from the consideration of the possibility of combining it with a regulator or a bridge or any other masonry works.
(iv)A relative economy of providing large number of small falls v/s small number of big falls should be worked out. The provision of small number of big

falls results in unbalanced earthwork, but there is always some saving in the cost of the fall structure.
(v) For a minor or distributory, falls may be located on the downstream of the outlets as this helps in increasing the command area and improving the efficiency of the outlet.

5.5 Canal Lining

Canal Lining is an impermeable layer provided for the bed and sides of canal to improve the life and discharge capacity of canal. 60 to 80% of water lost through seepage in an unlined canal can be saved by construction canal lining.

FIG. Canal Lining

5.5.1 Types of Canal Linings

Canal linings are classified into two major types based on the nature of surface and they are:

1. Earthen type lining
2. Hard surface lining

1. Earthen Type lining

Earthen Type lings are again classified into two types and they are as follows:

- Compacted Earth Lining
- Soil Cement Lining

Compacted Earth Lining

Compacted earth linings are preferred for the canals when the earth is available near the site of construction or In-situ. If the earth is not available near the site then it becomes costlier to construct compacted earth lining.

Compaction reduces soil pore sizes by displacing air and water. Reduction in void size increases the density, compressive strength and shear strength of the soil and reduces permeability. This is accompanied by a reduction in volume and settlement of the surface. Proper compaction is essential to increase the stability and frost resistance (where required) and to decrease erosion and seepage losses.

Fig : Compacted Earth Lining

Soil Cement Lining

Soil-cement linings are constructed with mixtures of sandy soil, cement and water, which harden to a concrete-like material. The cement content should be minimum 2-8% of the soil by volume. However, larger cement contents are also used.

In general, for the construction of soil-cement linings following two methods are used.

- Dry-mix method

- Plastic mix method

For erosion protection and additional strength in large channels, the layer of soil-cement is sometimes covered with coarse soil. It is recommended the soil-cement lining should be protected from the weather for seven days by spreading approximately 50 mm of soil, straw or hessian bags over it and keeping the cover moistened to allow proper curing. Water sprinkling should continue for 28 days following installation.

Fig Soil Cement Lining

2. Hard Surface Canal Linings

It is sub divided into 4 types and they are

- Cement Concrete Lining
- Brick Lining
- Plastic Lining
- Boulder Lining

Cement Concrete Lining

Cement Concrete linings are widely used, with benefits justifying their relatively high cost. They are tough, durable, relatively impermeable and hydraulically efficient. Concrete linings are suitable for both small and large channels and both high and low flow velocities. They fulfill every purpose of lining.

There are several procedures of lining using cement concrete

- Cast in situ lining
- Shortcrete lining
- Precast concrete lining
- Cement mortar lining

Fig : Cement Concrete Lining

Brick Lining

In case of brick lining, bricks are laid using cement mortar on the sides and bed of the canal. After laying bricks, smooth finish is provided on the surface using cement mortar.

Fig: Construction of Brick Canal Lining

Plastic Lining

Plastic lining of canal is newly developed technique and holds good promise. There are three types of plastic membranes which are used for canal lining, namely:

- Low density poly ethylene
- High molecular high density polythene
- Polyvinyl chloride

The advantages of providing plastic lining to the canal are many as plastic is negligible in weight, easy for handling, spreading and transport, immune to chemical action and speedy construction.

The plastic film is spread on the prepared sub-grade of the canal. To anchor the membrane on the banks ‘V trenches are provided. The film is then covered with protective soil cover.

Fig : Plastic Canal Lining

Boulder Lining

This type of lining is constructed with dressed stone blocks laid in mortar. Properly dressed stones are not available in nature. Irregular stone blocks are dressed and chipped off as per requirement.

When roughly dressed stones are used for lining, the surface is rendered rough which may put lot of resistance to flow. Technically the coefficient of rugosity will be higher. Thus the stone lining is limited to the situation where loss of head is not an important consideration and where stones are available at moderate cost.

Fig : Canal Lined with Boulders

5.6 Design Of Irrigation Canal:

Irrigation canals may be of two types:

5.6.1 Unlined Irrigation Canal:

The irrigation canal prepared by earth is called unlined canal

5.6.2 Lined Irrigation Canal:

The irrigation canal prepared by using different materials of construction i.e. bricks, P.C.C or R.C.C, is called lined irrigation canal.

Lining is indispensable when passing through the porous or sandy tracks. However in Pakistan majority of the canals are unlined whether or not they pass through the sandy soils. They were built during the last few decades and resulting a rise of ground water table thus creating water logging and salinity problems. Recently the irrigation canals are built with lining. Both types of canal are designed for uniform steady flow.

5.6.3 Design Of Unlined Irrigation Canal:

The design of unlined canal which will remain stable is an important challenge for the hydraulic & irrigation engineer. The solution of this problem consists in determining the depth, bed width, side slope and longitudinal slope of the channel so as to produce a non-silting and non-scouring velocity for the given discharge and sediment load.

Design of an irrigation canal implies a section which is stable that neither silts nor scour with the given discharge(Q), water surface slope (S) and silt charge. When a channel is stable, it means the flow in the channel is uniform steady flow.

Stable Channel:

When an artificial channel is used to carry the silty water, both the bed and banks scour or fill by changing the depth, gradient and width of the channel until a state of balance is attained at which channel is said to be stable channel. Stable channel is also called as non-silting & non-scouring channel.

Critical Velocity (V_o):

A velocity which will keep the silt in suspension without scouring the channel is called critical velocity. It is a standard velocity. It is also called as non-silting & non-scouring velocity. It is denoted by V_o.

Critical Velocity Ratio (m):

It is defined as the mean actual velocity(V) to the critical velocity(V_o). Mathematically,

$$m = \frac{V_o}{V}$$

The value of 'm' ranges b/w$(0.9 - 1.1)$. In irrigation canal system the value of 'm' decreases from head to tail.

Reduced Distance $(R.D)$:

It is the distance from the near/relative headwork and known as reduced distance.

$$1\ R.D = 1000\ ft \qquad \&$$

$$5\ R.D = 1\ mile \qquad (for\ canal)$$

In case of canal one mile is equal to 5000 feet. Reduced distance is taken along the canal.

Bed Slope (S):

It is the bed slope of the channel due to which water flows under gravity. For most of the channels in Punjab, the longitudinal bed slope is taken as 1 ft/mile. Mathematically,

$$S = \frac{1\,ft}{1\,mile\;(canal)} = \frac{1\,ft}{5000\,ft}$$

There are two main theories being developed for the designing of unlined irrigation canal.

1. Kennedy's silt theory
2. Lacey's regime theory

5.7 Advantages of Canal Lining

1. It reduces the loss of water due to seepage and hence the duty is enhanced.
2. It controls the water logging and hence the bad effects of water-logging are eliminated.
3. It provides smooth surface and hence the velocity of flow can be increased.
4. Due to the increased velocity the discharge capacity of a canal is also increased.
5. Due to the increased velocity, the evaporation loss also can be reduced.
6. It eliminates the effect of scouring in the canal bed
7. The increased velocity eliminates the possibility of silting in the canal bed.
8. It controls the growth of weeds along the canal sides and bed.
9. It provides the stable section of the canal.
10. It reduces the requirements of land width for the canal, because smaller section of the canal can be used to produce greater discharge.
11. It prevents the sub-soil salt to come in contact with the canal water. 12. It reduces the maintenance cost for the canals.

5.8 Disadvantages of Canal Lining

1. The initial cost of the canal lining is very high. So, it makes the project very expensive with respect to the output.
2. It involves many difficulties for repairing the damaged section of lining.

3. It takes too much time to complete the project work.
4. It becomes difficult, if the outlets are required to be shifted or new outlets are required to be provided, because the dismantling of the lined section is difficult.

5.9 BREACHES:

Every year, a number of breach failures occur in Irrigation Canals in Sindh. In addition to that, breach failures also can cause water shortages when the failure occurs during the peak demand period.

5.9.1 CAUSES OF BREACHES

i) NATURAL DISASTER
ii) HUMAN INTERFERENCE

5.9.2 OCCURENCE OF BREACHES DUE TO NATURAL DISATSER

- HEAVY RAINS
- WIND STORMS
- FALIING OF DEAD AND HOLLOW TREES

5.9.3 OCCURENCE OF BREACHES DUE TO HUMAN INTERFERENCE

- OBSTRUCTION OF FLOW
- CUTTING OF BANKS
- TRESPASSING
- POOR COMPACTION OF BANKS
- SLOUGHING
- VEGETATION GROWTH
- PIPING

5.9.4 CONTROLS:

- Proper maintenance of canal
- Formation of berms

- Dowels to be provided
- Sarkanda growth to be inhibited
- Dead trees to be removed
- Escape channels must be operational
- Trespassing to be prohibited
- Unauthorized use of service road to be avoided
- Strict action against the culprits of water theft
- Syphon pipes of tube wells to be avoided
- Porcupine holes and Rain gharas shall be attended forthwith
- Water courses along the channel must be avoided
- Proper surveillance of channels should be done
- Construction of recharge wells

5.9 Closing of Breaches

- Arranging reduction of canal supply from head of the channel.
- Closing of channel as per regulation orders.
- Collection of earth on upstream and downstream of the bank.
- A ring bund is marked at the breach site for filling of earth when less or no water is passing through the breach.
- Earth filling on the alignment on the ring bund shall be done with compaction in layers till the top level of the bank is attained.

- Bamboos / Killa bushing is done in the design berm width along the breach site with 50 ft. up / down stream of the breach.

- Additional Pushta with the bank is also provided at the breach site to cover the Hydraulic gradient.

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E-NOTES

SUBJECT: IRRIGATION **SUBJECT CODE: -**

COURSE- DIPLOMA **BRANCH: CIVIL ENGINEERING**

SEMESTER 4TH **CHAPTER NAME: TUBE-WELL IRRIGATION**

(PREPARED BY: Mr. ANKUR CHAUHAN, LECTURER, CE)

6.1 GROUND WATER RESOURCES

The amount of water stored in the earth’s crust may be of the order of 8 billion cubic kilometres, half of which is at depths less than 800 m. This water inside the earth is about 35 times the combined storage of all the world’s rivers, fresh water lakes, reservoirs, and inland seas, and is about one-third the volume of water stored in the arctic and antarctic ice fields, the glaciers of Greenland, and the great mountain systems of the world. All of this ground water, however, cannot be utilised because of physiographic limitations.

The estimate of the present ground water resource in India is of the order of 650 cubic kilometres (as against 1880 cubic km for surface water resources), out of which utilisable ground water is assessed at around 420 cubic km (as against 690 cubic km for surface water resources). *Ground water* is that part of the subsurface water which occurs within the saturated zone of the earth’s crust where all pores are filled with water. Ground water has also been referred to as that part of the subsurface water which can be lifted or which flows naturally to the earth’s surface. A hole or shaft, usually vertical, is excavated in the earth to lift ground water to the earth’s surface and is termed a well. A well can also be used for disposal of water, artificial recharge, draining out agricultural lands, and relieving pressures under hydraulic structures. The Chinese are known to be the first to have drilled deep wells using bamboo rods tipped with iron. The rods were lifted and dropped manually and the method was similar to the method now known as cable tool drilling. Ground water flows to the earth’s surface through naturally discharging springs and streams and rivers which are sustained by ground water itself when overland runoff is not present. Following significant features of ground water should always be kept in mind while managing ground water:

(i) Ground water is a huge water resource, but is exhaustible and is unevenly available.

(ii) Ground water and surface water resources are interrelated and, hence, should be considered together.

(iii) Excessive and continued exploitation of ground water must be avoided as natural replenishment of the ground water resource is a very slow process.

(iv) Ground water is generally better than surface water in respect of biological characteristics. On the other hand, surface water is generally better than ground water in terms of chemical characteristics.

(v) Ground water may be developed in stages on ‘‘pay-as-you-go’’ or ‘‘pay-as-you-grow’’ basis. Surface water development usually needs large initial capital investment.

(vi) Underground reservoirs storing ground water are more advantageous than surface reservoirs.

(vii) Ground water is generally of uniform temperature and mineral quality and is free of suspended impurities.

(viii) Ground water source has indefinite life, if properly managed.

Ground water source is replenished through the processes of infiltration and percolation. *Infiltration* is the process by which the precipitation and surface water move downward into the soil. *Percolation* is the vertical and lateral movement through the various openings in the geological formations. Natural sources of replenishment include rainwater, melting snow or ice and water in stream channels, and lakes or other natural bodies of water. Rainwater may infiltrate into the ground directly or while flowing over the land enroute to a river, or stream, or other water bodies. Artificial sources of replenishment (or recharge) include the following:

(i) Leakage from reservoirs, conduits, septic tanks, and similar water related structures.

(ii) Irrigation, or other water applications including deliberate flooding of a naturally porous area.

(iii) Effluents discharged to evaporation or percolation ponds.

Injection through wells or other similar structures.

6.2 Wells and Tube Wells Irrigation in India:

Merit and Demerits

A well is a hole dug in the ground to obtain the subsoil water. An ordinary well is about 3-5 metres deep but deeper wells up-to 15 metres are also dug.

This method of irrigation has been used in India from time immemorial. Various methods are used to lift the ground water from the well for irrigation, drinking, bathing and for other purposes.

Well irrigation is popular in areas where sufficient sweet ground water is available. These areas include a large part of the Great Northern Plain, the deltaic regions of the Mahanadi, the Godavari, the Krishna and the Cauvery, parts of the Narmada and the Tapi valleys and the weathered layers of the Deccan Trap and crystalline rocks and the sedimentary zones of the Peninsula.

However, the greater part of the Peninsular India is not suitable for well irrigation due to rocky structure, uneven surface and lack of underground water. Large dry tracts of Rajasthan, the adjoining parts of Punjab, Haryana, and Gujarat and some parts of Uttar Pradesh have brackish ground water which is not fit for irrigation and human consumption and hence unsuitable for well irrigation.

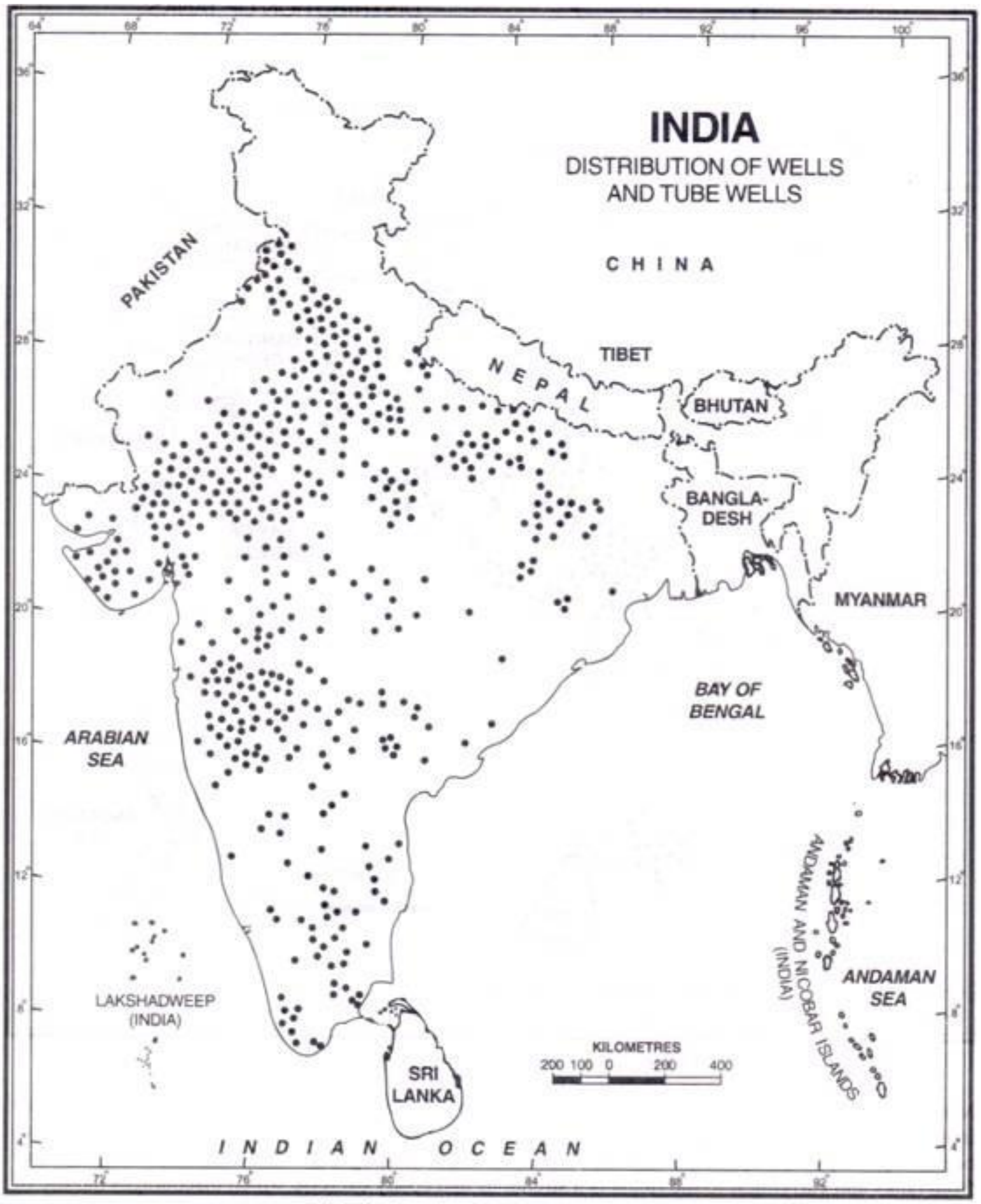


FIG. 17.3. India : Distribution of Wells

There were about 5 million wells in 1950-51 and their number has now increased to about 12 million. Well irrigation accounts for more than 60 per cent of the net irrigated area in the country against 29.2 per cent of canal and only 4.6 per cent of tank irrigation. It accounted 59.78 lakh hectares in 1950-51 which rose to about 332-77 lakh hectares in 2000-01 thereby registering more than fivefold increase in well irrigation.

Uttar Pradesh has the largest area of 93-84 lakh hectares under well irrigation which accounts for about 28-19 per cent of the well irrigated area of India. This is followed by Rajasthan (10-44%), Punjab (8-65%), Madhya Pradesh (7-97%), and Gujarat (7-34%) Bihar (6-29%), Andhra Pradesh (5-87%), Maharashtra (5-75%), Haryana (4-41%), Tamil Nadu (4-35%), West Bengal (4 19%) and Karnataka (3.06%).

In Gujarat, about 82-31 per cent of the net irrigated area is under well irrigation. The other states where well irrigation plays a significant role are Punjab (79.96%), Uttar Pradesh (73.22%), Rajasthan (70.78%), Maharashtra (64.62%), Madhya Pradesh (64.11%) and West Bengal (59.35%) (See Table 17.3). Uttar Pradesh, Rajasthan, Punjab, Madhya Pradesh, Gujarat, Bihar and Andhra Pradesh account for three-fourths of the total well irrigated area of India.

A tube well is a deeper well (generally over 15 metres deep) from which water is lifted with the help of a pumping set operated by an electric motor or a diesel engine. Obviously, a tube well cannot be constructed everywhere and requires some geographical conditions favouring its installation.

The main factors are:

(i) There should be sufficient quantity of ground water because a tube well can generally irrigate 2 hectares per day against 0.2 hectares per day irrigated by an ordinary well.

(ii) The water level should be nearly 15 metres. If the water table is more than 50 metres deep the cost of pumping out water from the tube well becomes uneconomic.

(iii) There should be regular supply of cheap electricity or diesel so that water from the tube well can be taken out at the hour of need.

(iv) The soil in the immediate neighbourhood of the tube-well should be fertile so that there is demand for irrigation and the cost involved in the construction and operation of the tube well can be recovered by the increased farm production.

The first tube well of India was sunk in Uttar Pradesh in 1930. Till 1951 India had just 2,500 tube wells. The central and the state governments are helping the farmers by distributing pumping sets, granting loans and giving subsidies. The number of electrical pumpsets/tube wells increased from 2 lakh in 1960 to over 4 million in 1995-96 while the dieselized pumpsets increased from 2 3 lakh to about 3 million during the same period.

In several areas, the ‘persian wheel’ earlier used for lifting water has been replaced by tube wells. Tamil Nadu with 11 lakh tube wells has the largest number in the country followed by Maharashtra (9 lakh), Andhra Pradesh (6.7 lakh), Uttar Pradesh (5.3 lakh), Madhya Pradesh (4.6 lakh), Karnataka (4.4 lakh), Punjab (3.9 lakh) and Haryana (3.5 lakh) Thus more than three-fourths of India’s tube wells are functioning in Tamil Nadu, Maharashtra, Andhra Pradesh, Uttar Pradesh, Madhya Pradesh, Karanataka and Punjab.

Merits of Well and Tube Well Irrigation:

1. Well is simplest and cheapest source of irrigation and the poor Indian farmer can easily afford it.

2 Well is an independent source of irrigation and can be used as and when the necessity arises. Canal irrigation, on the other hand, is controlled by other agencies and cannot be used at will.

3. Excessive irrigation by canal leads to the problem of reh which is not the case with well irrigation.

4. There is a limit to the extent of canal irrigation beyond the tail end of the canal while a well can be dug at any convenient place.

5 Several chemicals such as nitrate, chloride, sulphate, etc. are generally found mixed in well water. They add to the fertility of soil when they reach the agricultural field along with well water.

6. The farmer has to pay regularly for canal irrigation which is not the case with well irrigation.

Demerits of Well and Tube Well Irrigation:

1. Only limited area can be irrigated. Normally, a well can irrigate 1 to 8 hectares of land.

2. The well may dry up and may be rendered useless for irrigation if excessive water is taken out

3. In the event of a drought, the ground water level falls and enough water is not available in the well when it is needed the most.

4. Tubewells can draw a lot of groundwater from its neighbouring areas and make the ground dry and unfit for agriculture.

5. Well and tube well irrigation is not possible in areas of brackish groundwater.

6.3. Cone of Depression:

The existence of hydraulic gradient induces flow of water into the well from the surrounding aquifer. Since the water moves towards the well from all directions it forms successive cylindrical sections. As the water approaches the well the surface area of each cylindrical section goes on reducing. Although the surface area of cylindrical rings reduces the rate of flow is same through all cylindrical sections.

As a result the velocity of flow is smaller at outer most rings which gradually increases towards the well. With increasing velocity the hydraulic gradient also increases as the flow approaches the well. This situation continues to exist so long as head difference is maintained due to pumping. The form of surface created by increasing hydraulic gradient is cone shaped. It is therefore called cone of depression and it represents drawdown at various points in the aquifer. Figure 16.5 shows various terms used in well hydraulics.

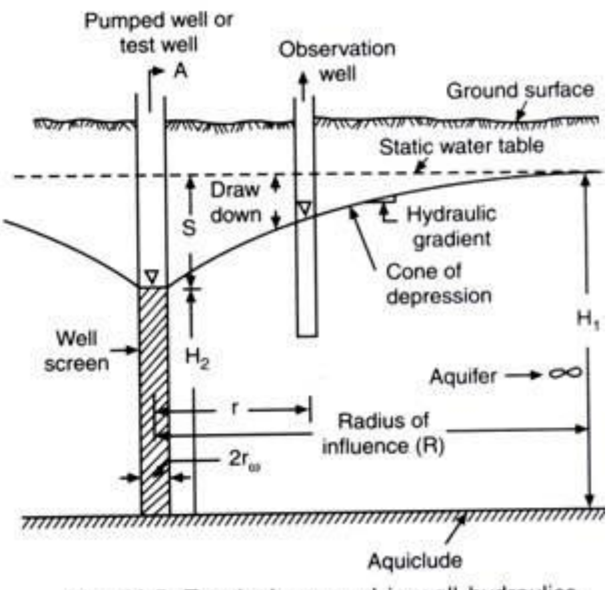


Fig. 16.5. Terminology used in well hydraulics

6.4. Radius of Influence:

It is distance from the centre of the well to the point at which the drawdown is zero. The point at which drawdown is zero indicates the outer limit of the cone of depression. The cones of depression are larger for wells sunk in the confined aquifer. Therefore, radius of influence is also greater in confined aquifer than in the unconfined aquifer. It may be noted that drawdown, cone of depression and radius of influence are the three parameters of the same phenomenon, are closely inter-related and are characteristic features of every pumped well.

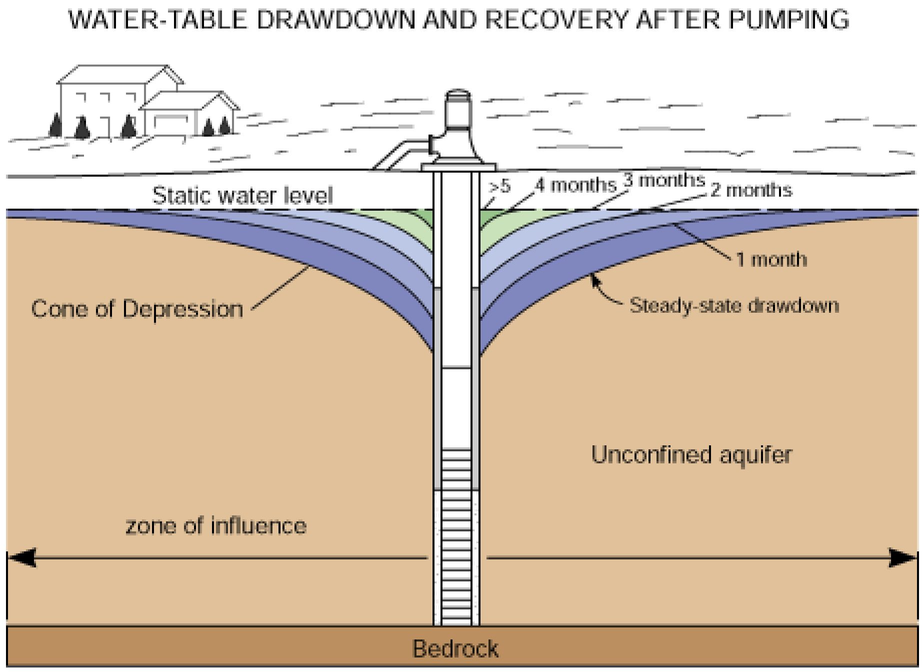
They depend on the following:

i. Aquifer characteristics;

ii. Well discharge, i.e., pumping rate;

iii. Duration of pumping; and

iv. Slope of water table recharge within the influenced zone.



FIGURE

In areas where the water table is declining, the aquifer may become progressively less useful for various types of withdrawals as the water level decreases to and past the elevation at which high-rate drawdowns would be in excess of the available saturated thickness. the extended caption further defines and discusses some of the issues that suggest a possible need for definition of a sustainability reserve--the amount of water in storage that would be required for effective long-term management and reliable use whatever amount is determined to be sustainable for a given aquifer subunit. This would be the amount of water in storage that would trigger mandatory use reductions if a transition plan is not already in effect. Management subunits can be defined on the basis of surface and bedrock topography, alluvial channels, aquifer characteristics, and the present distribution of various types of water use; such considerations effectively determine both transition strategies and long-term management principles.

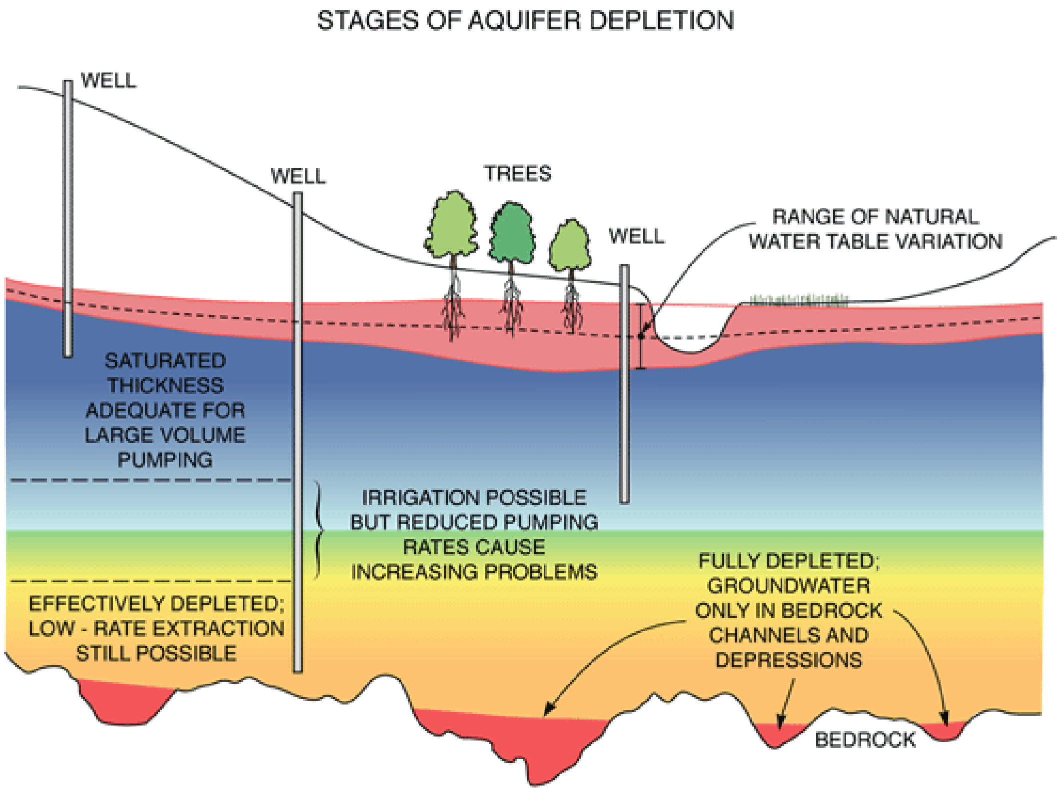


Figure 2: Resource use zones and progressive aquifer exhaustion.

As pumping continues, the rate of local drawdown decreases and eventually stabilizes as the withdrawal is compensated for by inflow of groundwater from the surrounding area. As this happens, the measurable decline in the water table spreads outward. When the groundwater system has adjusted to the pumping, the resulting pattern of water table depression is sometimes referred to as steady-state drawdown; this feature is illustrated in figure 1. The pattern of water table distortion is called the *cone of depression*, and the area over which the depression can be detected is called the *zone of influence* of the well. This zone of influence can easily have dimensions of a mile or more, depending on the characteristics of the aquifer.

Irrigation pumping is the major aquifer stress and the most demanding application, since as normally practiced it requires high single-well withdrawal rates to extract large volumes of water over a limited period of time. This in turn creates large local drawdowns (cones of depression), which therefore require a certain minimum saturate thickness for the pumps to function effectively. Municipal, industrial, or other relatively large-volume uses are not as demanding, because they are intermittent and/or spread more uniformly throughout the year.

6.5 AGUIFIERS:

Aquifers in geological terms are referred to as bodies of saturated rocks or geological formations through which volumes of water find their way (permeability) into wells and springs. Classification of these is a function of water table location within the subsurface, its structure and hydraulic conductivities into two namely; Confined Aquifers and Unconfined Aquifers and then characterized these aquifers.

Aquifers must not only be permeable but must also be porous and are found to include rock types such as sandstones, conglomerates, fractured limestone and unconsolidated sand, gravels and fractured volcanic rocks (columnar basalts). While some aquifers have high porosity and low permeability others have high porosity and high productivity. Those with high porosity and low permeability are referred to as poor aquifers and include rocks or geological formation such as granites and schist while those with high porosity and high permeability are regarded as excellent aquifers and include rocks like fractured volcanic rocks.

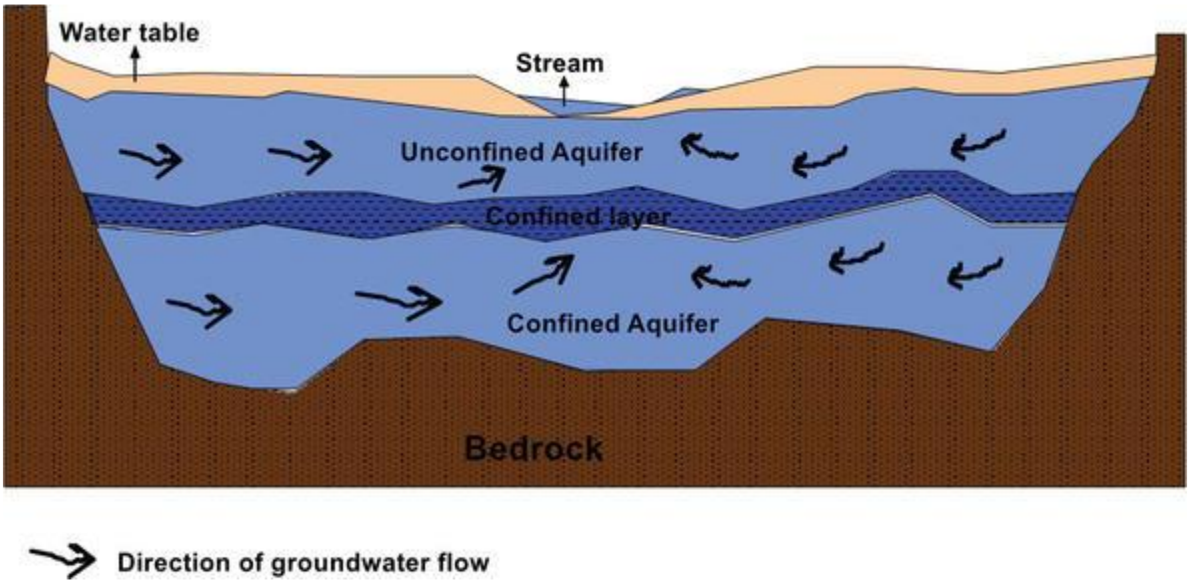
6.5.1 Classification of aquifers

Aquifers are generally been classed into two main categories namely confined aquifer and unconfined aquifers.

6.5.1.1. Confined aquifers

Confined Aquifers are those bodies of water found accumulating in a permeable rock and are been enclosed by two impermeable rock layers or rock bodies. Confined Aquifers are aquifers that are found to be overlain by a confining rock layer or rock bodies, often made up of clay which might offer some form of protection from surface contamination. The geological barriers which are non-permeable and found exist between the aquifer causes the water within it to be under pressure which is comparatively more than the atmospheric pressure. The presence of fractures, or cracks in bedrocks is also capable of bearing water in large openings within bedrocks dissolving some of the rock and accounts for high yields of well in karst terrain counties like Augusta, Bath within Virginia. Groundwater flow through aquifers is either vertically or horizontally at rates often influenced by gravity and geological formations in these areas.

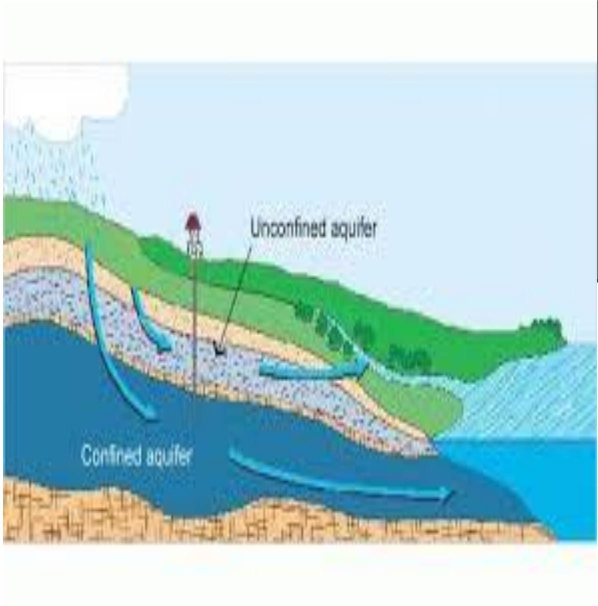
Confined aquifers could also be referred to as "Artesian aquifers" which could be found most above the base of confined rock layers. Punctured wells deriving their sources from artesian aquifers have fluctuation in their water levels due more to pressure change than quantity of stored water. The punctured well serve more as conduits for water transmission from replenishing areas to natural or artificial final points. In terms of storativity, confined aquifers have very low storativity values of 0.01 to 0.0001.

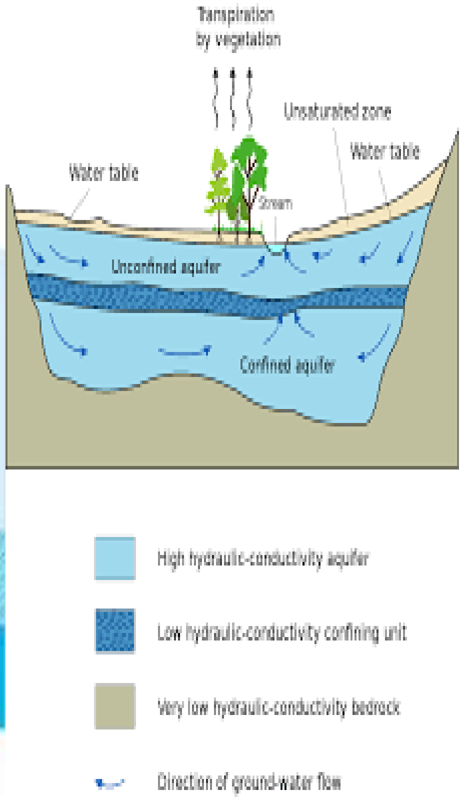


6.5.1.2. Unconfined aquifer

Unconfined Aquifer unlike confined aquifers are generally found located near the land surface and have no layers of clay (or other impermeable geologic material) above the water table although they are found lying relatively above impermeable clay rock layers. The uppermost boundary of groundwater within the unconfined aquifer is the water table, the groundwater in an unconfined aquifer is more vulnerable to contamination from surface pollution as compared to that in confined aquifers this been so due to easy groundwater infiltration by land pollutants. Fluctuation in the level of groundwater varies and depends on the stored up groundwater in the space of the aquifer which in turn affects the rise or fall of water levels in wells that derive their source from aquifers. Unconfined aquifers have a storative value greater than 0.01.

"Perched aquifers" are special cases of unconfined aquifers occurring in situation where groundwater bodies are separated from their main groundwater source by relatively impermeable rock layers of small areal extents and zones of aeration above the main body of groundwater The quantity of water found available in this type of aquifer is usually minute and available for short periods of time.





6.6 Yield of Wells:

It is well known that under the favourable condition water tries to maintain its own level. Hence, it is obvious that the level of water in a well approximately indicates the level of waters table under normal conditions of no withdrawal. As the water is pumped out or withdrawn from the well the level of water in the well falls more quickly than the ground water level and consequently if forms a cone of depression. The difference of level of waters table and the water level in the well now is called a head of depression.

Actually under this head water percolates into the well through soil pores. Naturally when depression head is more the rate of water contribution to the well will also be more. If the depression head goes on increasing, due to continued water withdrawal from the well then a time may come when the increased velocity will dislodge the soil particles. At this stage the percolating water brings soil particles with it in the well.

Naturally this stage is critical and hence various terms, for example, depression head, rate of percolation, (it is also termed yield of well and is expressed in cubic metres per hour or in litres per minute) velocity of percolation are prefixed with the term critical.

It is very essential that the critical depression head should not be allowed to reach or be allowed to exceed for a particular well withdrawal as after that it may create unstable conditions for the well structure. Sufficient margin of safety or a factor of safety should be provided (Generally factor of safety is 3 to 4).

It should be noted now that whenever "yield of well" is referred to, its means maximum safe yield unless otherwise stated. Yield of well is the rate at which water percolates into the well under the safe maximum working head or critical depression head. It is expressed in m^3/hr or It/min. The yield of open well can be determined by any one of the two methods, namely, pumping test and recuperation test.

Pumping Test:

In this method water is withdrawn from the well freely till a critical depression head or a safe maximum head is created. Once this stage is reached the rate of pumping is so adjusted as to maintain the constant water level in the well. Thus the depression head remains constant. Naturally at his stage the rate at which water is pumped out of the well will be equal to the rate at which water percolates into the well. This rate is expressed in m^3/hr or It/min and will be obviously the yield of the well.

Recuperation Test:

In this method water level in the well is depressed by pumping to any level below the normal level. Then the pumping is stopped and time taken by the percolating water to fill the well to any particular level is noted. Total quantity of water percolated into the well is calculated by knowing cross-sectional area and rise in the water level after stoppage of pumping. The rate of percolation or the yield of well can be arrived at by dividing the quantity of water by the time. This test is carried out generally in a driest period to take worst condition into account.

Now it can be inferred that the actual pumping test of determining available yield is most reliable but it is difficult to conduct the test accurately. Whereas recuperation test is very simple to perform but it does not give the maximum safe yield. The reason is as the water level in the well rises the safe maximum working head is not maintained throughout the period of observation.

6.7 Specific Yield of Wells:

Rate of water percolation in the well or yield of a well in m^3/hr under a head of one metre is called the specific yield of the well. From the above definition it is clear that the specific yield depends on: (i) position of the water-table, (ii) permeability and porosity of the soil formation, (iii) the rate of water withdrawal from the well, and (iv) quantity of water storage in the well. Specific yield of the well is also called specific capacity of the well.

1. Strainer Type Tube Wells:

In tube wells the metal pipe driven in ground is perforated to allow only clear water to enter the hole. It is obvious that if no other means is adopted the perforations in the metal tube will have to be made very fine. It is very costly process.

As an alternative wire net may be wrapped on the cylindrical frame of small diameter but it is liable to break as it is very delicate. So the best and most commonly adopted practice is to provide a pipe with fairly big perforations and surrounding that is a wire net or a strainer with smaller openings.

The wire net with finer openings excludes the objectionable soil particles from entering the tube well. Total area of the openings in the metal tube and in the strainer is kept the same. This is because if the area of opening is same the velocity of inflow will be the same.

Moreover there is some annular space left between the perforated metal tube and the strainer. If the space is not left the strainer may rest directly over the tube and consequently the open area of perforations will be reduced.

Normally the mesh size of the wire net or strainer is kept equal to D_{60} to D_{70} of the surrounding soil. This type of well derives water from one aquifer of unlimited extent or from a confined aquifer or from number of aquifers.

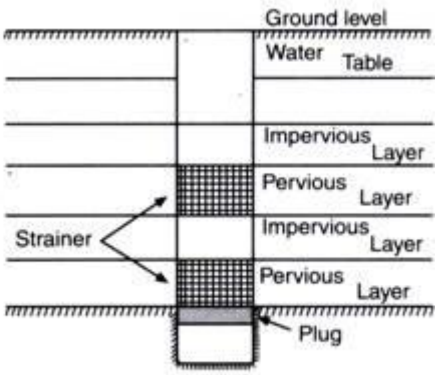


Fig. 18.1. Strainer type tubewell

The perforated pipe extends only for the aquifer portions of the formation while for other portion the pipe is kept plain. At the bottom a tube well is plugged. The plug is kept a little above the bottom. This procedure prevents failure of the plug due to the weight of the well. The strainer type tube well is normally suitable and therefore very widely used. When a term tube well is used it refers to strainer well unless otherwise stated.

2. Cavity Type Tube Well:

In this type water contribution to bore hole takes place through the bottom layer only. It is clear that in principle it is similar to the category of the deep wells under open wells.

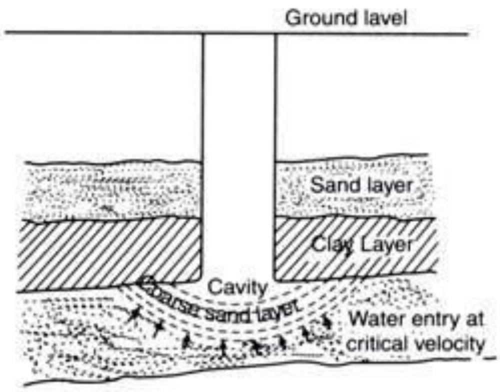


Fig. 18.2. Cavity type tubewell

It derives water from the previous layer underlying the hard impervious layer. The tube well is taken down till it penetrates the impervious or mota layer and reaches the water bearing layer. In the initial stages when the water is pumped out fine sand comes in the tube well with the water and consequently a hollow or cavity is formed at the bottom. The bottom of the cavity for some thickness is thus made free of finer particles.

After the cavity formation only clear water enters the tube well. Since the rate of pumping is more, the velocity of water entering the coarse sand layer is critical but when it comes in the hollow the velocity is reduced. Finally the water enters the tube well at the bottom with a velocity lower than the critical velocity. The main difference between a strainer and cavity tube well is that in the former the inflow is radial whereas in the later it is spherical.

3. Slotted Type Tube well:

Sometimes the nature of subsoil formation is not anticipated correctly. Obviously bore hole driven for constructing strainer well will be a failure. If a mota formation is present cavity well may be resorted to. But if neither of the conditions are existing the slotted tube well can be rightly constructed. There should be of course an aquifer present at the bottom. In the bore hole (say 36 cm diameter) a 15 cm diameter education pipe is lowered till it reaches the bottom. The bottom of the education pipe is slotted

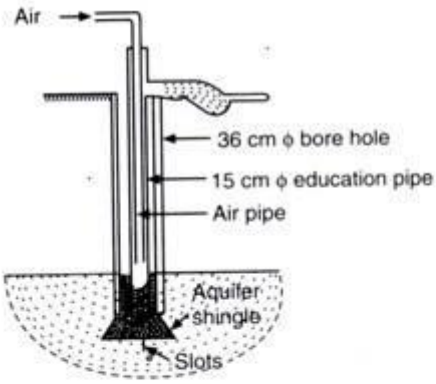


Fig. 18.3. Slotted type tubewell

The size of the slots may be 25 mm x 3 mm with 12 mm spacing. As the slots are quite wide, to avoid sand entry in the pipe a filter of shingle is provided at bottom, surrounding the slotted pipe portion. Finally before withdrawing the 36 cm diameter pipe casing the shingle is poured in the annular space between the education pipe and the casing pipe. The development of this well is done gradually with the compressed air. Thus the slotted tube well, unlike strainer well receives inflow only at bottom through shingle shrouding.

6.8 Boring Methods of Exploration

The boring methods are used for exploration at greater depths where direct methods fail. These provide both disturbed as well as undisturbed samples depending upon the method of boring. In selecting the boring method for a particular job, consideration should be made for the following:

- The materials to be encountered and the relative efficiency of the various boring methods in such materials

- The available facility and accuracy with which changes in the soil and ground water conditions can be determined
- Possible disturbance of the material to be sampled

The different types of boring methods are:

1. Displacement boring
2. Wash boring
3. Auger boring
4. Rotary drilling
5. Percussion drilling
6. Continuous sampling

1. Displacement Boring

It is combined method of sampling & boring operation. Closed bottom sampler, slit cup, or piston type is forced in to the ground up to the desired depth. Then the sampler is detached from soil below it, by rotating the piston, & finally the piston is released or withdrawn. The sampler is then again forced further down & sample is taken. After withdrawal of sampler & removal of sample from sampler, the sampler is kept in closed condition & again used for another depth.

Features

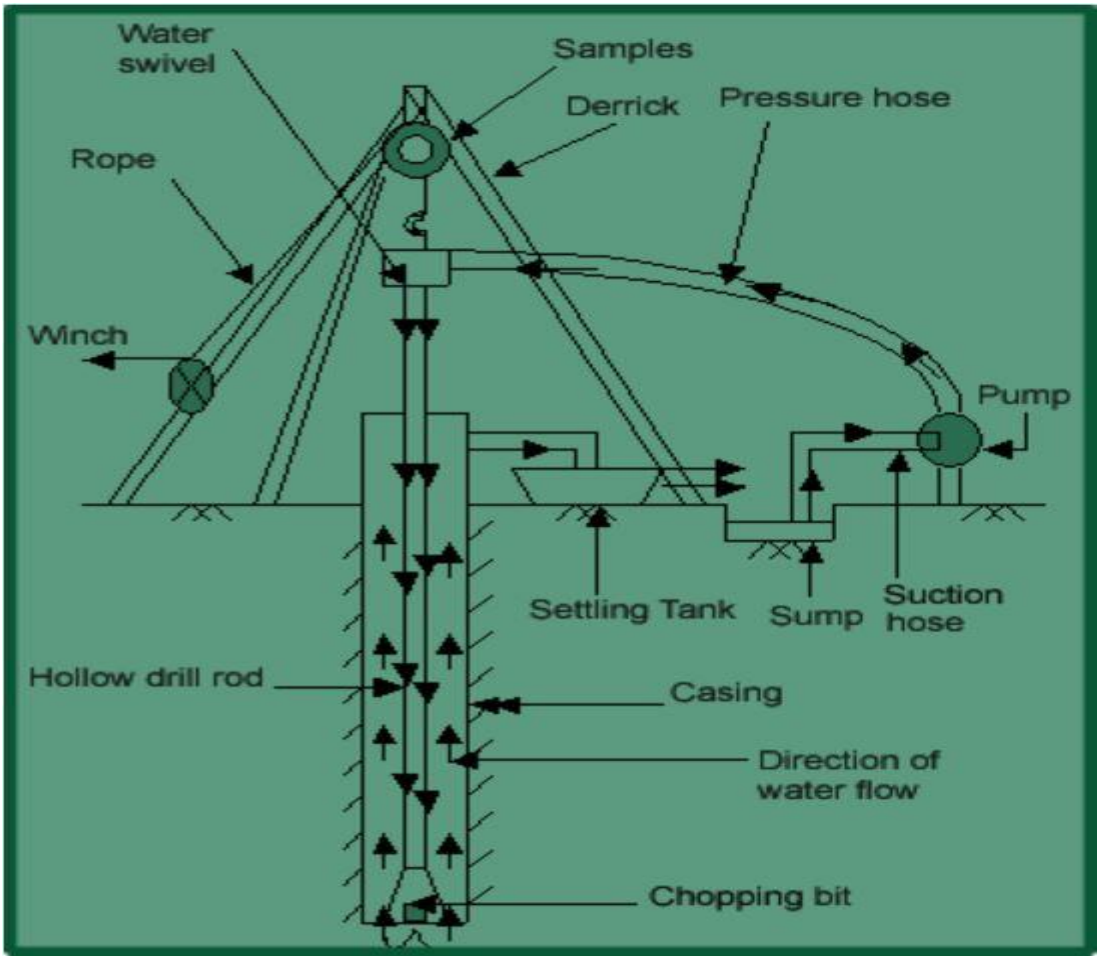
- Simple and economic method if excessive caving does not occur. Therefore not suitable for loose sand.
- Major changes of soil character can be detected by means of penetration resistance.
- These are 25mm to 75mm holes.
- It requires fairly continuous sampling in stiff and dense soil, either to protect the sampler from damage or to avoid objectionably heavy construction pit.

2. Wash Boring

It is a popular method due to the use of limited equipments. The advantage of this is the use of inexpensive and easily portable handling and drilling equipments. Here first an open hole is formed on the ground so that the soil sampling or rock drilling operation can be done below the hole. The hole is advanced by chopping and twisting action of the light bit. Cutting is done by forced water and water jet under pressure through the rods operated inside the hole.

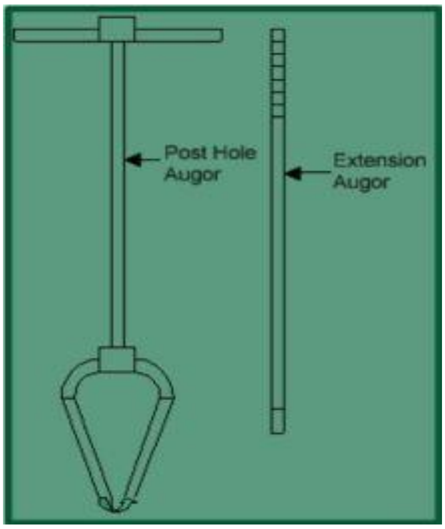
In India the “Dheki” operation is used, i.e., a pipe of 5cm diameter is held vertically and filled with water using horizontal lever arrangement and by the process of suction and application of pressure, soil slurry comes out of the tube and pipe goes down. This can be done upto a depth of 8m –10m (excluding the depth of hole already formed beforehand).

Just by noting the change of colour of soil coming out with the change of soil character can be identified by any experienced person. It gives completely disturbed sample and is not suitable for very soft soil, fine to medium grained cohesionless soil and in cemented soil.



Wash Boring

3. Auger Boring



Augers

This method is fast and economical, using simple, light, flexible and inexpensive instruments for large to small holes. It is very suitable for soft to stiff cohesive soils and also can be used to determine ground water table.

Soil removed by this is disturbed but it is better than wash boring, percussion or rotary drilling.

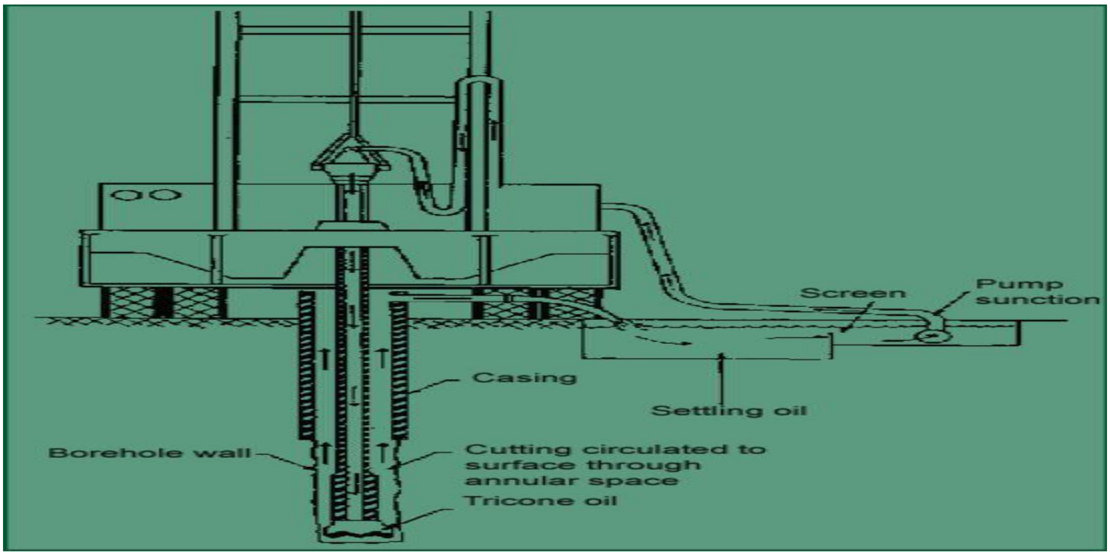
This method of boring is not suitable for very hard or cemented soils, very soft soils, as then the flow into the hole can occur. This method is also not suitable for fully saturated cohesionless soil.

4. Rotary Drilling

Rotary drilling method of boring is useful in case of highly resistant strata. It is related to finding out the rock strata and also to access the quality of rocks from cracks, fissures and joints. It can conveniently be used in sands and silts also. Here, the bore holes are advanced in depth by rotary percussion method which is similar to wash boring technique. A heavy string of the drill rod is used for choking action. The broken rock or soil fragments are removed by circulating water or drilling mud pumped through the drill rods and bit up through the bore hole from which it is collected in a settling tank for recirculation. If the depth is small and the soil stable, water alone can be used. However, drilling fluids are useful as they serve to stabilize the bore hole.

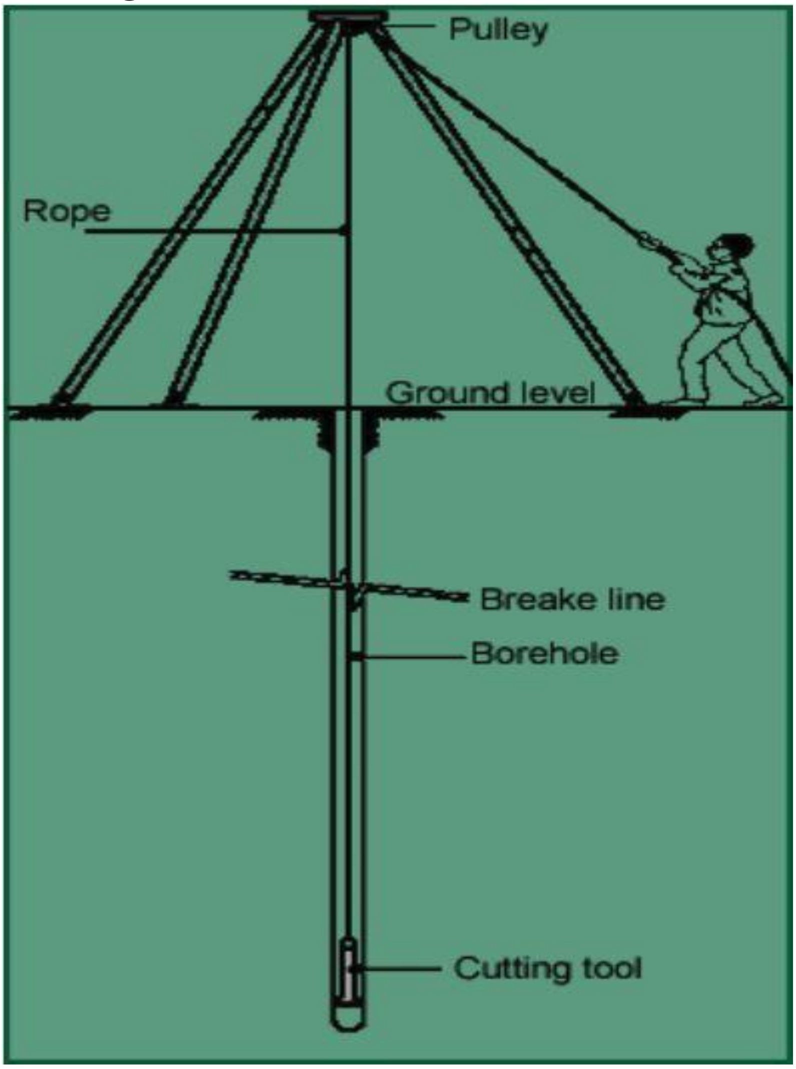
Drilling mud is slurry of bentonite in water. The drilling fluid causes stabilizing effect to the bore hole partly due to higher specific gravity as compared with water and partly due to formation of mud cake on the sides of the hole. As the stabilizing effect is imparted by these drilling fluids no casing is required if drilling fluid is used.

This method is suitable for boring holes of diameter 10cm, or more preferably 15 to20cm in most of the rocks. It is uneconomical for holes less than 10cm diameter. The depth of various strata can be detected by inspection of cuttings.



Rotary Drilling System

5. Percussion Drilling



Percussion Drilling

In case of hard soils or soft rock, auger boring or wash boring cannot be employed. For such strata, percussion drilling is usually adopted. Here advancement of hole is done by alternatively lifting and dropping a heavy drilling bit which is attached to the lower end of the drilling bit which is attached to the cable.

Addition of sand increases the cutting action of the drilling bit in clays. Whereas, when coarse cohesionless soil is encountered, clay might have to be added to increase the carrying capacity of slurry.

After the carrying capacity of the soil is reached, churn bit is removed and the slurry is removed using bailers and sand pumps. Change in soil character is identified by the composition of the outgoing slurry.

The stroke of bit varies according to the ground condition. Generally, it is 45-100cm in depth with rate of 35-60 drops/min.

It is not economical for hole of diameter less than 10cm. It can be used in most of the soils and rocks and can drill any material.

One main disadvantage of this process is that the material at the bottom of the hole is disturbed by heavy blows of the chisel and hence it is not possible to get good quality undisturbed samples. It cannot detect thin strata as well.

6. Continuous Sampling

The sampling operation advances the borehole and the boring is accomplished entirely by taking samples continuously. The casing is used to prevent the caving in soils. It provides more reliable and detail information on soil condition than the other methods. Therefore it is used extensively in detailed and special foundation exploration for important structures.

It is slower method and more expensive than intermittent sampling. When modern rotary drilling rigs or power driven augers are not available, continuous sampling may be used to advantage for advancing larger diameter borings in stiff and tough strata of clay and mixed soil.

In the Boston district, corps of Engineers has made faster progress and reduced cost by use of continuous sampling in advancing 3-inch diameter borings through compact gravelly glacial till, which is difficult to penetrate by any boring method.

6.9 Importance of Water Harvesting

Rainwater harvesting, in its broadest sense, is a technology used for collecting and storing rainwater for human use from rooftops, land surfaces or rock catchments using simple techniques such as jars and pots as well as engineered techniques. Rainwater harvesting has been practiced for more than 4,000 years, owing to the temporal and spatial variability of rainfall. It is an important water source in many areas with significant rainfall but lacking any kind of conventional, centralised supply system. It is also a good option in areas where good quality fresh surface water or ground water is lacking. Water harvesting enables efficient collection and storage of rainwater, makes it accessible and substitute for poor quality water. There are a number of ways by which water harvesting can benefit a community.

- Improvement in the quality of ground water,
- Rise in the water levels in wells and bore wells that are drying up,
- Mitigation of the effects of drought and attainment of drought proofing,
- An ideal solution in areas having inadequate water resources,
- Reduction in the soil erosion as the surface runoff is reduced,
- Decrease in the choking of storm water drains and flooding of roads and
- Saving of energy to lift ground water.

6.9.1Types of Water Harvesting

Rainwater Harvesting: Rainwater harvesting is defined as the method for inducing, collecting, storing and conserving local surface runoff for agriculture in arid and semi-arid regions. Three types of water harvesting are covered by rainwater harvesting.

- Water collected from roof tops, courtyards and similar compacted or treated surfaces is used for domestic purpose or garden crops.
- Micro-catchment water harvesting is a method of collecting surface runoff from a small catchment area and storing it in the root zone of an adjacent infiltration basin. The basin is planted with a tree, a bush or with annual crops.
- Macro-catchment water harvesting, also called harvesting from external catchments is the case where runoff from hill-slope catchments is conveyed to the cropping area located at foothill on flat terrain.

Flood Water Harvesting: Flood water harvesting can be defined as the collection and storage of creek flow for irrigation use. Flood water harvesting, also known as 'large catchment water harvesting' or 'Spate Irrigation', may be classified into following two forms:

- In case of 'flood water harvesting within stream bed', the water flow is dammed and as a result, inundates the valley bottom of the flood plain. The water is forced to infiltrate and the wetted area can be used for agriculture or pasture improvement.
- In case of 'flood water diversion', the wadi water is forced to leave its natural course and conveyed to nearby cropping fields.

Groundwater Harvesting: Groundwater harvesting is a rather new term and employed to cover traditional as well as unconventional ways of ground water extraction. Qanat systems, underground dams and special types of wells are a few examples of the groundwater harvesting techniques. Groundwater dams like 'Subsurface Dams' and 'Sand Storage Dams' are other fine examples of groundwater harvesting. They obstruct the flow of ephemeral streams in a river bed; the water is stored in the sediment below ground surface and can be used for aquifer recharge.

6.10 Runoff vs. Flood Water Harvesting

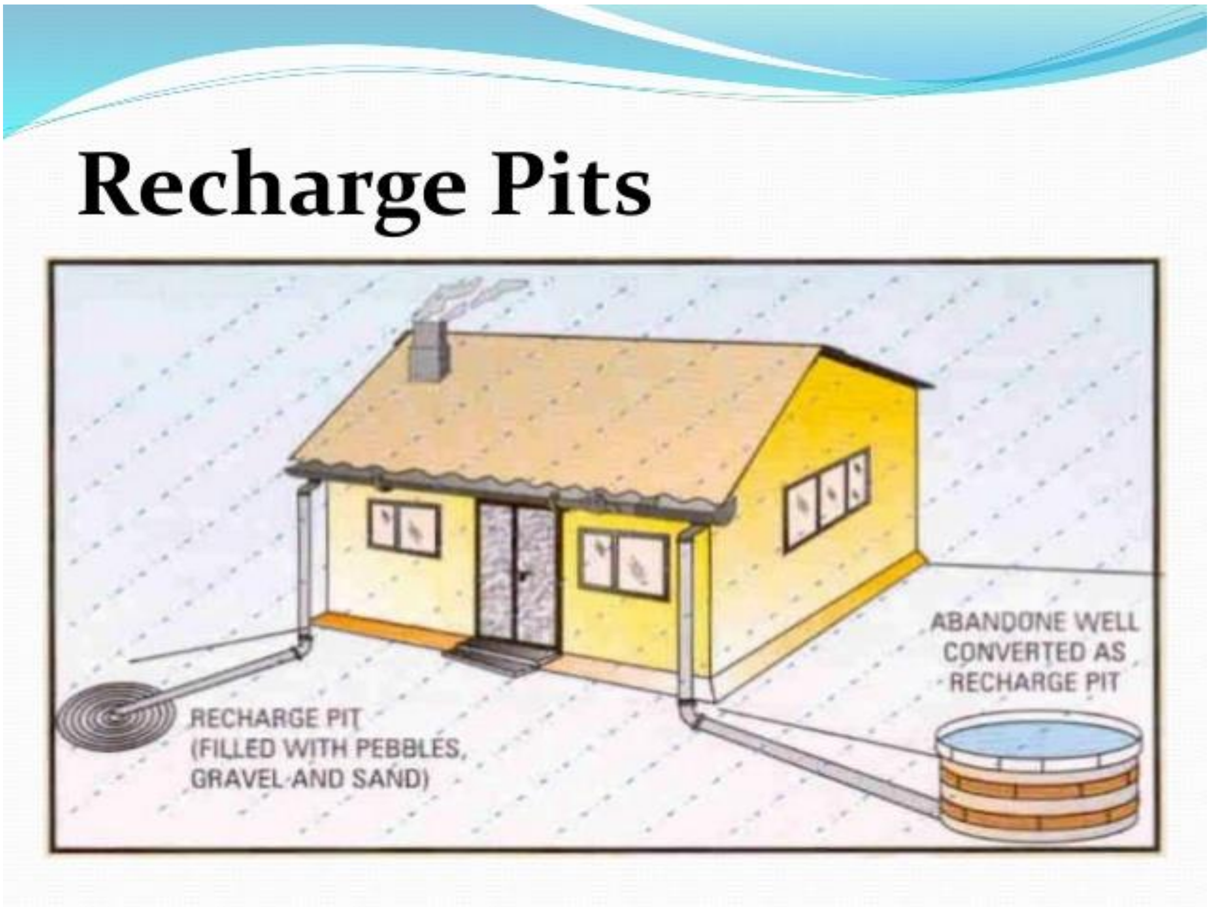
- Water harvesting techniques which harvest runoff from roofs or ground surfaces fall under the term rainwater harvesting while all systems which collect discharges from watercourses are grouped under the term flood water harvesting.
- Runoff harvesting increases water availability for on-site vegetation while flood waters harvesting provide a valuable source of water to local and downstream water users and play an important role in replenishing floodplains, rivers, wetlands and groundwater.
- Runoff harvesting reduces water flow velocity, as well as erosion rate and controls siltation problem while in flood water harvesting**,** floodwater enters into the fields through the inundation canals, carrying not only rich silt but also fish which can swim through the canals into the lakes and tanks to feed on the larva of mosquitoes.

6.11 Recharge Pits

Our country is rich in resources. The prevalence of different meteorological and climatic conditions supports various species of plants and animal life including human beings. Being the smartest among animal kingdom, we humans have taken out the ways of using the resources to its maximum. And since we are getting very large in numbers, our efforts have led to the overuse or rather exploitation of natural resources. Groundwater is one natural resource which is being taken for granted.

Groundwater is the water that percolates into the land. The replenishing sources of the groundwater are the flowing river streams or lakes or the rainwater. The quality of sand and the vegetation or trees in the area controls the amount of water that can be absorbed by the ground, replenishing the lost groundwater aquifers. With the loss of both- the quality of sand and the vegetation, the land is struggling to get enough water for percolation. The extraction of this low quantity groundwater through handpumps and borewells have worsened the condition. This calls for the measure called ***artificial groundwater recharge.***

Amongst many methods, use of recharge pits for artificially recharging dewatered aquifers, is popular.



Recharge Pit- Selection of the Site

Recharge pits are closed well like structure, which is covered by filling the stones, after digging the land to make a pit.

The pit, if aimed for recharging the borewell, must be constructed near the borewell, as close as possible. In another case, the selection of the site becomes the most important step in the construction of recharge pit.

The site is well suited if:

- It has a sufficiently clean and large catchment area
- The location permits fast infiltration and percolation of water
- In a more ideal situation, it is in the valley of the surface layout

The infiltration offered by the selected location further depends upon:

- The depth of groundwater – the lower the better
- Soil surface
- Underlying soil type – offering high percolation rate

The groundwater recharge by constructing recharge pit is best practice to be followed in alluvial areas where there are exposed permeable rocks on the land surface or at the shallow depth.

6.11.1 Construction of Recharge Pit

Recharge pit can be constructed with any shape and size. Its size should remain proportional to rainwater catchment area, but the ideal size is considered to be 1-2 meters wide and 2-3 meters deep. The percolation rate of the soil also contributes towards the size of the recharge pit.

The excavation of the identified site is continued till a layer of porous soil or weathered rock or fracture is reached.

Backfilling

The excavated recharge pit once dug, is ready to be filled with jelly and sand. Jellies of different sizes are arranged at the bottom of the pit, which forms a large gap to allow water to pass through them. The smaller sized jellies are put on the top so that they could support the top layer of sand. A mesh between the layer of sand (for covering the top of the pit) and small-sized jellies is helpful in preventing the sand from escaping at the bottom of the pit.

The leaves, planted earth or a layer of soil can also be used for covering the top of the pit. They are equally able to filter the water.

It was observed that the rate of recharge increases as the side slope of the pit is increased.

6.11.2 Maintenance of the Recharge Pit

To ensure the recharge pit continues to perform its function, proper monitoring must be performed, and timely cleaning should be scheduled.

- The unfiltered runoff water deposits a thin film of sediments on the walls and bottom of the pit. Clean the pit for such deposition.
- The recharge pit can be backfilled with boulders (5-20 cm) at the bottom, gravels (5-10mm) in between and coarse sand (1.5- 2mm) in graded form at the top. The coarse sand layer helps in absorbing the silt that comes with runoff water, thus preventing its further deposition.
- Install a mesh at the rooftop catchment area to prevent debris and other solid wastes from going into the pit.
- The top layer of the sand must be cleaned periodically, for having a maintained rate of recharge.

INTERNATIONAL INSTITUTE OF TECHNOLOGY & MANAGEMENT, MURTHAL SONEPAT

E-NOTES

SUBJECT: IRRIGATION **SUBJECT CODE: -**

COURSE- DIPLOMA **BRANCH: CIVIL ENGINEERING**

SEMESTER 4TH **CHAPTER NAME: DAMS AND RESERVOIR**

(PREPARED BY: Mr. ANKUR CHAUHAN, LECTURER, CE)

7.1 GENERAL:

DAMS AND RESERVOIRS NORMALLY THOUGH NOT NECESSARILY GO TOGETHER. WHEN A BARRIER IS CONSTRUCTED ACROSS THE RIVER WITH A VIEW TO FORMING A RESERVOIR, SUCH A BARRIER IS TERMED AS A DAM.

7.2 Types of Dams in Construction

7.2.1 Classification Based on Construction Material used for a Dam

Rigid Dam

A dam is said to be Rigid Dam if it is constructed using rigid construction materials such as masonry, concrete, steel, timber etc. The basic shape of rigid dam is triangular. Rigid dams constructed using different rigid materials are discussed below.

1. Masonry Dam

Masonry dams are built using either stone masonry or brick masonry. Cement mortar is used to join the masonry blocks. Gravity dam, arch dam etc. are examples of masonry dams.

Fig 1: Nagarjuna Sagar Masonry Dam, India

2. Concrete Dam

Concrete is most commonly used material to construct a dam. Most of the major dams in the world are built using concrete. Gravity dams, arch dam, Buttress dam etc. can be constructed using concrete.

Fig 2: Three Gorges Concrete Dam, China

3. Timber Dam

Timber dams generally used for temporary purposes such as to divert the water for the construction of main dam, to control flood water flow etc. Timber dams are suitable up to 9 meters height.

Fig 3: Timber Dam

4. Steel Dam

Steel dams are also used for temporary requirements like timber dams. Steel plates and inclined struts are used for the construction of steel dam. This type of dams are suitable up to 15 to 18 meters of height.

Fig 4: Redridge Steel Dam, USA

Non-Rigid Dam

Non-rigid dams are constructed using non rigid materials such as earth, rocks etc. Basic shape of non-rigid dam Trapezoidal. Non-rigid dams of different materials are

- Earthen Dams
- Rock Fill Dams

5. Earthen Dam

Earthen dams are made of ordinary soil which is cheaply available. This type of dams are suitable where the foundation soil is very weak and not strong enough to carry the weight of masonry dam. Since it is constructed using soil the cost of construction is very less compared to rigid type dam.

Fig 5: Earthen Dam

6. Rock Fill Dam

Rock fill dams are constructed using rocks and boulders. Upstream side of dam is built with dry rubble masonry and loose rock fill is provided on the downstream side. A reinforced concrete slab layer is also provided on the upstream side to make it water tight.

It is more stable than earthen dams and its flexible nature helps it better against earthquake forces.

Fig 6: Damghan Rock-fill Dam, Iran

7.2.2 Classification Based on Structure and Design of a Dam

Depending upon structure and design dams are classified into

- Gravity dam
- Arch dam
- Buttress dam
- Embankment dam

7. Gravity Dam

A Gravity dam is a structure which resists the external forces by its own weight or self-weight. Gravity dams are generally constructed by using masonry or concrete.

Various external forces like water pressure, uplift pressure, wave pressure, ice pressure, earth quake pressure etc. are resisted by its self-weight only which acts vertically downwards. So, good foundation is required to construct gravity dam preferably rocky strata under the dam.

The shape of cross section of gravity dam is approximately triangular in shape. Infiltration gallery can be provided within the dam to resist uplift pressure. The failure of gravity dam may occurs due to sliding, overturning or crushing at toe. Hence, higher factor of safety is recommended for the design of gravity dam.

Fig 7: Grand Coulee Gravity Dam, USA

8. Arch Dam

An arch dam is curved in plan with its convex upstream. Various forces coming onto the dam are resisted by its arch action. It is constructed using masonry or concrete but requires less material compared to gravity dam.

The loads coming onto the dam are transferred to the abutments of dam. So, abutments must be stronger and generally natural formations like hills are used as abutments. Arch dams are generally preferred for narrow valleys.

Arch dam is economical when the length of dam is less than its height. So, this type of dams can be build up to greater heights.

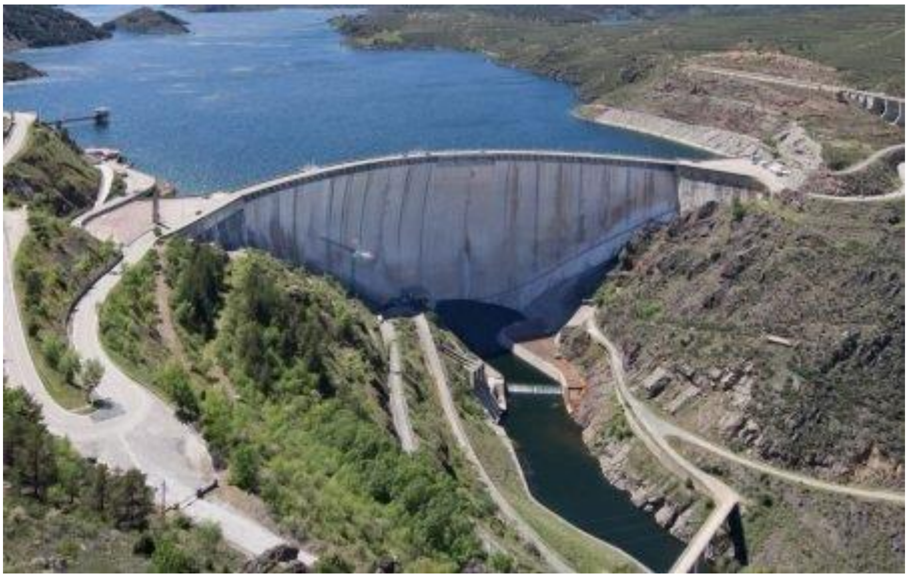


Fig 8: El Atazar Arch Dam, Spain

9. Buttress Dam

A buttress dam contains face slab, buttresses and base slab. Face slab is provided on the upstream side with some inclination and this slab is supported by series of buttresses which are nothing but supports. Base slab acts as foundation for the whole dam which receives the load from buttresses and face slab.

Buttress dam is either straight or curved in plan. Greater the height of dam higher the number of buttresses. This type of dams are preferred where the foundation soil is very weak. The space available between the buttresses can used for several purposes like water treatment plant installation, power plant installation etc.

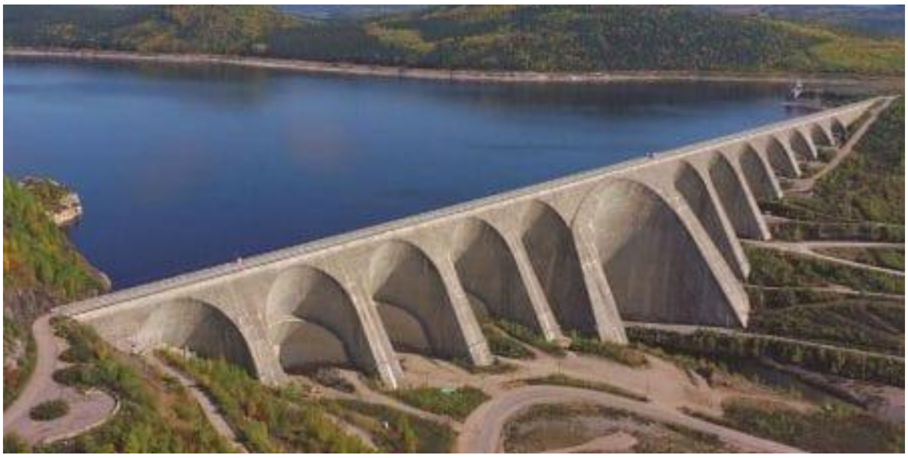


Fig 9: The Daniel-Johnson Buttress Dam, Canada

10. Embankment Dam

Embank dam is made of soil or rocks. This type of dams are come under non rigid type dams. Embankment dams are again classified into three different types

- Homogeneous Embankment Type Dam
- Zoned Embankment Type Dam
- Diaphragm Embankment Dam

Homogeneous Embankment Type Dam

If the dam is constructed using only one type of soil then it is called as homogeneous embankment type dam. But homogeneity of soil makes the dam pervious and allow seepage of water through the dam. To overcome this stone pitching is recommended on the upstream side.

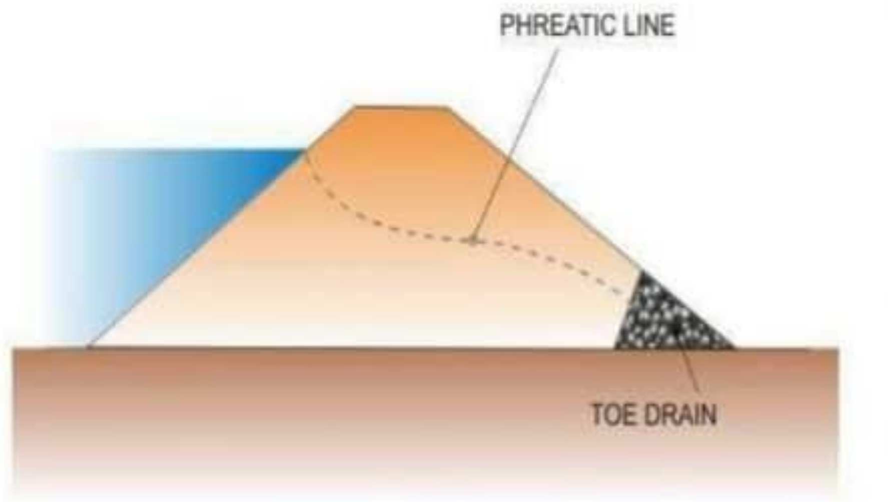


Fig 10: Homogeneous Embankment Dam

Zoned Embankment Type Dam

Zoned embankment dam consists an impervious soil zone inside the pervious soil layer. Clay or silt or mixture of clay and silt is used to make the impervious zone. Ordinary soil is used for make the previous outer layer.

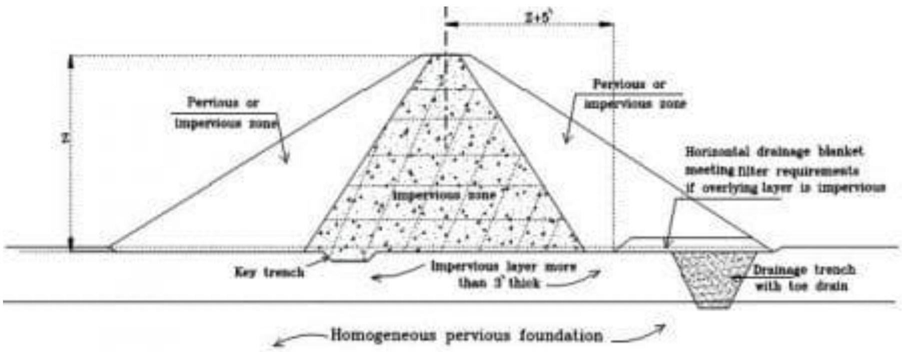


Fig 11: Zoned Embankment Dam

Diaphragm Embankment Dam

Diaphragm embankment dam consists a diaphragm inside the earthen dam and it is made of impervious soils or concrete or steel or timber. This diaphragm prevents the seepage of water through dam section.

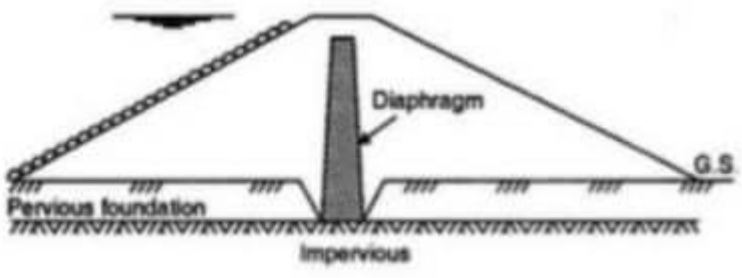


Fig 12: Diaphragm Embankment Dam

7.2.3 Classification Based on Functions of a Dam

Based on Functions Dams are classified into

- Storage dam
- Diversion Dam
- Detention Dam
- Debris dam
- Coffer dam

11. Storage Dam

Storage dam is constructed to store water on the upstream side especially during rainy seasons and is released during dry weather season or when there is higher demand of water. The stored water can also be used to generate power, irrigation, water supply etc.

Fig 13: Storage Arch Dam

12. Diversion Dam

Diversion dam is a dam which is constructed to divert the flow of water into other channel or canal. This type dams are generally used to fill the irrigation channels.

Fig 14: Granite Reef Diversion Dam, USA

13. Detention Dam

The main purpose of Detention dam is to control floods. During flood period, it stores the water and protects the downstream side from damage due to floods. After the flood period the stored water is released at a controlled rate without effecting the downstream side.

14. Debris Dam

Debris dam is built to retain the debris of the river water. Sand, gravel, driftwood etc. are debris generally flow with river water. The water on the downstream side of debris dam is clear.

Fig 15: Mono Debris Dam, USA

15. Cofferdam

Cofferdam is temporary structure which generally acts like diversion dam. Cofferdam provides dry area for the construction of main dam by diverting the water flow into other watercourse. It is constructed on upstream side or fully around the construction site.

Fig 16: Coffer Dam

16. Hydro-power Dam

Hydro-power dam is used to generate electricity by rotating turbines with the help of water falling from upstream side to downstream side of dam.

Fig 17: Cheruthoni Hydropower Dam, India

7.2.4 Classification Based on Hydraulic Design of Dam

Based on hydraulic design dams are classified into 2 types as follows

- Overflow dam
- Non-overflow dam

17. Overflow Dam

Overflow dam is a dam which allows the water over its crest when surplus water is flowing on the upstream side. This is also called as spillway dam or over fall dam.

Fig 18: Canyon Lake Dam, USA

18. Non-Overflow Dam

A dam which do not allow the surplus water to overflow over its crest. But in general spillway is provided for any type dam to release the excess water from upstream side.

Fig 19: Non-overflow Dam

7.2.5 Classification Based on Gross Storage of Dam

Dams are classified into three types based on gross storage capacity of dam and they are

- Small Dam
- Medium Dam
- Large Dam

19. Small Dam

A dam is called as small dam if its gross storage capacity is in between 0.5 to 10 MCM (million cubic meters). Hydraulic head of small dam is generally about 7.5 to 12 meters.

Fig 20: Small Dam

20. Medium Dam

If gross storage capacity of a dam is in between 10 to 60 MCM then it is said to be medium storage dam. Its hydraulic head is 12 to 30 meters.

Fig 21: Medium Dam

21. Large Dam

A dam is said to be large dam if its gross storage capacity is above 60 MCM. Hydraulic head of a large dam is greater than 30 meters.

Fig 22: Large Dam

7.3 Earthen Dam:

An earthen embankment is a raised confining structure made from compacted soil. The purpose of an earthen embankment is to confine and divert the storm water runoff. It can also be used for increasing infiltration, detention and retention facilities. Earthen embankments are generally trapezoidal in shape and most simple and economic in nature. They are mainly built with clay, sand and gravel, hence they are also known as earth fill dams or earthen dams. They are constructed where the foundation or the underlying material or rocks are weak to support the masonry dam or where the suitable competent rocks are at greater depth. They are relatively smaller in height and broader at the base.

7.3.1 Components of An Earthen Dam

The various components of an earthen dam are shown in Fig.

Shell, Upstream Fill, Downstream Fill or Shoulder: These components of the earthen dam are constructed with pervious or semi-pervious materials upstream or downstream of the core. The upstream fill is called the upstream shell and the downstream portion is the downstream shell.

Upstream Blanket: It is a layer of impervious material laid on the upstream side of an earthen dam where the substratum is pervious, to reduce seepage and increase the path of flow. The blanket decreases both the seepage flow and excess pressure on the downstream side of the dam. A natural blanket is a cover of naturally occurring soil material of low permeability.

Drainage Filter: It is a blanket of pervious material constructed at the foundation to the downstream side of an earthen dam, to permit the discharge of seepage and minimize the possibility of piping failure.

Cutoff Wall or Cutoff: It is a wall, collar or other structure intended to reduce percolation of water through porous strata. It is provided in or on the foundations.

Riprap: Broken stones or rock pieces are placed on the slopes of embankment particularly the upstream side for protecting the slope against the action of water, mainly wave action and erosion.

Core Wall, Membrane or Core: It is a centrally provided fairly impervious wall in the dam. It checks the flow of water through the dam section. It may be of compacted puddled clay, masonry, or concrete built inside the dam.

Toe Drain: It is a drain constructed at the downstream slope of an earthen dam to collect and drain away the seepage water collected by the drain filters.

Transition Filter: It is a component of an earthen dam section which is provided with core and consists of an intermediate grade of material placed between the core and the shells to serve as a filter and prevent lateral movement of fine material from the core.

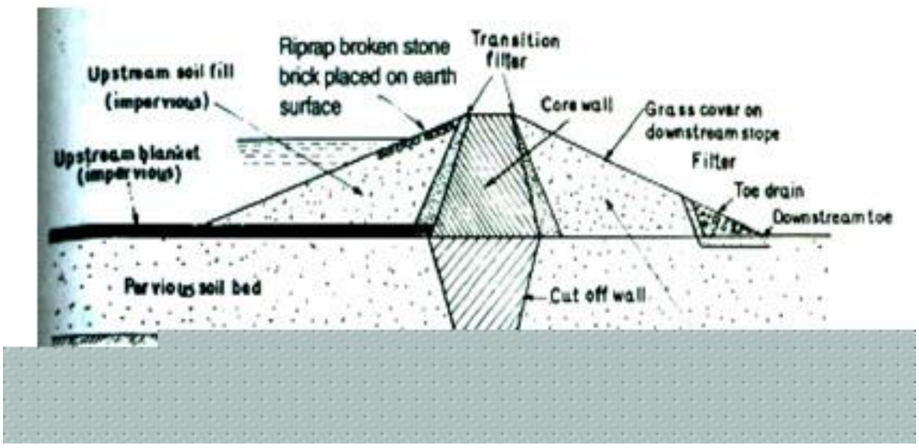


Fig. Cross-section of an Earthen Dam with Various Components.

7.3.2 Advantages

- Design procedures are straightforward and easy.
- Local natural materials are used.
- Comparatively small establishment and equipment are required.
- Earth fill dams resist settlement and movement better than more rigid structures and can be more suitable for areas where earth movements are common.

7.3.2 Disadvantages

- An earthen embankment is easily damaged or destroyed by water flowing on, over or against it. Thus, a spillway and adequate upstream protection are essential for any earthen dam.
- Designing and constructing adequate spillways is usually the most technically difficult part of any dam building work. Any site with a poor quality spillway should not be used.
- If it is not adequately compacted during construction, the dam will have weak structure prone to seepage.
- Earthen dams require continual maintenance to prevent erosion, tree growth, subsidence, animal and insect damage and seepage.

7.4 Types of Earthen Dam

1. Based on the method of construction:

(a) Rolled Fill Earthen Dams: In this type of dams, successive layers of moistened or damp soils are placed one above the other. Each layer not exceeding 20 cm in thickness is properly consolidated at optimum moisture content maintained by sprinkling water. It is compacted by a mechanical roller and only then the next layer is laid.

(b) Hydraulic Fill Earthen Dam: In this type of dams, the construction, excavation and transportation of the earth are done by hydraulic methods. Outer edges of the embankments are kept slightly higher than the middle portion of each layer. During construction, a mixture of excavated materials in slurry condition is pumped and discharged at the edges. This slurry of excavated materials and water consists of coarse and fine materials. When it is discharged near the outer edges, the coarser materials settle first at the edges, while the finer materials move to the middle and settle there. Fine particles are deposited in the central portion to form a water tight central core. In this method, compaction is not required.

2. Based on the mechanical characteristics of earth materials used in making the section of dam:

(a) Homogeneous Earthen Dams: It is composed of one kind of material (excluding slope protection). The material used must be sufficiently impervious to provide an adequate water barrier, and the slopes must be moderately flat for stability and ease of maintenance (Fig.).

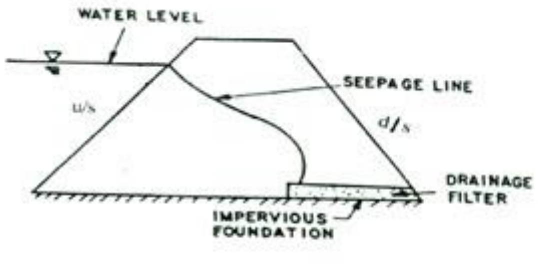


Fig. Homogenous Earthen Dam. (Source: Michael and Ojha, 2012)

(b) Zoned Earthen Dams: It contains a central impervious core, surrounded by zones of more pervious material, called shells. These pervious zones or shells support and protect the impervious core

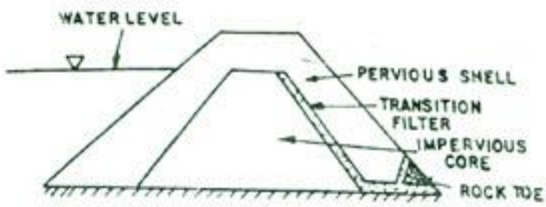


Fig. Zoned Earthen Dam. (Source: Michael and Ojha, 2012)

(c) Diaphragm Earthen Dam: This type of dam (Fig. 11.4) is a modified form of homogenous dam which is constructed with pervious materials, with a thin impervious diaphragm in the central part to prevent seepage of water. The thin impervious diaphragm may be made of impervious clayey soil, cement concrete or masonry or any impervious material. The diaphragm can be constructed in the central portion or on the upstream face of the dam. The main difference in zoned and diaphragm type of dams depends on the thickness of the impervious core or diaphragm. The thickness of the diaphragm is not more than 10 m.

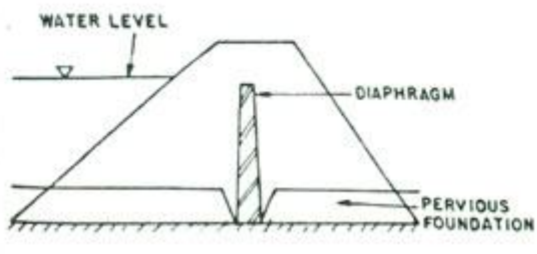


Fig. Diaphragm Earthen Dam. (Source: Michael and Ojha, 2012)

7.6 Design Criteria

Following main design criteria may be laid down for the safety of an earth dam:

1. To prevent hydraulic failures the dam must be so designed that erosion of the embankment is prevented. For this purpose, the following steps should be followed:

(a) Spillway capacity is sufficient to pass the peak flow.

(b) Overtopping by wave action at maximum water level is prevented.

(c) The original height of structure is sufficient to maintain the minimum safe freeboard after settlement has occurred.

(d) Erosion of the embankment due to wave action and surface runoff does not occur.

(e) The crest should be wide enough to withstand wave action and earthquake shock.

2. To prevent the failures due to seepage:

(a) Quantity of seepage water through the dam section and foundation should be limited.

(b) The seepage line should be well within the downstream face of the dam to prevent sloughing.

(c) Seepage water through the dam or foundation should not remove any particle or in other words cause piping.

(d) There should not be any leakage of water from the upstream to the downstream face. Such leakage may occur through conduits, at joints between earth and concrete sections or through holes made by aquatic animals.

3. **To prevent structural failures:**

(a) The upstream and downstream slopes of the embankment should be stable under all loading conditions to which they may be subjected including earthquake.

(b) The foundation shear stresses should be within the permissible limits of shear strength of the material.

4. Downstream Drainage System: It is performed by providing the filter material in the earthen dam which is more pervious than the rest of the fill material. It reduces the pore water pressure thus adding stability to the dam.

Three types of drains used for this purpose are:

a) Toe Drains

b) Horizontal Blanket

c) Chimney Drains.

7.7 Causes of Failures of Earthfill Dams

Earthfill dams are less rigid and more susceptible to failure. Like most of engineering structures, earth dams may fail due to various reasons such as faulty design, improper construction and poor maintenance practices, etc. Different causes of failure of earthfill dams are explained below.

Different causes of failure of earthfill dams are as follows:

1. Hydraulic Failures
2. Seepage Failures
3. Structural Failures

1. Hydraulic Failures of Earthfill Dams

4 out every 10 earthen dams have failed due to hydraulic failures. The Hydraulic failure of an earthen dam arise due to any of the following causes.

- Erosion of Upstream face
- Erosion of Downstream toe
- Due to Over-topping
- Due to Frost Action
- Due to formation of Gullies

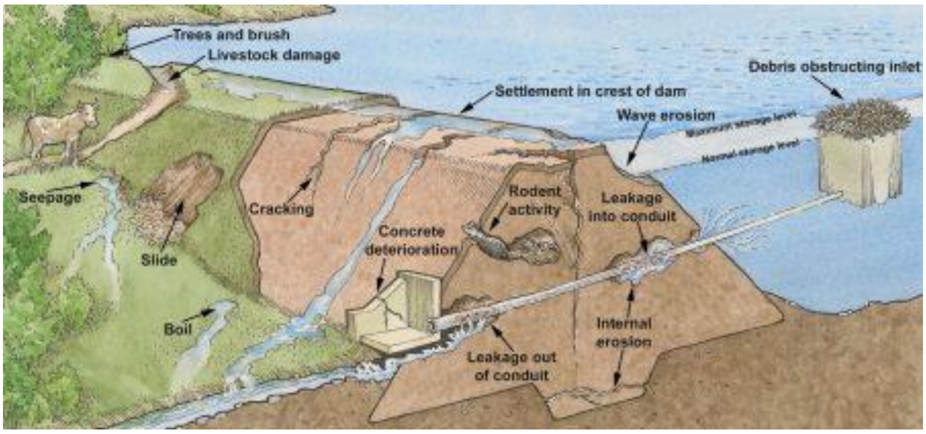


Fig 1: Various Causes of Failures of Earth dams

1.1 Erosion of Upstream face

The upstream face of dam may subjected water waves which are formed due to winds and these waves notch-out the soil from upstream face which causes erosion. Sometimes this may also cause slip of upstream slope. To overcome this, stone pitching or rip rap should be provided on upstream face of dam.

Fig 2: Erosion of Upstream

1.2 Erosion of Downstream toe

The tail water present on the downstream side or cross-currents may come from spillway buckets may affects the downstream toe portion and erosion occurs.

To prevent this problem, stone pitching or rip rap should be provided on the downstream face of dam up to a depth of normal tail water level. To prevent cross currents from spillway, sidewalls of spillway should be constructed with adequate height and length.

Fig 3: Erosion of Downstream Due to Spillway Overflow

1.3 Due to Over-topping

Hydraulic failure also occurs when the water over-tops the dam crest. This may be due to insufficient capacity of spillway or design without proper estimation of flood level or problem in lifting of spillway gates during flood times. To prevent over-topping of dam, adequate freeboard should be provided.

Fig 4: Over-topping of Dam

1.4 Due to Frost Action

In low temperature zones, the upper portion of dam may subjected to frost and heaves and cracks may form in the soil. These cracks will cause seepage through them cause failure. So, in such zones, additional freeboard should be provided which is generally 1.5 m excess to the normally provided freeboard.

1.5 Erosion of Downstream face Due to Gullies

When the downstream face of dam is subjected to heavy rains, the rainwater or runoff will flow with high downward velocities which causes erosion of soil on the downstream face and this may also lea to formation of gullies.

This can be prevented by providing berms on the downstream face at suitable heights. Drainage facilities should be provided at these berms so, runoff will be collected here before reaching high downward velocity resulting elimination of erosion.

By grassing the downstream face also erosion due to runoff can be prevented. It is also important to inspect and fill the gullies or cuts with new soil from time to time during rainy seasons.

Fig 5: Formation of Gullies Due to Rainwater

2. Seepage Failure of Earthfill Dams

Seepage through earthen dam is casual but it is considered as harmless when it is limited or controllable. If it is uncontrollable or concentrated seepage then there occurs problems such as piping and sloughing. 1 out of every 3 failed dam cases have seepage failures.

- Piping through Foundation
- Piping through Dam body
- Sloughing of Downstream toe

2.1 Piping through Foundation

When the foundation of earthen dam consists gravel or coarse sand layers or fissures etc., the water from upstream will seep through it. The seepage at higher gradient erode the soil and creates hollow spaces inside the foundation which is called as piping through foundation.

This problem will cause the dam to sink downwards resulting failure of dam. Hard and impermeable strata should be selected as foundation for dam to avoid piping through foundation.

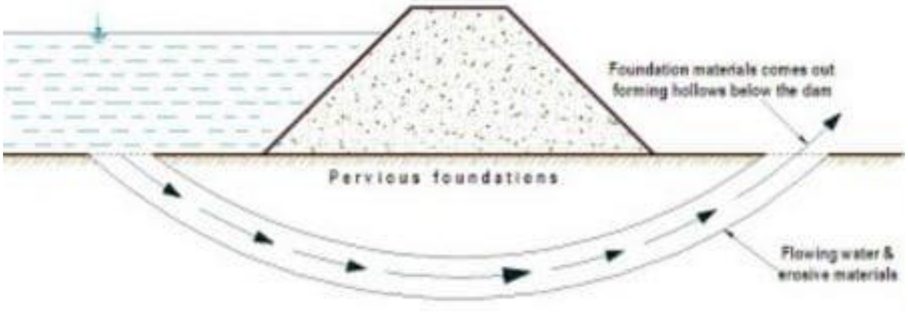


Fig 6: Piping Through Foundation

2.2 Piping through Dam body

Piping through dam body will occur due to seepage of water through dam body. This is mainly due to insufficient compaction of soil used for the dam, faulty construction of dam, shrinkage cracks, animal burrows in dam body, etc.

This problem will arise mostly near the pipe conduits passing through dam body. Piping may develop due to seepage along the outer side of conduit or due to leakage of conduit inside the dam body. To prevent this, the soil layers around the conduits must be fully compacted as well as the conduits should not be overloaded.

Fig 7: Piping Through Dam Body Near Conduit Region

2.3 Sloughing of Downstream toe

IF the downstream toe of dam gets saturated by piping or any seepage action, it will get eroded and forms small slide or small slump. The slump will create steeper face which again gets eroded due to seepage and form slump again. This progressive removal of saturated soil is called sloughing. This will finally lead to removal of soil from whole downstream face and makes the dam body thin resulting failure of dam.

Fig 8: Sloughing of Downstream

3. Structural Failure of Earthfill Dams

Another cause for failure of earthen dams is structural failures. About 1/4th of earthen dams have failed due to structural failures.

- Sliding of Foundation
- Sliding of Embankment

3.1 Sliding of Foundation

Sliding of foundation is nothing of sliding of whole dam body. This occurs when the foundation contain soft clay, fine silt etc. This type of foundation material will cause sliding of entire dam which will cause cracks on the top of embankment and forms mud waves near the upstream heel.

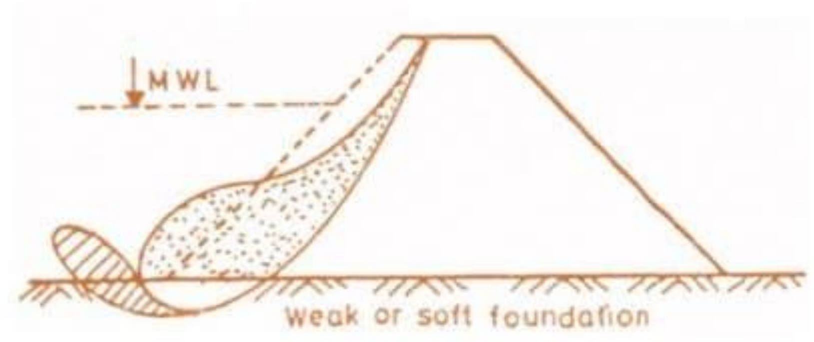


Fig 9: Sliding of Foundation

3.2 Sliding of Embankment

Sliding of embankment occurs when the slope of embankment is too steep. When the reservoir water level is suddenly draw down, then there is a chance of sliding of upstream slope. Similarly when the reservoir is at full level, then there is a chance of downstream slope failure.

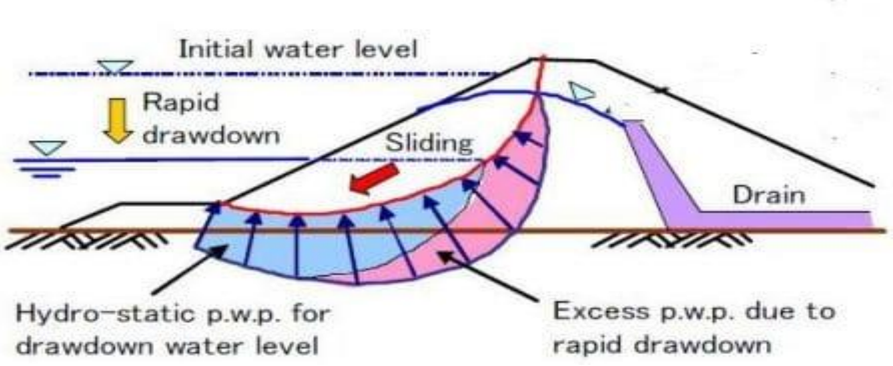


Fig 10: Upstream Slope Failure

The above failures are mainly due to excessive pore water pressure which reduces the soil shear strength. Among the both cases, downstream slope slide is very dangerous. Most of embankments are failed during consolidation process.

7.8 REMEDIAL MEASURES

Strengthening, repairs and remedial measures are not amenable to standardization and should be carefully selected depending upon (a) the risk element as influenced by the height of the dam, reservoir volume and potential loss to life and properties etc. (b) the economic value of water stored (c) nature of foundation stratum and (d) materials and methods used in construction of the dam. Measures generally used are as follows:

1) Monitoring distress level
2) Seepage control measures
3) Construction and/or repair of drains filters and relief wells
4) Strengthening by grouting or other methods
5) Filling of fractures, cavities and sink holes
6) Construction or repair of slope protection
7) Reconstruction of deteriorated zones
8) Upstream stabilization methods
9) Downstream stabilization methods
10) Raising of dam
11) Increase in spillway capacity
12) Construction of fuse plug/breaching section;
13) Lowering of reservoir level.

7.9 Gravity Dam

- Gravity dams are massive structure dam which is constructed of concrete or stone masonry. These dams are hold by the gravity to the ground.
- A gravity dam depends on its own weight for stability and is usually straight in plan although sometimes slightly curved.
- A gravity dam can hold a large amount of water.
- As they rely on their own weight, it is necessary to construct them on a solid foundation of bedrocks.

- A gravity dam may be constructed either of masonry or of concrete.
- Masonry gravity dams are nowadays constructed of only small heights.
- All major and important gravity dams are now constructed of concrete only.
- A gravity dam may be either straight or curved in plan.

- A gravity dam is mostly straight in plan and is known as ‘straight gravity dam’. However, it may also be slightly curved in plan.
- A curved gravity dam resists the external forces by its weight and not by arch action.
- The most ancient gravity dam on record was built in Egypt more than 400 years B.C. of un-cemented masonry.
- Archaeological experts believe that this dam was kept in perfect condition for more than 45 centuries.
- Most of the gravity dams are solid, so that no bending stress is introduced at any point and hence, they are sometimes known as ‘solid gravity dams’.
- A gravity dam, however, can be hollow and is known as ‘hollow gravity dam’.
- Gravity dams are particularly suited across gorges with very steep side slopes where earth dams might slip.
- Where good foundations are available, gravity dams can be built up to any height. The highest dams in the world are of gravity type.

7.9.1 Construction of Gravity Dams.

- Before construction work in a river channel can be started, the stream flow must be diverted.
- In two-Stages construction, the flow is diverted to one side of the channel by a cofferdam while working proceeds on the other side.
- After work on the lower portion of one side of the dam is complete, flow is diverted through outlets in this portion or may even be permitted to over top the completed portion while work proceeds in the other half of the channel.
- If geologic and topographic conditions are favorable, a tunnel or diversion channel may be used to convey the entire flow around the dam site.
- A tunnel is particularly advantageous if it will serve some useful purpose after completion of the dam.
- Four 50 feet circular concrete-lined tunnels were used for diversion at **Hoover Dam** and later converted to outlet works.
- A diversion channel or tunnel should be capable of carrying a flow selected by frequency analysis as a reasonable risk in view of the hazards on each particular job.
- It is advantageous to schedule construction of the lower portion of a dam during normal low-flow periods to minimize the diversion problem.
- The foundation must be excavated to solid rock before any concrete is poured.
- After excavation, cavities or faults in the underlying strata are sealed with concrete or grout.
- Frequently a grout curtain is placed near the heel of the dam to reduce seepage and uplift.
- A cement grout and water are sometimes mixed with a small amount of fine aggregates (sand) is forced under pressure into the holes drilled into the rocks.
- Grouting at pressures up to about 40 psi may be done before concrete is placed for the dam, but high-pressure grouting (200 psi) is done from permanent galleries in the dam after the dam is complete so that the weight of the dam can resist the grouting pressures.
- Concrete for the dam is usually placed in blocks depending on the dimensions of the dam, with a maximum width of about 50 ft on large dams.
- The maximum height of a single pour is usually about 5 ft.
- Sections are poured alternately so that each block is permitted to stand several days before another one is poured next to it or on top of it.

- After individual sections are poured, they are sprinkled with water and otherwise protected from the drying effect of the air.
- After the form work is removed, the lateral surfaces of each section are painted with a paint (asphaltic emulsion) to prevent adherence to adjoining sections and to form construction joints to reduce cracking of the concrete.
- Keyways are provided between sections to carry the shear forces from one section to the adjacent one and make the gravity dam act as a monolithic structure.
- Metal water stops are also placed in the vertical construction joints near the upstream face to prevent leakage.
- Inspection galleries to permit access to the interior of the dam are formed as the concrete is placed.
- These galleries may be necessary for grouting operation, for operation and maintenance of gates and valves, and as intercepting drains for water which seeps into the gravity dam.
- When concrete sets, a great deal of heat is liberated, and the temperature of the mass is raised.
- As the concrete cools, it shrinks, and cracks may develop. To avoid cracks, a special type of cement (low-heat cement) may be used.
- Very lean mixes are also used for the interior of the dam. Two sacks of cement per cubic yard of concrete are not uncommon.
- In addition, the materials which go into the concrete may be cooled before mixing concrete.
- For best results, the temperature of the concrete mix should be between 50° and 80°F.
- Occasionally, further cooling is accomplished by circulating cold water through pipes embedded in the concrete, although this is expensive and is generally used only on large gravity dams.

7.9.2 Advantages of gravity dams.

There is no type of dam more permanent than one of the solid concrete, nor does any other type require less for maintenance. As compared to earth and rock-fill dams gravity dams have the following advantages :

1. Gravity dams are relatively more strong and stable than earth dams. They are particularly suited across gorges having very steep side slopes where earth dam, if constructed, might slip.

2. Gravity dams are well adapted for use as an overflow spillway crest. Earth dams cannot be used as overflow dams. Due to this, a gravity overflow dam is often used for the spillway feature of earth and rock-fill dams.

3. They can be constructed of any height, provided suitable foundations are available to bear the stresses.

The height of an earth dam is usually limited by the stability of its slopes requiring a very wide base width. Highest dams in the world are made of gravity dams only.

4. Gravity dam is specially suited to such areas where there is likelihood of very heavy downpour. The slopes of earth dam might get washed away in such a situation.

5. They requires the least maintenance.

6. The failure of this dam, if any, is not sudden. It gives enough warning time before the area to downstream side is flooded due to the damage of the structure.

On the contrary, an earth dam generally fails suddenly.

7. Deep-set sluices can be used in the gravity dams, to retard the sedimentation or silt deposit in the reservoir. The trap efficiency of a reservoir of an earth dam is more than that of a reservoir of gravity dam.

8. They are cheaper in the long run since it is more permanent than any other type. Thus the benefit-cost ratio of such a dam is always higher.

7.9.3 Disadvantages of Gravity Dams.

The disadvantages of gravity dam, as compared to an earth dam are as follows:

1. Gravity dams can be constructed only on sound rock foundations. They are unsuitable on weak foundations or on permeable foundations on which earth dams can be constructed with suitable foundation treatment.

2. The initial cost of a gravity dam is always higher than an earth dam. Hence, where funds are limited and where suitable materials are available for the construction of an earth dam, the earth dam may be preferred.

3. If mechanized plants, such as manufacturing and transporting mass concrete, curing of concrete etc. are not available, a gravity dam may take more time to construct.

4. They require skilled labor or mechanized plants for its construction.

5. It is very difficult to allow subsequent rise in the height of a gravity dam, unless specific provisions have been made in the initial design.

7.10 Small Dams

Small dams can be used to generate electricity from running or falling water (called small hydropower, and micro-hydropower when it is very small). Where there is enough water from rivers or streams, micro-hydropower is the least costly way to provide electricity to rural communities. These projects can be set up and managed by villagers. In China,India, and Nepal, thousands of small hydropower projects supply power to villages and towns.

In small hydropower projects, water is channeled from a river or stream and runs downhill through a pipe. The falling water in the pipe turns a turbine, and then returns to the river or stream. Small dams do not displace people or change the flow of the river the way large dams do. Micro-hydropower projects use dams only a few meters tall to direct water toward the turbine.

7.11 Different Types of Spillways

A spillway is a hydraulic structure built at a dam site for diverting the surplus water from a reservoir after it has been filled to its maximum capacity. Spillways are classified into different types on the basis of the arrangement of the control structure, a conveyance channel and a terminal structure. In this article, we will discuss in brief all the different types of spillways with pictures.

7.11.1 Types of Spillways

Different types of spillways are as follows:

1. Straight Drop Spillway
2. Ogee Spillway
3. Shaft Spillway
4. Chute Spillway
5. Side Channel Spillway
6. Siphon Spillway
7. Labyrinth Spillway

1. Straight Drop Spillway

A Straight drop spillway consists of low height weir wall having its downstream face roughly or perfectly vertical. When the water level in the reservoir rises above the normal pool level, the surplus water falls freely from the crest of the weir and hence it is known as **Straight drop spillway** or **free overfall spillway**.

Fig 1: Straight Drop Spillway

To prevent the scouring of downstream bed from falling water jet, an artificial pool with a concrete apron and low secondary dam is constructed on the downstream side. Proper ventilation should be provided on the underside portion of a falling jet to prevent pulsating and fluctuating effects.

Sometimes, an overhanging projection is provided on the crest of the weir to prevent the entrance of small discharges onto the face of the weir wall. Straight drop spillways are most suitable for thin arch dams, earthen dams or bunds.

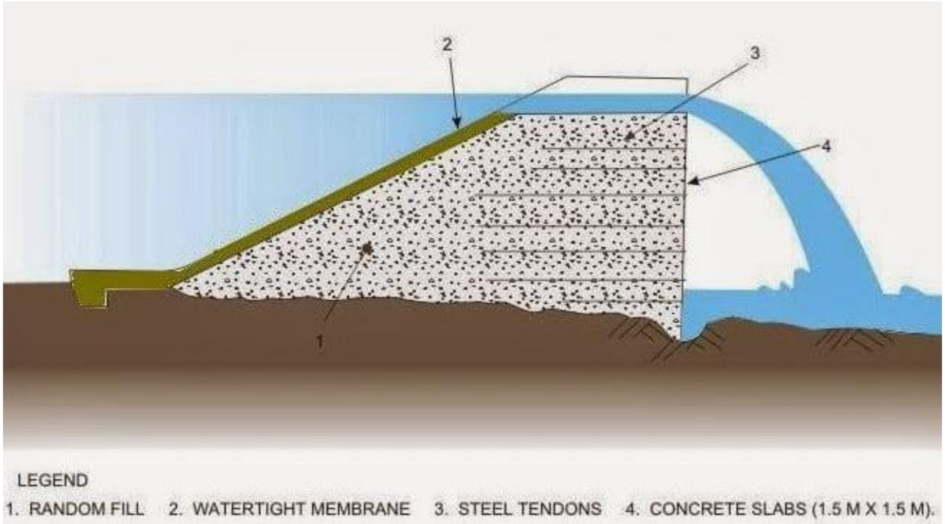


Fig 2: Straight Drop Spillway Components

2. Ogee Spillway

Ogee spillway, as the name says, represents the shape of the downstream face of the weir. It is an improved form of a straight drop spillway. In this case, the downstream face of the weir is constructed corresponding to the shape of lower nappe of freely falling water jet which is in ogee shape.

The ogee shape of the downstream face is designed on the basis of the principle of a projectile. In general, the shape of lower nappe of the water jet is not constant for all water heads hence, the shape obtained for the maximum head is taken into account while designing ogee spillway.

Fig 3: Ogee Spillway of Walayar dam, India

Whenever there is surplus water, it will be freely disposed of through ogee spillway along its ogee shaped crest hence it can also be called as an overflow spillway. Ogee spillways are most commonly used in case of gravity dams, arch dams, buttress dams, etc. For gravity dams, it is generally located within the dam body.

3. Shaft Spillway

A Shaft spillway is a type of spillway which consists of a vertical shaft followed by a horizontal conduit. The surplus water enters into the vertical shaft and then to the horizontal conduit and finally reaches the downstream of the channel.

Fig 4: Shaft Spillway

The shaft constructed is either artificial or natural. Excavation for the natural shaft is possible only when the hard rocky layer is present on the upstream side. The horizontal conduit either passes through the dam body or through the foundation of the dam.

In the case of large projects, the inlet hole of the vertical shaft is specially shaped which is called as **morning glory** or **glory hole of the spillway**. Hence, shaft spillway is also called as Morning glory spillway or Bell Mouth spillway. Shaft spillway is recommended when there is no space to provide for other types of spillways such as ogee spillway, straight drop spillway, etc.

Fig 5: Morning Glory Spillway, Monticello Dam

4. Chute Spillway

Chute spillway is a type of spillway in which surplus water from upstream is disposed to the downstream through a steeply sloped open channel. It is generally constructed at one end of the dam or separately away from the dam in a natural saddle in a bank of the river.

Chute spillway is suitable for gravity dams, earthen dams, rockfill dams, etc. But it is preferred when the width of the river valley is very narrow. The water flows along the steeply sloped chute or trough or open channel and reaches the downstream of the river. Chute spillway is also called as trough spillway or open channel spillway.

The slope of chute spillway is designed in such a way that the flow should be always in supercritical condition. To dissipate energy from the falling water, energy dissipators can be provided on the bed of chute spillway.

Fig 6: Chute Spillway, Tehri Dam, India

5. Side Channel Spillway

Side channel spillway is similar to chute spillway but the only difference is the crest of side channel spillway is located on one of its sides whereas crest of chute spillway is located between the side walls. In other words, the water spilling from the crest is turned to 90 degrees and flows parallel to the crest of side channel spillway unlike in chute spillway.

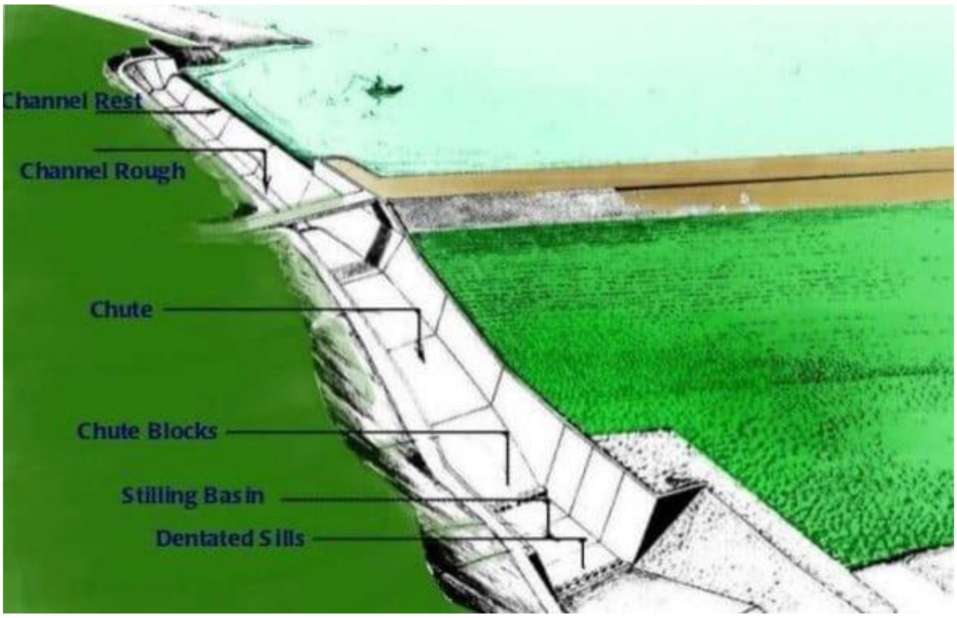


Fig 7: Side Channel Spillway

Side channel spillways are preferred over chute spillways when flanks of sufficient width are not available, usually to avoid heavy cutting. The angle of turn of water flow after passing weir crest can also be kept between 0^0 and 90^0.

Fig 8: Side Channel Spillway of Hoover Dam, USA

6. Siphon Spillway

A siphon spillway is a type of spillway in which surplus water is disposed to downstream through an inverted U shaped conduit. It is generally arranged inside the body or over the crest of the dam.

In both types of siphon spillways, air vents are provided at the bent portion of the upper passageway to prevent the entrance of water when the water level is below the normal poll level. Whenever the level rises above normal pool level, water enters into the conduit and is discharged to the downstream of the channel by siphonic action.

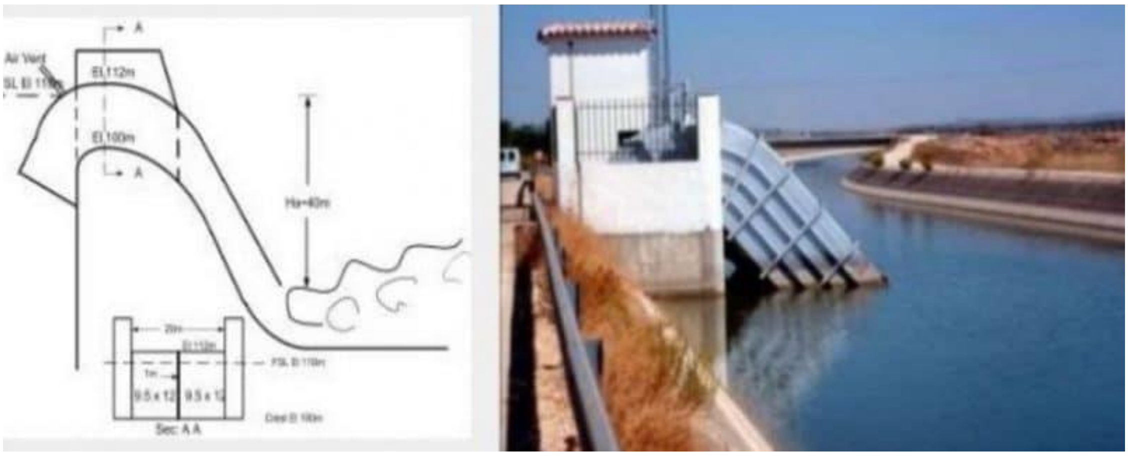


Fig 9: Siphon Spillway

7. Labyrinth Spillway

A labyrinth spillway is a type of spillway in which the weir wall is constructed in a zigzag manner in order to increase the effective length of the weir crest with respect to the channel width. This increase in effective length raises the discharge capacity of the weir and hence higher water flow at small heads can be conveyed to the downstream easily.

Fig 10: Labyrinth spillway of Lake Brazos Dam, United States

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E-NOTES

SUBJECT: IRRIGATION **SUBJECT CODE: -**

COURSE- DIPLOMA **BRANCH: CIVIL ENGINEERING**

SEMESTER 4TH **CHAPTER NAME: CANAL HEADWORKS**

(PREPARED BY: Mr. ANKUR CHAUHAN, LECTURER, CE)

8.1 Definition:

Any hydraulic structure which supplies water to the off taking canal. Diversion head-work provides an obstruction across a river, so that the water level is raised and water is diverted to the channel at required level. The increase water level helps the flow of water by gravity and results in increasing the commanded area and reducing the water fluctuations in the river.

Diversion head-work may serve as silt regulator into the channel. Due to the obstruction, the velocity of the river decreases and silt settles at the bed. Clear water with permissible percentage of silt is allowed to flow through the regulator into the channel.

To prevent the direct transfer of flood water into the channel.

8.2 Functions of a Headwork

A headwork serves the following purposes

- A headwork raises the water level in the river
- It regulates the intake of water into the canal
- It also controls the entry of silt into the canal
- A head work can also store water for small periods of time.
- Reduces fluctuations in the level of supply in river

8.3 Types of Canal Headworks

1. Storage headwork
2. Diversion headwork

8.3.1 Storage Headworks

When dam is constructed across a river to form a storage reservoir, it is known as storage head work. It stores water during the period of excess supplies in the river and releases it when demand overtakes the available supplies.

8.3.2 Diversion Headworks

When a weir or barrage is constructed across a river to raise the water level and to divert the water to the canal, then it is known as diversion head work. The flow in the canal is controlled by canal head regulator.

8.3.2.1 Functions of Diversion Headworks

- It raises the water level in the river so that the command area can be increased.
- It regulates the intake of water into the canal.
- It controls the silt entry into the canal.
- It reduces fluctuations in the level of supply in the river.
- It stores water for tiding over small periods of short supplies.

A diversion headwork can further be sub-divided into two principal classes:

1. Temporary spurs or bunds
2. Permanent weirs and barrages

Temporary spurs or bunds

Temporary spurs or bunds are those which are temporary and are constructed every year after floods, however, for important works, weirs or barrages are constructed since they are of permanent nature if properly designed.

8.4 PERMANENT WEIRS AND BARRAGES

Weirs:

The weir is a solid obstruction put across the river to raise its water level and divert the water into the canal. If a weir also stores water for tiding over small periods of short supplies, it is called as ‘storage weir’. The main difference between the storage weir and dam is only in height and duration for which the supply is stored. A dam stores the supply for a comparatively longer duration.

Barrage:

The function of barrage is similar to that of weir; but the heading up of water is affected by the gates alone. No solid obstruction is put across the river. The crest level in the barrage is kept at a low level. During the floods, the gates are raised to clear off the high flood level, enabling the high flood to pass downstream to mix afflux. When the flood recedes, the gates are lowered and the flow is obstructed, thus raising the water level to upstream of the barrage. Due to this, there is less silting and better control over the levels. However, barrages are much more costly than weirs.

8.5 Component parts of Diversion Headwork

1. Weir or Barrage
2. Divide Wall
3. Fish Ladder
4. Approach Canal
5. Silt prevention device
6. Canal head regulator
7. River training works

8.6 Location of Headworks

1. Rocky Stage
2. Sub mountainous or boulder stage: boulder or gravel
3. Alluvial plan

8.6.1 Rocky stage:

River steep slope, high velocity

Advantages:

1. Good foundation at shallow depth
2. Comparatively silt free water for turbines
3. High head for hydro-electric work

Disadvantages:

1. Long ---- length of canal. In reach soil is good for agriculture.
2. More cross damage works
3. More falls (ground steep gradient - lined to permit high velocity)
4. Costly head regulator excluding shingle
5. Frequent repairs of the weirs.

8.6.2 Sub mountainous or boulder stage: boulder or gravel

Advantages:

1. Less training works
2. Suitable soil for irrigation available
3. Availability of construction material locally.
4. Falls can be utilized for power generation

Disadvantages:

1. It has a strong sub-soil flow as a result
2. Reduce in storage and damage floor downstream
3. More percolation loss from canal
4. More x-drainage works

5. Less demand of water at head reaches (more idle length of canal)

8.6.3 Alluvial plan:

Advantages:

1. x- section of river alluvial sand silt
2. Bed slope small, velocity gentle
3. No idle length of canal
4. less x- drainage works
5. Comparatively less sub soil flow

Disadvantages:

1. Cost of head-work is more due to poor foundation
2. More river training works
3. Problem of silt in canal

8.7 Components of diversion headworks

The various components of diversion headworks are as follows:

1. Weir or Barrage
2. Divide wall or divide groyne
3. Fish ladder
4. Undersluices or scouring sluices
5. Silt excluder
6. Canal head regulator
7. River training works such as Marginal bunds and Guide bunds

Weir

A weir is a structure constructed across a river to raise its water level and divert the eater into the canal. On the crest of the weirs usually shutters are provided so that part of the raising up of water is carried out by shutters. During floods the shutters may be dropped down to allow water to flow over the crest of the weir. Weir is usually aligned at right angles to the direction of flow of the river.

Horns Mill weir

Weirs may be classified according to the material of construction and certain design features into the following three types.

- Masonry weirs with vertical drop or vertical drop weirs.
- Rockfill weirs with sloping aprons.
- Concrete weirs with a downstream glacis

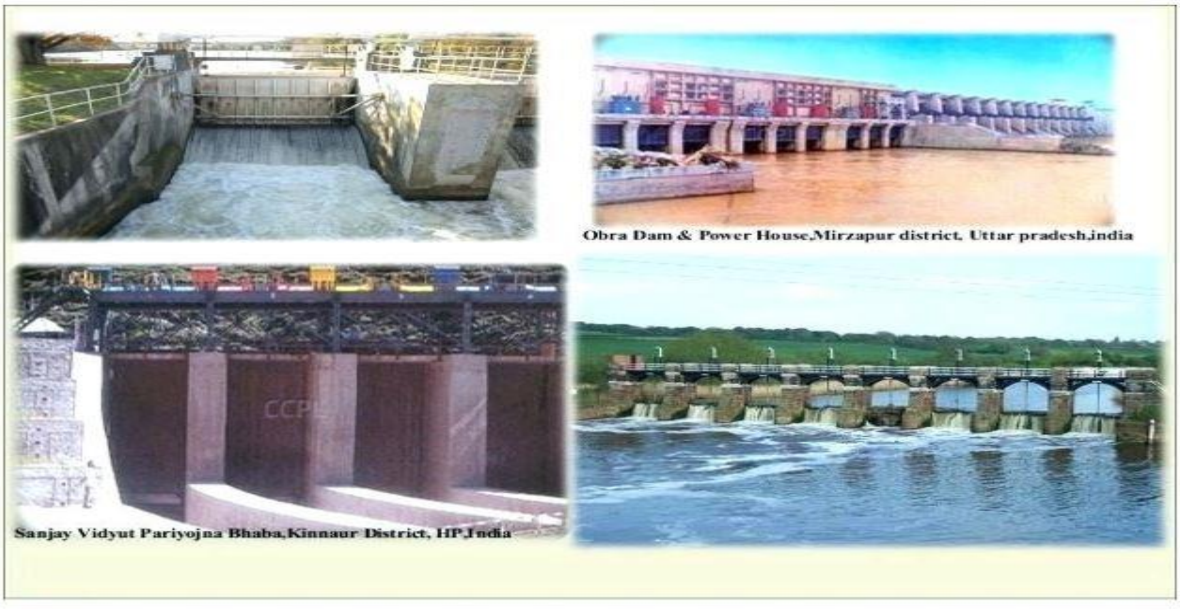
Barrage

In the case of a barrage the crest is kept at a low level and the raising up of water level (or ponding) is accomplished mainly by means of gates. During floods these gates can be raised clear off the high flood level and thus enable the high flood to pass with minimum of afflux (or heading up of water on the upstream side). A barrage provides better control on the water level in the river but it is comparatively more costly.

Barrage on Kshipra River (Newkem)

Divide wall or divide groyne

A divide wall is a long masonry or concrete wall or groyne (an embankment protected on all sides by stone or concrete blocks) which is constructed at right angles to the axis of the weir to separate the undersluices from the rest of the weir. If two canals take off, one on either side of the river, then two divide walls are required, one on each side. The top width of the divide wall is about 1.5 to 2.5m. The divide wall extends on the upstream side up to a distance little beyond the beginning of the canal head regulator and on the downstream side up to the end of the loose protection.



Divide wall

Fish ladder & Diversion headworks

Large rivers have various types of fish, many of which are migratory. They move from one part of the river to another according to the season. In our country generally fish move from upstream to downstream in the beginning of winter in search of warmth and return upstream before monsoon for clearer water. Due to the construction of a weir or barrage across the river such migration of the fish will be obstructed and if no arrangement is made in the weir or barrage for this migration, large scale destruction of the fish life may take place in the river.

Thus to enable the fish to migrate fish ladder is provided. Since most fish can travel upstream only if the velocity of flow does not exceed 3 to 3.5 m/s, the design of the fish ladder should be such that it constantly releases water at a velocity not exceeding this value.

Fish ladder (NOAA's National Ocean Service)

Undersluices or Scouring sluices

The undersluices are the openings provided in the weir wall with their crest at a low level. These openings are fully controlled by gates. They are located on the same side as the off taking canal. If two canals take off, one on either side of the river, then it would be necessary to provide undersluices on either side of the canal.

Undersluices

Silt excluder

Silt excluders are a type of silt control device which functions to exclude silt from water to entering the canal. These devices are particularly provided on the river bed in front of the head regulator. A silt excluder usually consists of a number of rectangular tunnels resting on the floor of the undersluice pocket. The bottom portion of the tunnels is formed by the floor of undersluice pocket. The top level portion of the roof of tunnel is kept same as the level of the crest or sill of the head regulator. The tunnels are constructed with variable lengths. The tunnel nearest to the crest is of same length as the length of the head regulator. But all other successive tunnels have a decreasing length.

Silt excluder (Springer)

Canal Head regulator

It is a structure constructed at the head of a canal from the upstream of the weir or barrage constructed. It consists of number of spans separated by piers which supports the gates provided for the regulation of water flow to the canal. The spans ranging from 6 to 8 m are used with counterbalanced steel gates which are operated manually by winches. Also larger spans are used if necessary or the condition is economical.

Canal head regulator

River training works

River training is defined as the various measure adopted on a river to stabilize the river channel along a certain cross section for a particular alignment. These measures are adopted because the rivers in alluvial plane frequently alter their courses and subsequently cause damage to the land and property adjacent to them. Some of the major river training works are explained as below:

Marginal bunds

Marginal bunds or levees are the earthen embankments which are provided to confine the flood water from the river within an allowable cross-section and in between the embankments. Thus the spreading of flood water beyond these marginal bunds is prevented.

Marginal bund

Guide banks or Guide bunds

The guide bunds are also a type of earthen embankments provided to confine the flood water of alluvial rivers within a reasonable length of waterway and provide a straight and non-tortuous approach towards the constructions works across the river. They are also used to prevent the river from changing its course and outflanking the construction work. In India the guide banks were first designed by Bell and hence these are also known as Bell's bunds. The initial design by Bell was later modified by Spring and Gales and this modified design is commonly adopted these days.

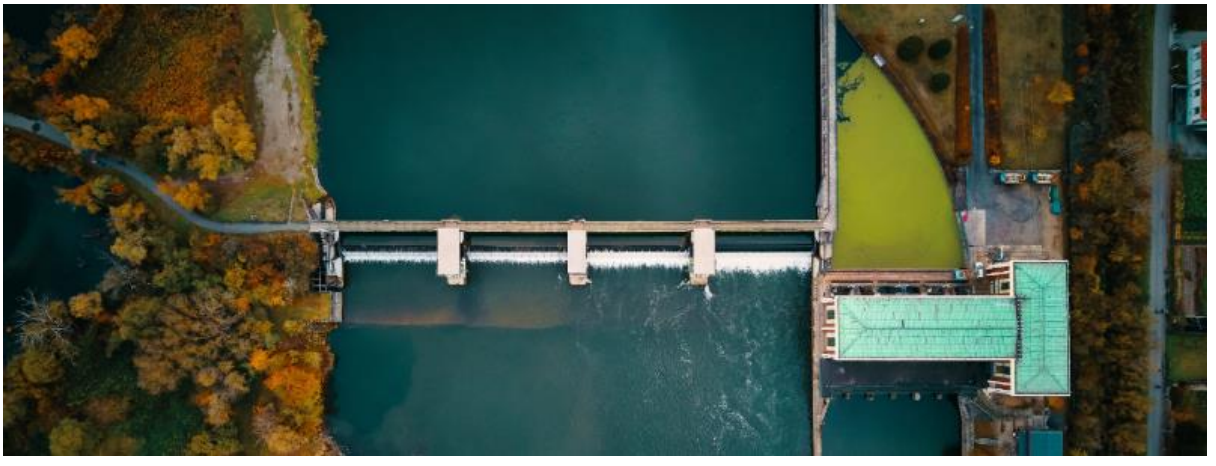
There is some confusion around the difference between weirs and barrages, more particularly how they fit in the spectrum of dams category as a whole. Effectively, both weirs and barrages are what's called headworks that are used to increase the head of water on the upstream side.

8.8 In this article, you will learn the differences between a weir and barrage.

Weirs

A weir is simply a concrete or masonry structure that is built through an open channel, for instance, a river. In most cases, it is built to control water flow, measure the discharge, prevent flooding and make rivers navigable. It can be built with different materials such as wood, concrete or a mixture of rocks, gravel, and boulders depending on age and purpose.

Barrages



On the other hand, a barrage is a concrete structure that consists of a series of large gates that can be opened or closed to control the amount of water that flows through them. This allows the structure to adjust and stabilize the elevation of the upstream water for irrigation and other systems. The valves are positioned between the pillars that have the task of supporting the water load of the pool created.

8.9 Differences Between Weirs & Barrages

A weir is an impermeable barrier that is built across a river to raise the water level on the upstream side. Here, the water level is at the required height and excess water then can flow over the weir.

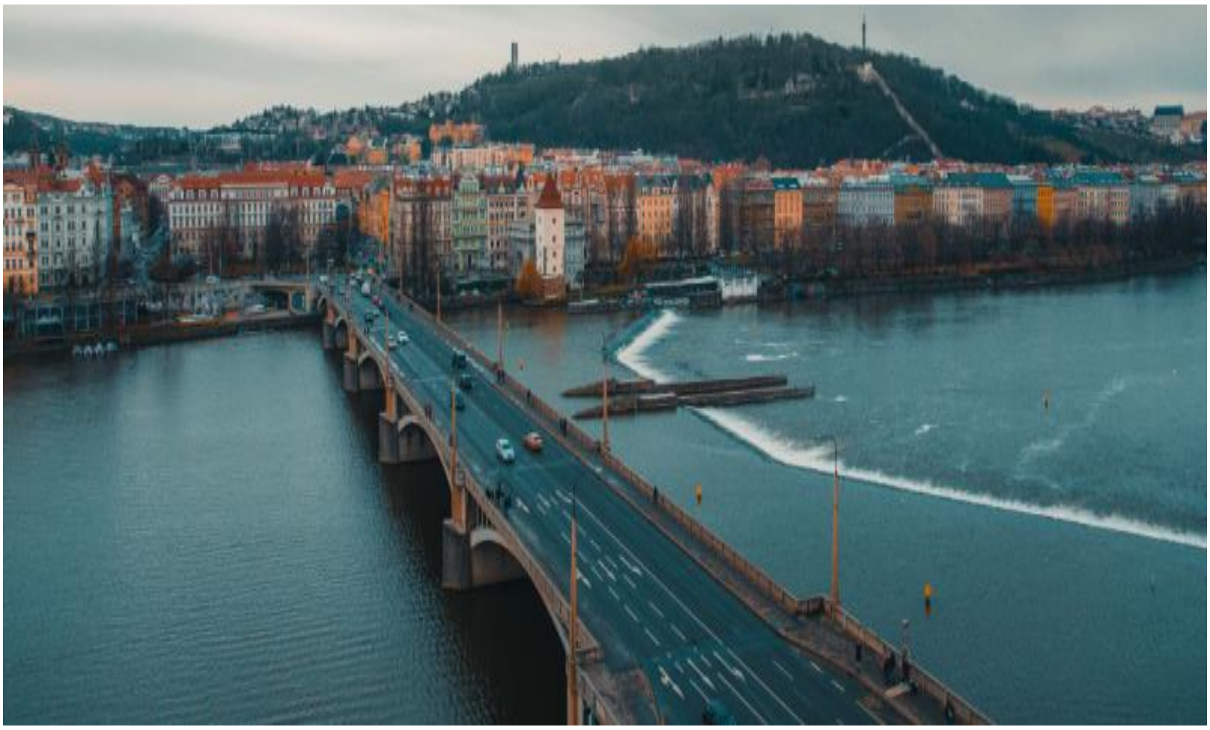
It is usually built on the other side of a flooded river.

On the other hand, a barrage involves adjustable gates installed over a dam to maintain the water surface at different levels and at different times. The water level is adjusted by opening the valves or gates. These gates are supported by pillars at both ends and are also positioned at different levels. They are usually operated by cables from the cabin.

Both weirs and barrages are obstacles to the watercourse, but the barrage is an expensive structure, while the weir is a relatively cheap structure.

Barrages are built near cities so that the amount of water flowing in the river can be controlled by opening and closing the gates to save the city from flooding. A weir, in contrast, is built, for example, in tourist destinations and preservation areas to allow the fish to swim upstream.

8.10 Similarities Between Weirs & Barrages



- They’re both used to control floods.
- Both help to make a river navigable.
- Both measure discharge.

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E-NOTES

SUBJECT: IRRIGATION **SUBJECT CODE: -**

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SEMESTER 4TH **CHAPTER NAME: RIVER DRAINAGE WORKS**

(PREPARED BY: Mr. ANKUR CHAUHAN, LECTURER, CE)

9.1 Definition:

A cross drainage work is a structure carrying the discharge from a natural stream across a canal intercepting the stream. Canal comes across obstructions like rivers, natural drains and other canals. The various types of structures that are built to carry the canal water across the above mentioned obstructions or vice versa are called cross drainage works. It is generally a very costly item and should be avoided by:

- Diverting one stream into another.
- Changing the alignment of the canal so that it crosses below the junction of two streams.

9.2 Types of cross drainage works

Depending upon levels and discharge, it may be of the following types:

Cross drainage works carrying canal across the drainage:

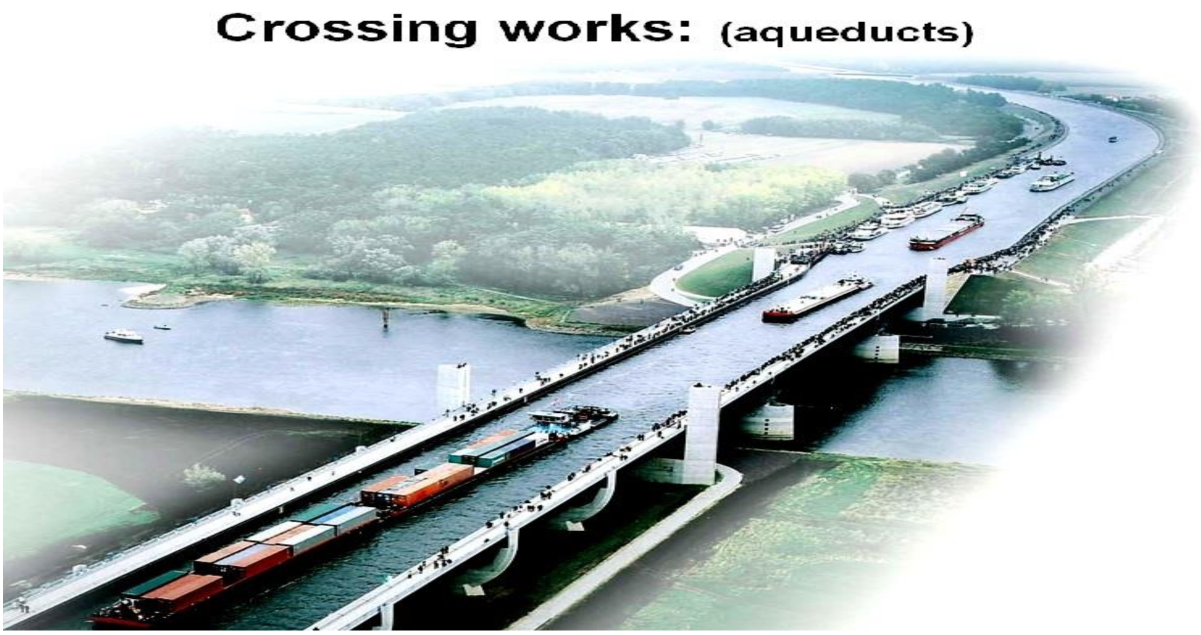
the structures that fall under this type are:

1. An Aqueduct
2. Siphon Aqueduct

1. **Aqueduct:**

When the HFL of the drain is sufficiently below the bottom of the canal such that the drainage water flows freely under gravity, the structure is known as Aqueduct.

- In this, canal water is carried across the drainage in a trough supported on piers.
- Bridge carrying water
- Provided when sufficient level difference is available between the canal and natural and canal bed is sufficiently higher than HFL.



2. Siphon Aqueduct:

In case of the siphon Aqueduct, the HFL of the drain is much higher above the canal bed, and water runs under siphonic action through the Aqueduct barrels.

The drain bed is generally depressed and provided with floors, on the upstream side, the drainage bed may be joined to the pucca floor either by a vertical drop or by glacis of 3:1. The downstream rising slope should not be steeper than 5:1. When the canal is passed over the drain, the canal remains open for inspection throughout and the damage caused by flood is rare. However during heavy floods, the foundations are susceptible to scour or the waterway of drain may get choked due to debris, tress etc.

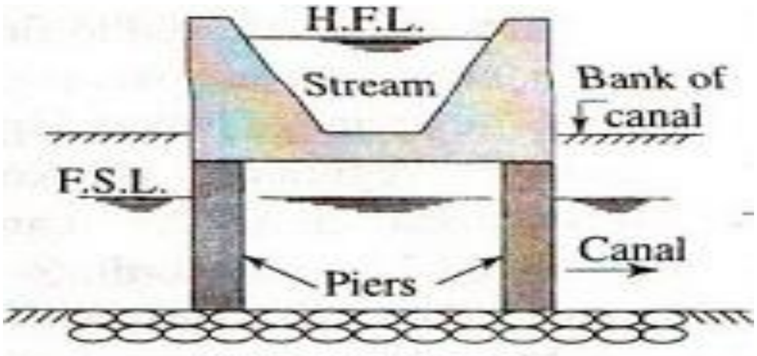
Cross drainage works carrying drainage over canal.

The structures that fall under this type are:

1. Super passage
2. Canal siphon or called syphon only

1. Super passage:

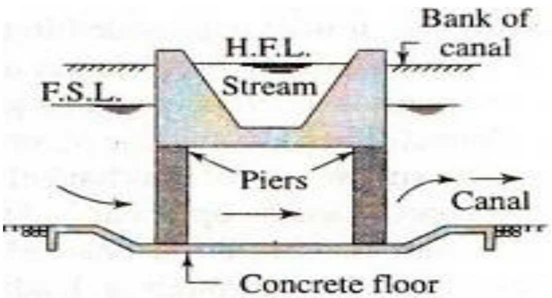
- The hydraulic structure in which the drainage is passing over the irrigation canal is known as super passage. This structure is suitable when the bed level of drainage is above the flood surface level of the canal. The water of the canal passes clearly below the drainage
- A super passage is similar to an aqueduct, except in this case the drain is over the canal.
- The FSL of the canal is lower than the underside of the trough carrying drainage water. Thus, the canal water runs under the gravity.
- Reverse of an aqueduct



Super passage

2. Canal Syphon:

- If two canals cross each other and one of the canals is siphoned under the other, then the hydraulic structure at crossing is called “canal siphon”.
- In case of siphon the FSL of the canal is much above the bed level of the drainage trough, so that the canal runs under the siphonic action.
- The canal bed is lowered and a ramp is provided at the exit so that the trouble of silting is minimized.
- Reverse of an aqueduct siphon
- In the above two types, the inspection road cannot be provided along the canal and a separate bridge is required for roadway. For economy, the canal may be flumed but the drainage trough is never flumed.



Siphon super passage

9.3 Classification of aqueduct and siphon aqueduct

Depending upon the nature of the sides of the aqueduct or siphon aqueduct it may be classified under three headings:

Type I:

Sides of the aqueduct in earthen banks with complete earthen slopes. The length of culvert should be sufficient to accommodate both, water section of canal, as well as earthen banks of canal with aqueduct slope. Sides of the aqueduct in earthen banks, with other slopes supported by masonry wall. In this case, canal continues in its earthen section over the drainage but the outer slopes of the canal banks are replaced by retaining wall, reducing the length of drainage culvert.

Type II:

Sides of the aqueduct made of concrete or masonry. Its earthen section of the canal is discontinued and canal water is carried in masonry or concrete trough, canal is generally flumed in this section.

9.4 Cross drainage works

Cross drainage works is a structure constructed when there is a crossing of canal and natural drain, to prevent the drain water from mixing into canal water. This type of structure is costlier one and needs to be avoided as much as possible.

Cross drainage works can be avoided in two ways:

- By changing the alignment of canal water way
- By mixing two or three streams into one and only one cross drainage work to be constructed, making the structure economical.

9.5 Types of Cross Drainage works:

There are three types of cross drainage works structures:

Type – 1: Cross drainage work carrying canal over the drain

The structures falling under this type are

- Aqueduct
- Syphon Aqueduct

Type – 2: Cross Drainage work carrying Drainage over the canal

The structures falling under this type are

- Super passage
- Canal Syphon

Type –3: Cross drainage works admitting canal water into the canal

The structures falling under this type are

- Level Crossing
- Canal inlets

Type – 1: Canal over drainage [HFL < FSL]

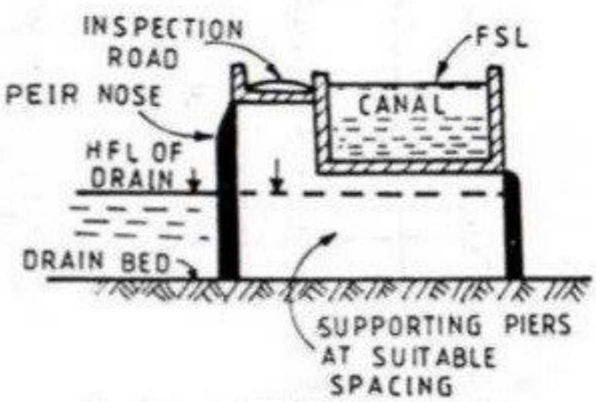
Aqueduct:

In an aqueduct, the canal bed level is above the drainage bed level so canal is to be constructed above drainage.

A canal trough is to be constructed in which canal water flows from upstream to downstream. This canal trough is to be rested on number of piers. The drained water flows through these piers upstream to downstream.

The canal water level is referred as full supply level (FSL) and drainage water level is referred as high flood level (HFL). The HFL is below the canal bed level.

Aqueduct is similar to a bridge, instead of roadway or railway, canal water are carried in the trough and below that the drainage water flows under gravity and possessing atmospheric pressure.



Typical cross-section of an aqueduct.

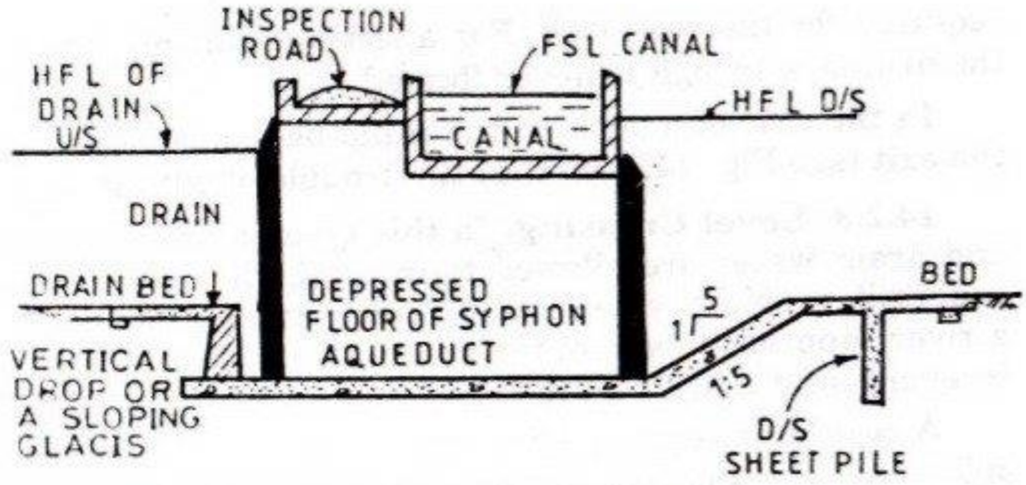
Fig (a) Aqueduct

Syphon Aqueduct:

In a syphon aqueduct, canal water is carrier above the drainage but the high flood level (HFL) of drainage is above the canal trough. The drainage water flows under syphonic action and there is no presence of atmospheric pressure in the natural drain.

The construction of the syphon aqueduct structure is such that, the flooring of drain is depressed downwards by constructing a vertical drop weir to discharge high flow drain water through the depressed concrete floor.

Syphonic aqueducts are more often constructed and better preferred than simple Aqueduct, though costlier.



Typical cross-section of a Syphon Aqueduct.

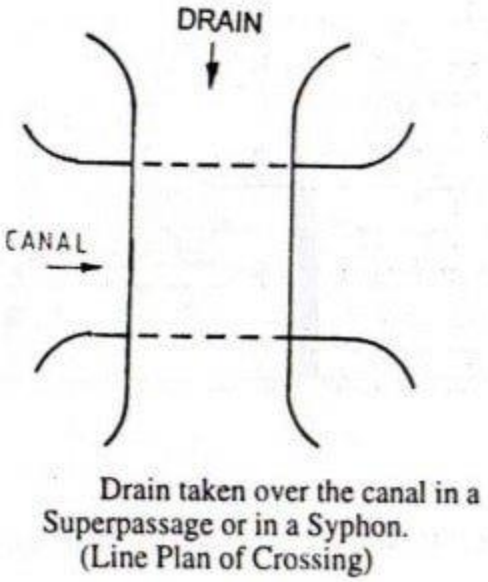
Fig (b) Syphon Aqueduct

Type – 2: Drainage over canal (HFL > FSL)

Super Passage:

Super passage structure carries drainage above canal as the canal bed level is below drainage bed level. The drainage trough is to be constructed at road level and drainage water flows through this from upstream to downstream and the canal water flows through the piers which are constructed below this drainage trough as supports.

The full supply level of canal is below the drainage trough in this structure. The water in canal flows under gravity and possess the atmospheric pressure. This is simply a reverse of Aqueduct structure.



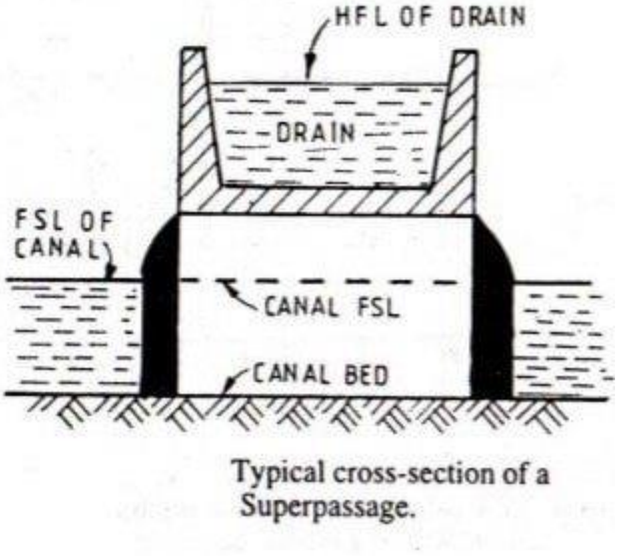


Fig (c) Super passage

Canal Syphon:

In a canal syphon, drainage is carried over canal similar to a super passage but the full supply level of canal is above than the drainage trough.so the canal water flows under syphonic action and there is no presence of atmospheric pressure in canal.

When compared, super passage is more often preferred than canal Syphon because in a canal Syphon, big disadvantage is that the canal water is under drainage trough so any defective minerals or sediment deposited cannot be removed with ease like in the case of a Syphon Aqueduct.

Flooring of canal is depressed and ramp like structure is provided at upstream and downstream to form syphonic action. This structure is a reverse of Syphon aqueduct.

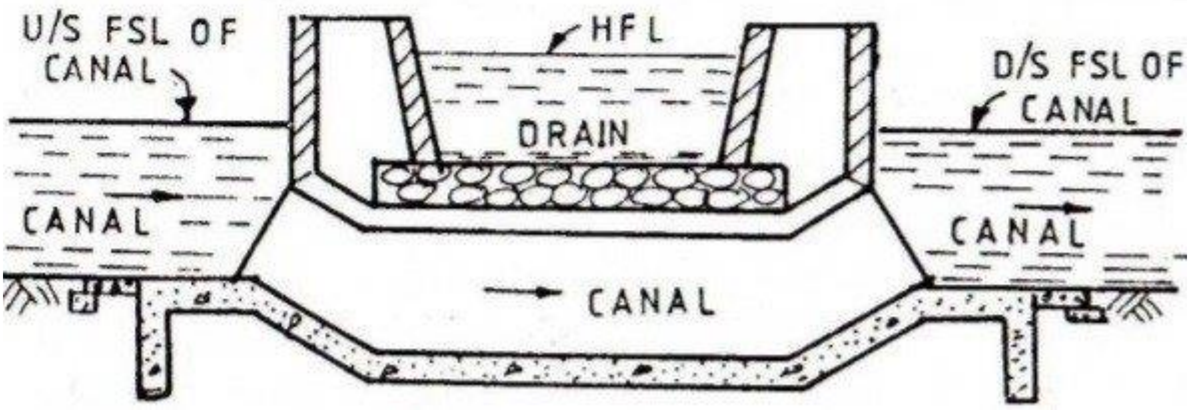


Fig (d) Canal Syphon

Type –3: Drainage admitted into canal (HFL = FSL)

In this case, the drainage water is to be mixed up with canal water, here the cost of construction is less but silt clearance and maintenance of canal water becomes really difficult. So the structures falling under this category are constructed with utmost care.

9.6 Level Crossing:

When the bed level of canal is equal to the drainage bed level, then level crossing is to be constructed. This consists of following steps:

1. Construction of weir to stop drainage water behind it
2. Construction of canal regulator across a canal
3. Construction of head regulator across a Drainage

Functioning of a level crossing:

In peak supply time of canal water parallel to drainage, both the regulators are opened to clear the drainage water from that of canal for certain time interval. Once the drainage is cleared, the head regulator is closed down. Anyhow, cross regulator is always in open condition throughout year to supply canal water continuously.

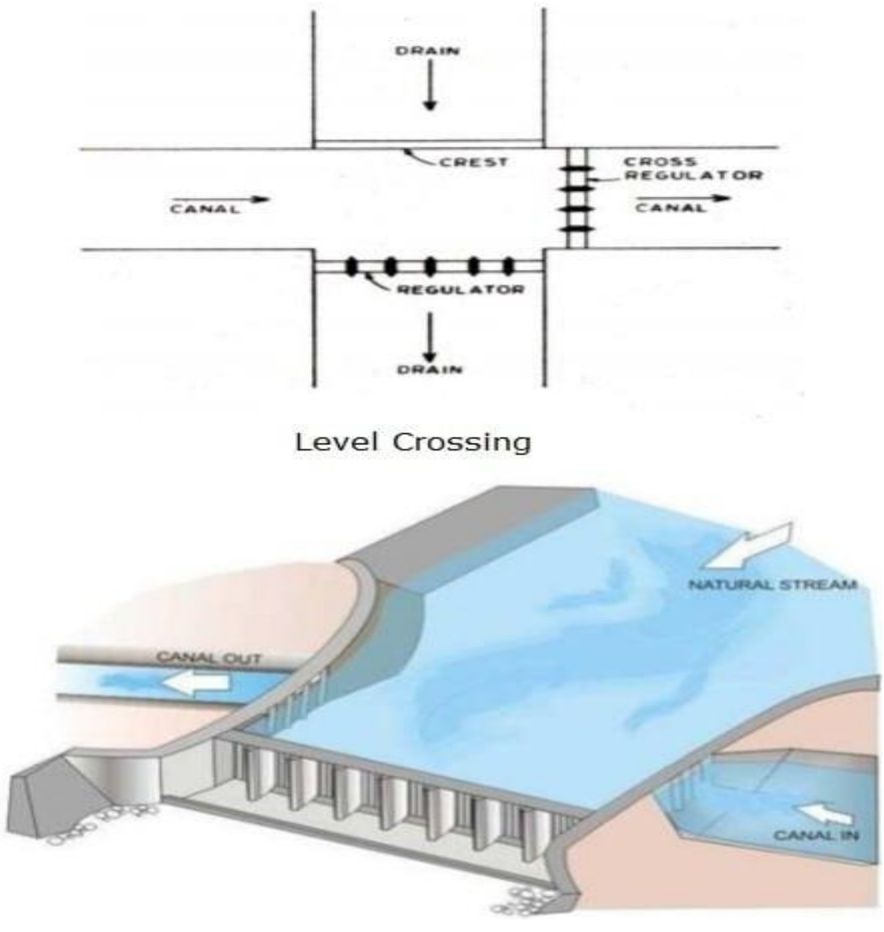


Figure (e) Level crossing

9.7 Canal inlets:

In a canal inlet structure, the drainage water to be admitted into canal is very less. The drainage is taken through the banks of a canal at inlet. And then this drainage mixed with canal travels certain length of the canal, after which an outlet is provided to create suction pressure and suck all the drainage solids, disposing it to the watershed area nearby.

There are many disadvantages in use of canal inlet structure, because the drainage may pollute canal water and also the bank erosion may take place causing the canal structure deteriorate so that maintenance costs are high. Hence this type of structure is rarely constructed.

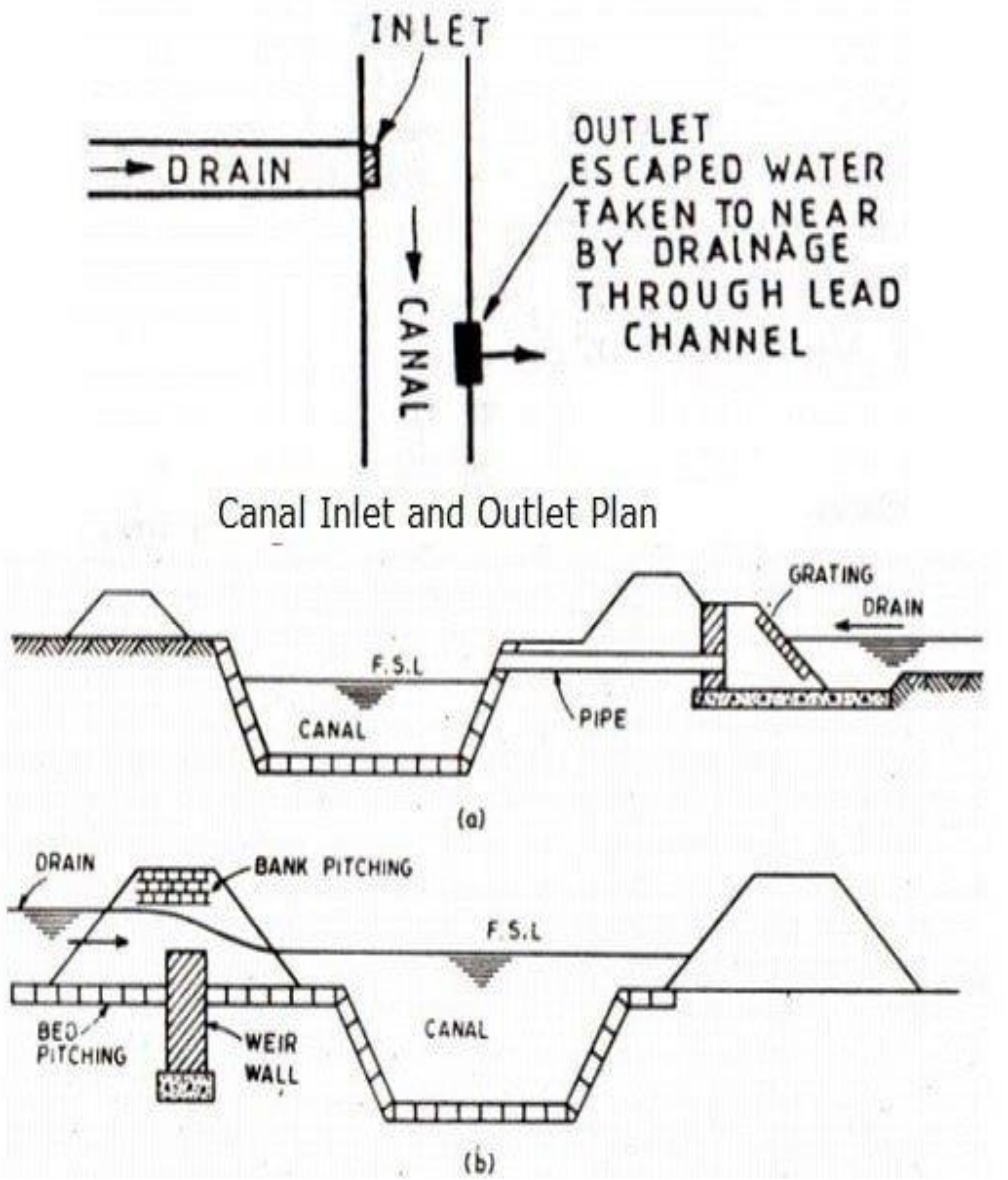


Figure (f) Canal inlet plan and cross sectional views (a) pipe type (b) open cut type

9.8 Selection of Site

The selection of a particular type of cross drainage work and the selection of its site depends upon various factors which can be summarized as follows:

i. Nature of the foundation available at site.

ii. Existing condition of a natural drain.

iii. Bed levels of the irrigation canal and the drain.

iv. Relative water levels of the canal and the drain.

v. Magnitude of the drain and the irrigation canal.

vi. Angle of crossing of the canal and the drain.

vii. Other available constructional facilities.

Usually the canal and the drain should cross each other at right angles. If such a crossing is not available the alignment of the canal may be altered to achieve normal crossing. When the drainage is much bigger in size in comparison with the canal it is advisable to allow the drain to flow unaltered. When the bed level of the canal is sufficiently higher than the High Flood Level (HFL) of the drain aqueduct should be constructed.

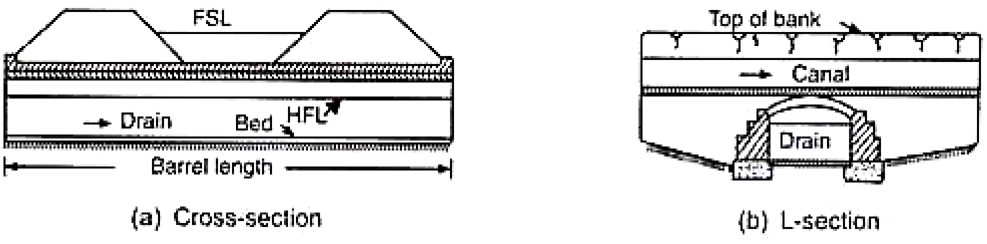


Fig. 12.15. Aqueduct with unobstructed canal

Alternatively when bed level of the drain is sufficiently higher than the Full Supply Level (FSL) of the canal super-passage may be constructed.

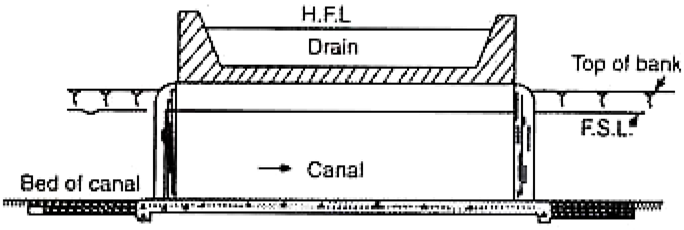


Fig. 12.16. Super-passage

When the level clearances are not sufficient for such crossings bed level of the conveyance channel passing at a lower level can be depressed at the crossing to lower the water level suitably. Such lowering is possible in case of aqueduct as well as super- passage. It is then called syphoning. To increase the clearances the alignment of the canal can be taken upstream or downstream of the drain as the situation demands.

When the drain is too big to be interfered with and levels so permit level crossing may be provided. In such a situation canal water is dropped in the drain/river from one bank and the canal is again taken-off from the other bank. This arrangement, however, requires an assemblage of hydraulic structures similar to and as big as any diversion headwork's.

INTERNATIONAL INSTITUTE OF TECHNOLOGY & MANAGEMENT, MURTHAL SONEPAT

E-NOTES

SUBJECT: IRRIGATION **SUBJECT CODE: -**

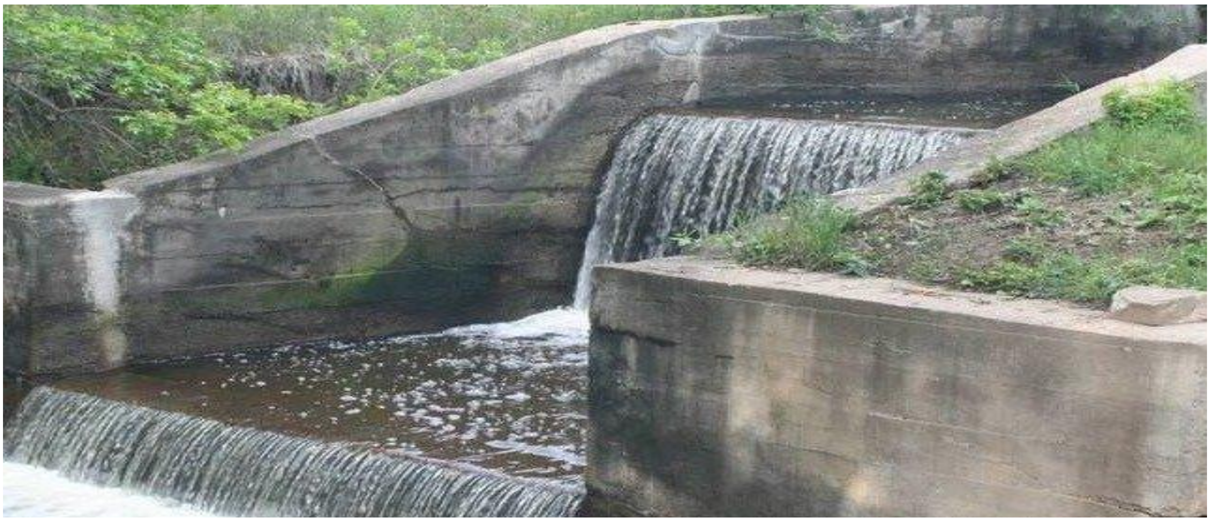
COURSE- DIPLOMA **BRANCH: CIVIL ENGINEERING**

SEMESTER 4TH **CHAPTER NAME: DESIGN OF HYDRAULIC STRUCTURES**

(PREPARED BY: Mr. ANKUR CHAUHAN, LECTURER, CE)

10.1 Canal Fall

Canal fall is a solid masonry structure which is constructed on the canal if the natural ground slope is steeper than the designed channel bed slope. If the difference in slope is smaller, a single fall can be constructed. If it is of higher then falls are constructed at regular suitable intervals.



10.2 Location of Canal Falls

Location of canal fall depends upon the following factors

1. Topography of canal
2. Economy of excavation or filling

The above two will decide the location of canal fall across canal. By understanding topographic condition we can provide the required type of fall which will give good results. At the same time, the provided falls is economical and more useful. So, economical calculation is also important. Unbalanced earth work on upstream and downstream result the project more uneconomical.

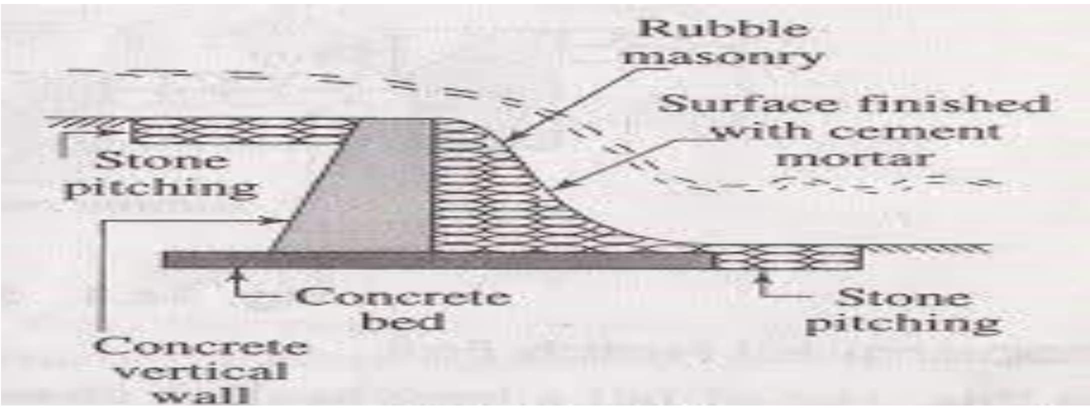
10.3 Types of Canal Falls and their Importance

The important types of falls which were used in olden days and those which are being used in modern days are described below:

- Ogee falls
- Rapids
- Stepped falls
- Trapezoidal notch falls
- Well type falls
- Simple vertical drop falls
- Straight glacis falls
- Montague type falls
- English falls or baffle falls

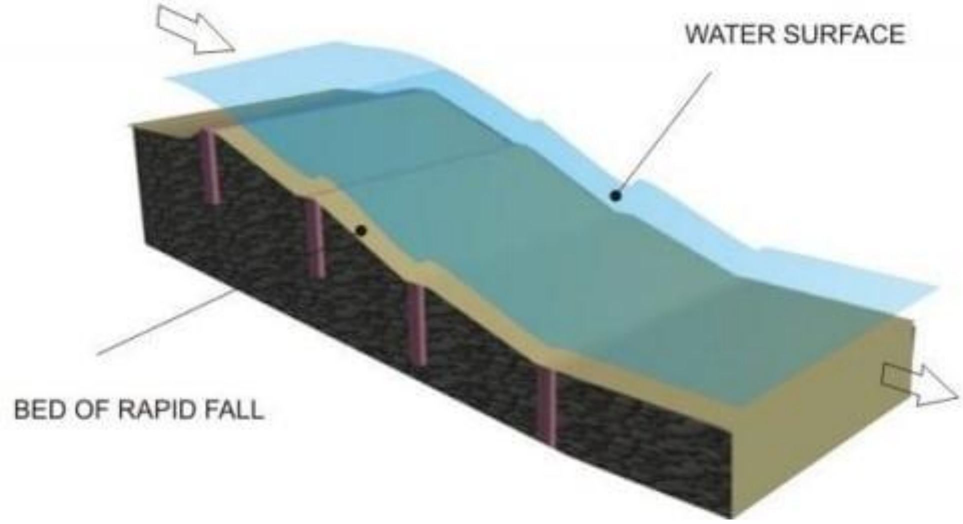
Ogee Canal Falls

Ogee curve is the combination of convex and concave curves. So, Ogee fall consists of both convex and concave curves gradually. This gradual combination helps to provide smooth transition of flow and also reduce the impact. If the canal natural ground surface is suddenly changed to steeper slope, ogee fall is recommended for that canal. Stone pitching is provided in the upstream and downstream of the fall.



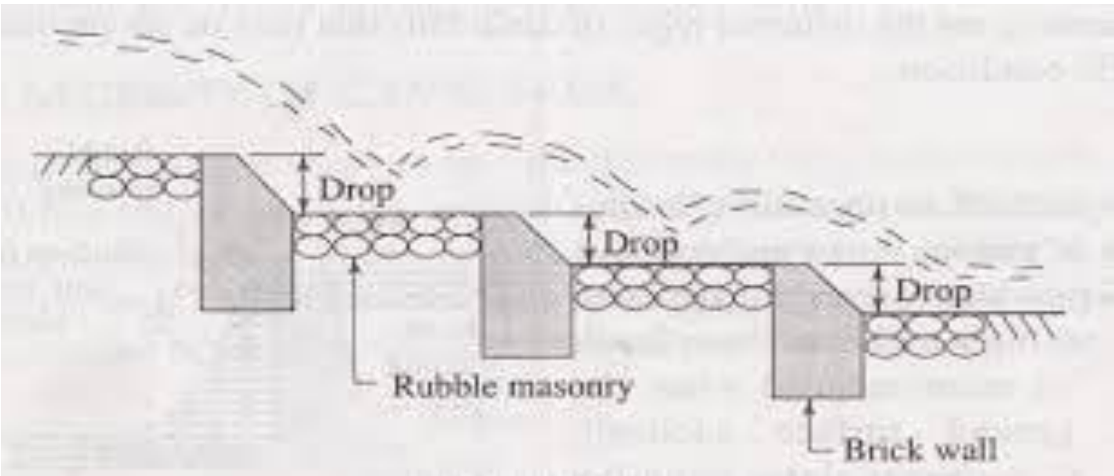
Rapid Canal Falls

Rapid fall consists a long sloping glacis. It is constructed if the available natural ground surface is plane and long. For this, a bed of rubble masonry is provided and it is finished with cement mortar of 1:3 ratio. To maintain the slope of bed curtain walls are provided at both upstream and downstream. Rapid falls are high priced constructions.



Stepped Canal Falls

As in the name itself, stepped fall consist vertical steps at gradual intervals. Stepped fall is the modification of rapid fall. It is suitable for the canal which has it upstream at very high level as compared to downstream. These two levels are connected by providing vertical steps or drops as shown in figure.

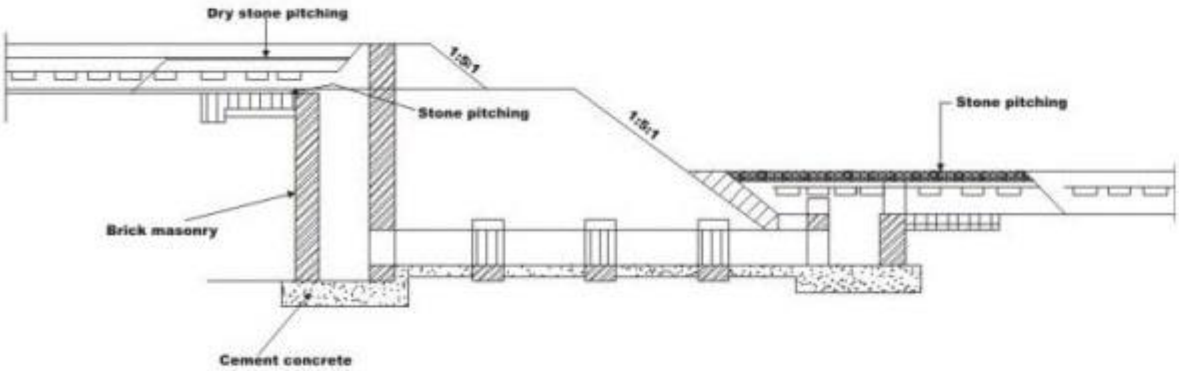


Trapezoidal Notch Canal Falls

In case of trapezoidal notch falls, a high crested wall is built across the channel and trapezoidal notches are provided in that wall. Trapezoidal falls are very economical and suitable for low discharges. Now a days this type of falls are using widely because of their simplicity and popularity.

Well Type Canal Falls

Well type falls are also called as syphon drop falls. In this case, an inlet well with pipe at its bottom is constructed in upstream. The pipe carries the water to downstream well or reservoir. If the discharge capacity is more than 0.29 cumecs then downstream well is preferred otherwise reservoir is suitable.



Simple Vertical Drop Falls (Sarda Type fall)

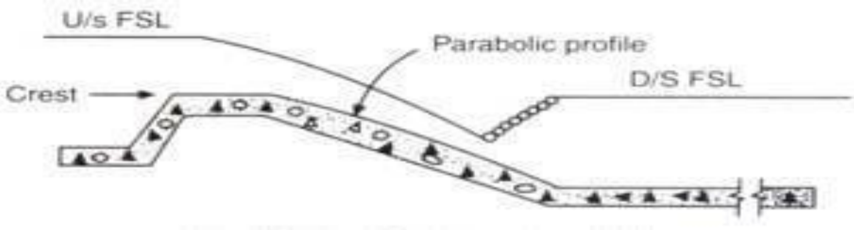
Simple vertical drop fall or sarda fall consists, single vertical drop which allows the upstream water to fall with sudden impact on downstream. The downstream acts like cushion for the upstream water and dissipate extra energy. This type of fall is tried in Sarda Canal UP (India) and therefore, it is also called Sarda Fall.

Straight Glacis Canal Falls

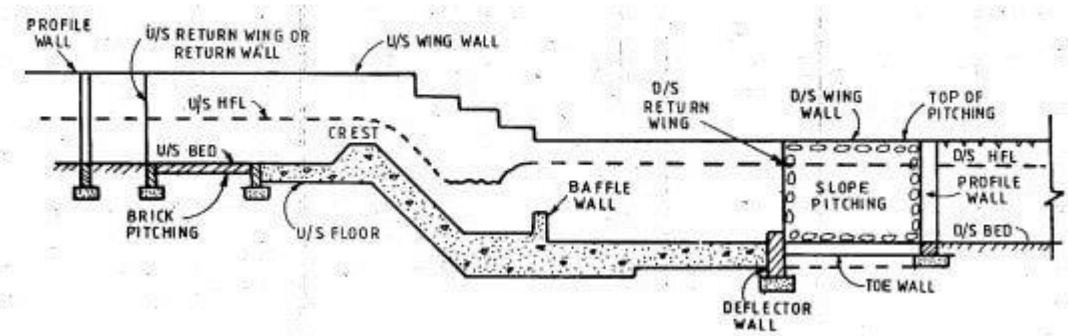
This is the modern type of construction, in which a raised crest is constructed across the canal and a gentle straight inclined surface is provided from raised crest to the downstream. The water coming from upstream crosses the raised crest and falls on inclined surface with sufficient energy dissipation.

Montague Type Canal Falls

Montage fall is similar to straight glacis fall but in this case the glacis is not straight. It is provided in parabolic shape to introduce the vertical component of velocity which improves the energy dissipation to more extent.



English or Baffle Canal Falls



In this case, straight glacis fall is extended as baffle platform with baffle wall. This is suitable for any discharge. The baffle wall is constructed near the toe of the straight glacis at required distance in designed height. The main purpose of the baffle wall is to create hydraulic jump from straight glacis to baffle platform.

10.4 REGULATORY WORKS:

Regulatory works are the hydraulic structures constructed across the canals to facilitate complete control over the flow of water in the irrigation canals.

The regulatory works are constructed to perform following functions:

1. A regulator regulates the flow of a canal by releasing measured quantity of water in the canal.

2. A fall or a rapid corrects the bed slope of a canal and prevents the canal from going into excessive filling.

3. An escape is a surplussing channel which takes away excess flow from an irrigation canal.

4. A silt ejector or a sluice removes the deposited silt from an irrigation canal and keeps it clean.

5. An outlet releases measured discharge from a canal into a field channel for irrigating crops.

6. A flume and a gauge well helps in measuring the canal discharge at a desired point.

10.5 REGULATORS:

For equitable and efficient distribution of irrigation water it is very essential to regulate the supply. A hydraulic structure constructed to regulate the water supply is called a regulator. The regulators not only regulate the irrigation water supply but also control the silt entry into the canal.

To regulate the water supply it is essential to have various vent-ways. The vent-ways are provided by constructing abutments and piers in the canal cross section. The grooves are made in the piers and abutments in which shutters operate. They control the openings. To control silt entry the shutters are provided in tiers. The lower tier is usually kept closed. Thus sill of the regulator is raised. As a result only top layers of silt free water enters the canal through the regulator.

For efficient and successful regulation it is essential that a regulator should serve the purpose of a meter also.

For economy a road or a rail bridge, if any, should be combined with the regulator. As then the piers, abutments and the foundation work is common to both structures.

10.5.1 Depending upon the location of a regulator following broad classification of regulators may be recognised:

(i) Canal head regulator.

(ii) Canal cross regulator.

(iii) Distributary head regulator.

1. Functions of Head Regulators:

It is a structure constructed at the entrance (the head) of the canal where it takes off from the river.

The regulator serves the following purposes:

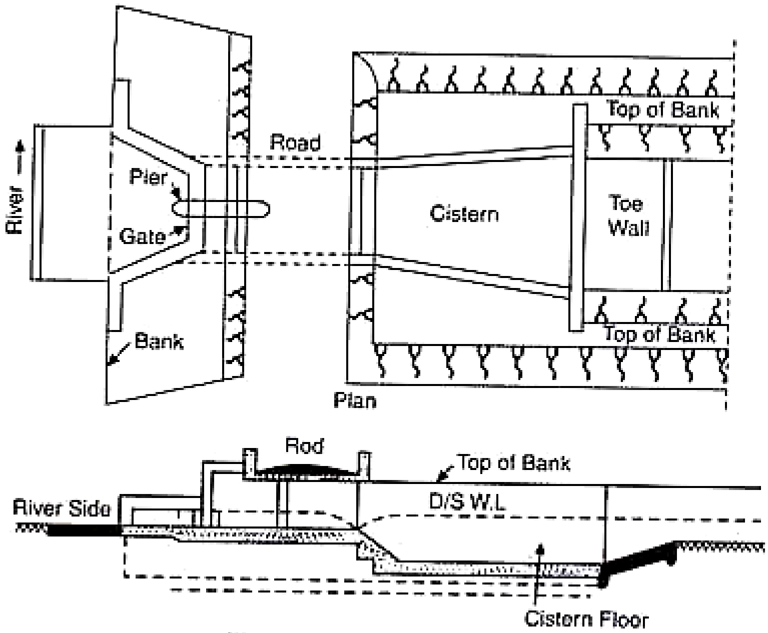


Fig. 12.11. Head regulator

i. It regulates the flow of irrigation water entering into the canal.

ii. It can be used as a meter for measuring the discharge.

iii. It regulates and prevents excessive silt entry into the canal.

It consists of a raised crest with abutments on both sides. The crest may be subdivided in various bays by providing piers on the crest. The piers support roadway and a platform for operating gates. The gates control the flow over the crest. They are housed and operated in grooves made in the abutments and piers. Sill of the regulator crest is raised to prevent silt entry. Sometimes the gates are provided in tiers. Then lower tiers may be kept closed to raise the sill of the regulator.

The head regulator is generally constructed with masonry. It should be founded on a good rock foundation. It should be safe against shear, sliding and overturning. It should be flanked with adequate wing walls. The head regulator should also be given proper protection by providing aprons on upstream and downstream side of the barrel. To prevent seepage cutoff is also essential. To take irrigation water at low velocities waterway of the head regulator should be sufficiently big.

2. Functions of Cross Regulator:

It is a hydraulic structure constructed across the canal to regulate the irrigation water supplies. It may be constructed across any type of canal main, branch or a distributary.

Following considerations make it necessary to construct a regulator across the canal:

(i) When due to inadequate supply the water level is lowered the off-taking channels do not get their proper share. A cross regulator is provided to raise the water level.

(ii) Sometimes it becomes necessary to carry out some necessary to carry out some repair works on a canal. The cross regulator if existing above that reach of the canal, it can be closed and repairs can be done efficiently.

(iii) Sometimes it is necessary to close the canal below a particular point. Say when there is no demand for irrigation water during a particular period.

(iv) When the costly headwork's are not constructed in the initial stages, the cross-regulator helps in regulating the canal supplies.

(v) Cross regulators divide long canal reach into smaller ones and make it possible to maintain the reach successfully and efficiently. For efficient functioning they should be spaced 10 to 13 km apart on the main canal and 7 to 10 km on the branches.

A cross-regulator is often combined with rail or a road bridge. When a fall is available on the canal the cross regulator is constructed as a fall-regulator. The cross- regulator may be flumed at the site. It is similar in construction to the head regulator.

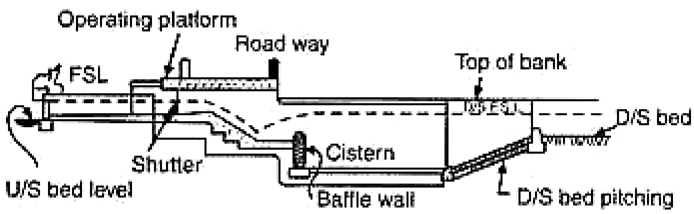


Fig. 12.12. Fall combined with a cross-regulator

3. Functions of Distributary Head Regulator:

It is a hydraulic structure constructed at the head of a distributary. This regulator performs the same functions as that of a head regulator.

i. It regulates the supply of the distributary.

ii. It can be used many times as a meter.

iii. It is also a silt selective structure.

iv. Distributary head regulator controls the flow in the distributary. By closing the gates distributary can be dried to carry out repairs or maintenance works.

The points to be considered in design are similar to those considered in the design of a head regulator. Only difference is that the distributary head regulator is much smaller in magnitude as compared to the head regulator. Figure 12.13 shows sectional end view of a distributary head regulator.

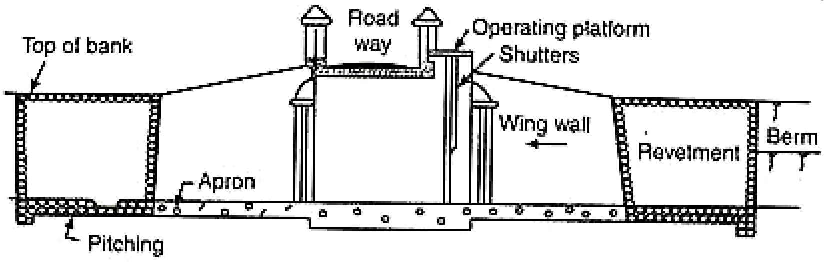


Fig. 12.13. Distributary head regulator

10.6 Canal Escape:

Canal escape is a structure to dispose of surplus or excess water from a canal. A canal escape essentially serves as a safety valve for the canal system. It provides protection of the canal against possible damage due to excess supplies which may be on account of either a mistake in releasing water at head-works, or a heavy rainfall due to which there may be sudden reduction in demand and the cultivators, therefore, close their outlets.

The excess supply makes the canal banks vulnerable to breaches or dangerous leaks and, hence, provision for disposing of excess supply in the form of canal escapes at suitable intervals along the canal is desirable. Besides, emptying of canal for repairs and maintenance and removing a part of sediment deposited in the canal can also be carried out with the help of the canal escapes.

The escapes are usually of the following types:

(i) Weir or surface escape:

These are weirs or flush escapes constructed either in masonry or concrete with or without crest shutters which are capable of disposing of surplus water from the canal.

(ii) Sluice escapes:

Sluices are also used as surplus escapes. These sluices can empty the canal for repairs and maintenance and, in some cases, act as scouring sluices to facilitate removal of sediment. Location of escape depends on the availability of suitable drains, depressions or rivers with their bed level at or below the canal bed level for disposing surplus water through the escapes, directly or through an escape channel.

10.7 Canal Outlets:

When the canal water has reached near the fields to be irrigated, it has to be transferred to the watercourses. At the junction of the watercourse and the distributary, an outlet is provided. An outlet is a masonry structure through which water is admitted from the distributary into a watercourse.

It also acts as a water-measuring device. The discharge though an outlet is usually less than 0.085 m^3/s. It plays a vital role in the warabandi system of distributing water. Thus, an outlet is like a head regulator for the field channel.

Canal outlets are of the following three types: 1. Non-Modular Outlets 2. Semi-Modular Outlets 3. Modular Outlets.

Type 1. Non-Modular Outlets:

In non-modular canal outlets, discharge capacity depends on the difference of water levels in the distributary and the watercourse. The discharge through non- modular outlets fluctuates over a wide range with variations in the water levels of either the distributary or the watercourse. The non-modular canal outlet is controlled by a shutter at its upstream end. Loss of head in non-modular outlet is less than that in a modular outlet.

Hence, non-modular canal outlets are very suitable for low head conditions. However, in non-modular canal outlets, the discharge may vary even when the water level in the distributary remains constant. Hence, it is very difficult to ensure equitable distribution of water at all outlets at times of keen demand of water.

The non-modular canal outlet is usually in the form of a submerged pipe outlet or a masonry sluice which is fixed in the canal bank at right angle to the direction of flow in the distributary. The diameter of the pipe varies from 10 to 30 cm. The pipe is laid on a light concrete foundation to avoid uneven settlement of the pipe and consequent leakage problems.

The pipe inlet is generally kept about 25 cm below the water level in the distributary. When considerable fluctuation in the distributary water level is anticipated, the inlet is so fixed that it is below the minimum water level in the distributary.

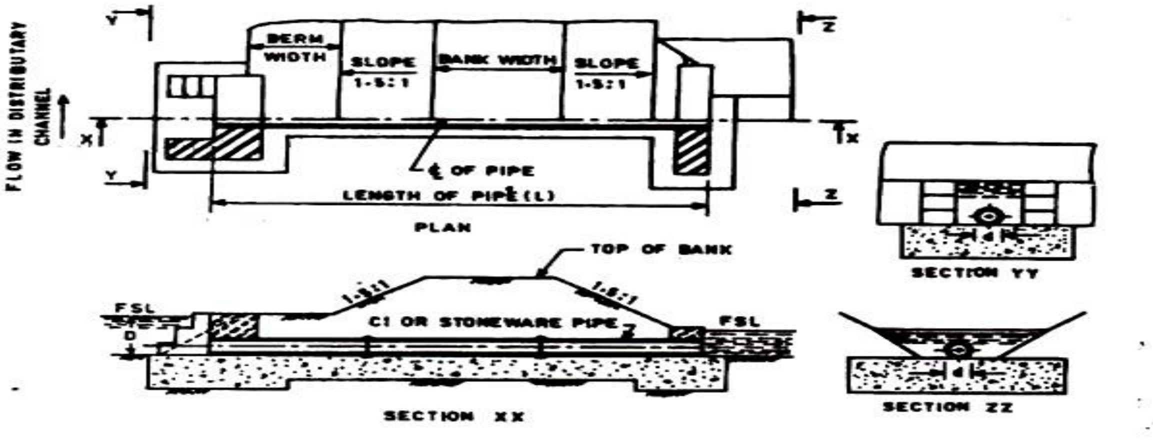


Fig. 7.9 Pipe outlet

Obviously, the discharge through non-modular outlets varies with water levels in the distributary and the watercourse. In case of fields located at high elevations, the watercourse level is high and, hence, the discharge is relatively small. But in case of fields located at low elevations, the discharge is relatively larger due to lower water course levels.

Further, depending upon the amount of withdrawal of water in the head reaches, the tail reach may be completely dry or get flooded. The discharge through pipe outlets can be increased by deepening the watercourse and thereby lowering the water level in it. The discharge varies from outlet to outlet because of flow conditions and also at different times on the same outlet due to sediment discharge in the distributary channel.

As such, proper and equitable distribution of water is very difficult. These are serious drawbacks of pipe outlets. The non-modular outlets can, however, work well for low heads too and this is their chief merit. Pipe outlets are adopted in the initial stages of distribution or for additional irrigation in a season when excess supply is available.

Type 2. Semi-Modular Outlets:

The discharge through a semi-modular canal outlet (or semi-module or flexible outlet) depends only on the water level in the distributary, and is unaffected by the water level in the watercourse provided a minimum working head required for its working is available.

A semi-module is more suitable for achieving equitable distribution of water at all outlets of a distributary. The only disadvantage of a semi-modular canal outlet is that it involves comparatively greater loss of head.

The simplest type of semi-modular canal outlet is a pipe outlet discharging freely into the atmosphere. The pipe outlet described as non-modular outlet works as semi-module when it discharges freely into the watercourse. The exit end of the pipe is placed higher than the water level in the watercourse.

In this case, working head H is the difference between water level in the distributary and the centre of the pipe outlet. The discharge through the pipe outlet cannot be increased by the cultivator by digging the watercourse and, thus, lowering the water level of the watercourse. Other types of flexible outlets include Kennedy’s gauge outlet, open flume outlet and orifice semi-modules.

(i) Kennedy’s Gauge Outlet:

This outlet was developed by R.G. Kennedy in 1906. It mainly consists of an orifice with bellmouth entry, a long-expanding delivery pipe and an intervening vertical air column above the throat. The air vent pipe permits free circulation of air around the jet.

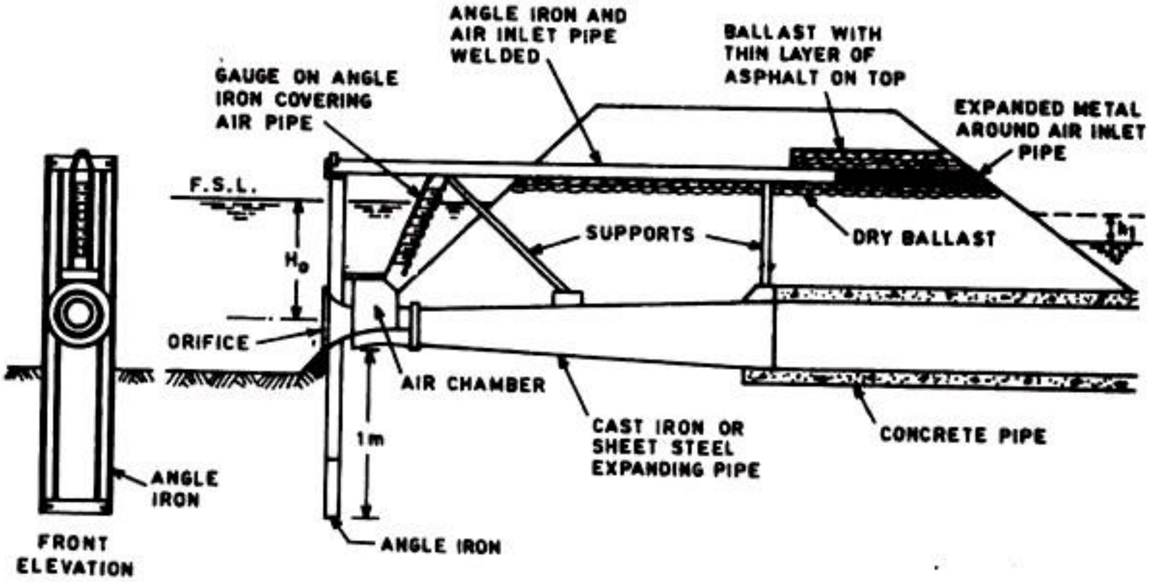


Fig. 7.10 Kennedy's gauge outlet

This arrangement makes the discharge through the outlet independent of the water level in the watercourse. The water jet enters the cast iron expanding pipe which is about 3 m long and at the end of which a cement concrete pipe extension is generally provided. Water is then discharged to the watercourse.

This outlet can be easily tampered with by the cultivator who blocks the air vent pipe to increase the discharge through the outlet. Because of this drawback and its high cost, Kennedy's gauge outlet is generally not used.

(ii) Open Flume Outlet:

An open flume outlet is a weir with sufficiently constricted throat to ensure supercritical flow, and long enough to ensure that the controlling section remains within the throat at all discharges up to the maximum. A gradual expansion is provided downstream of the throat. The entire structure is built in brick masonry, but the controlling section is generally provided with cast iron or steel bed and check plates.

This arrangement ensures the formation of hydraulic jump and hence the outlet discharge remains independent of the water level in the watercourse. Figure shows an open flume outlet which is commonly used in Punjab. The discharge through the canal outlet is proportional to $H^{3/2}$.

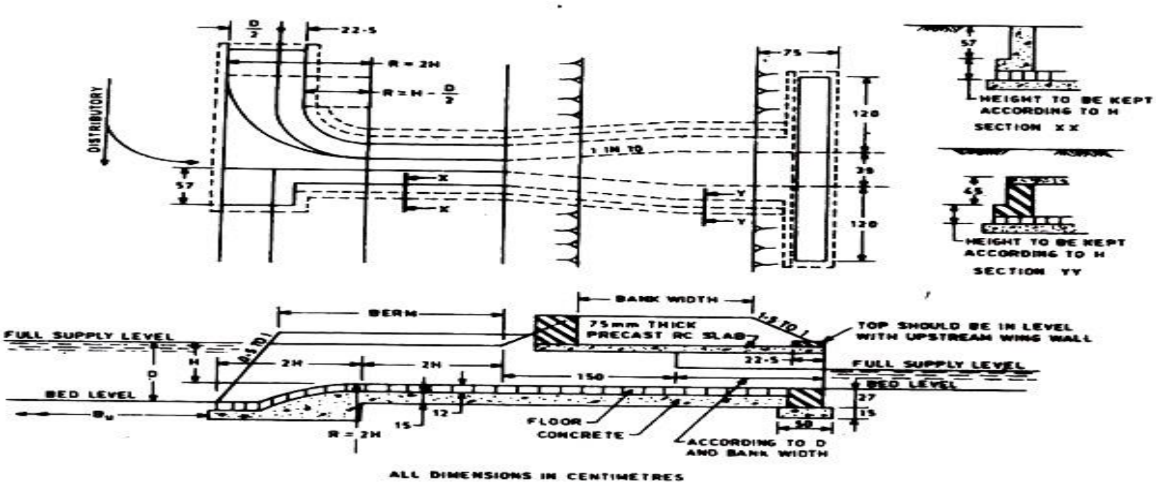


Fig. 7.11 Open flume outlet

(iii) Orifice Semi-Modules:

An orifice semi-module consists of an orifice followed by a gradually expanding flume on the downstream side. Supercritical flow through the orifice causes the formation of hydraulic jump in the expanding flume and, hence, the outlet discharge remains independent of the water level in the watercourse.

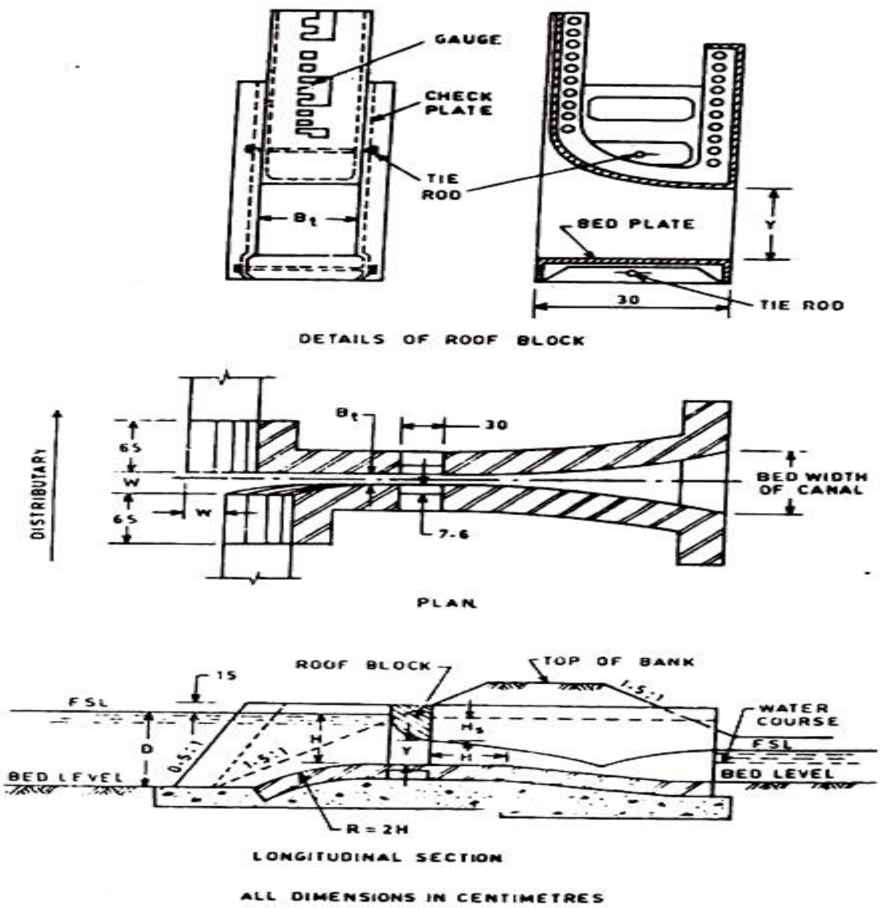


Fig. 7.12 Orifice semi-module

The roof block is suitably shaped to ensure converging streamlines so that the discharge coefficient does not very much. The roof block is fixed in its place by means of two bolts which are embedded in a masonry key. For adjustment, this masonry can be dismantled and the roof block is suitably adjusted.

After this, the masonry key is rebuilt. Thus, the adjustment can be made at a small cost. However, tampering with the outlet by the cultivators would be easily noticed through the damage to the masonry key. This is the chief merit of this outlet.

Type 3. Modular Outlets:

In modular canal outlets, the discharge is independent of the water levels in the distributary and the watercourse, within reasonable working limits. These outlets may have moving parts or may be without moving parts. In the latter case, these are called rigid modules. The modular canal outlets with moving parts are not simple to design and construct and are, hence, expensive.

A modular canal outlet supplies fixed discharge and, therefore, enables the farmer to plan his irrigation accordingly. However, in case of excess or deficient supplies in the distributary, the tail-end reach of the distributary may either get flooded or be deprived of water. This is due to the reason that the modular outlet would not adjust its discharge according to the level in the distributary.

But, if an outlet is to be provided in a branch canal which is likely to run with large fluctuations in discharge, a modular outlet would be an ideal choice. The outlet would be set at a level low enough to permit it to draw its due share when the branch is running with low supplies.

When the branch has to carry excess supplies to meet the demands of the distributaries, the discharge through the modular outlet would not be affected, and the excess supplies would reach up to the desired distributaries.

Similarly, if an outlet is desired to be located upstream of a regulator or a raised crest fall, a modular outlet would be a suitable choice. Most of the modular outlets have moving parts which make them costly to install as well as maintain.

Following two types of modular outlets (also known as rigid modules), however, do not have any moving part:

(i) Gibb’s rigid module

(ii) Khanna’s rigid module

(i) Gibb’s Rigid Module:

This module has an inlet pipe under the distributary bank. This pipe takes water from distributary to a rising spiral pipe which joins the eddy chamber. This arrangement results in free vortex motion. Due to this free vortex motion, there is heading up of water (due to smaller velocity at larger radius—a characteristic of vortex motion) near the outer wall of the rising pipe. The water surface, thus, slopes towards the inner wall.

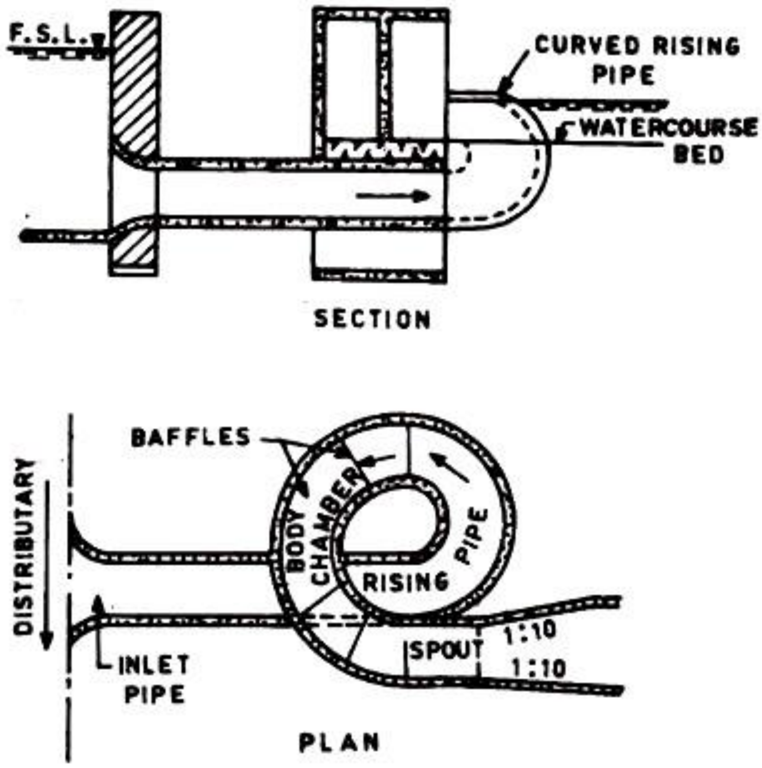


Fig. 7.13 Gibb's rigid module

A number of baffle plates of suitable size are suspended from the roof of the eddy chamber such that the lower ends of these plates slope against the flow direction.

With the increase in head, the wafer bank up at the outer wall of the eddy chamber and impinges against the baffles and spins round in the compartment between two successive baffle plates. This causes dissipation of excess energy and results in constant discharge. The outlet is relatively more costly and its sediment withdrawal is also not good.

(ii) Khanna's Rigid Orifice Module:

This canal outlet is similar to an orifice semi-module. But it has, in addition, sloping shoots fixed in the roof block. These shoots cause back flow and, thus, keep the outlet discharge constant.

If the water level in the distributary is at or below its normal level, the outlet behaves like an orifice semi-module. But when the water level in the parent channel is above its normal level, water level rises in chamber A and enters the first sloping shoot. This causes back flow and dissipates additional energy.

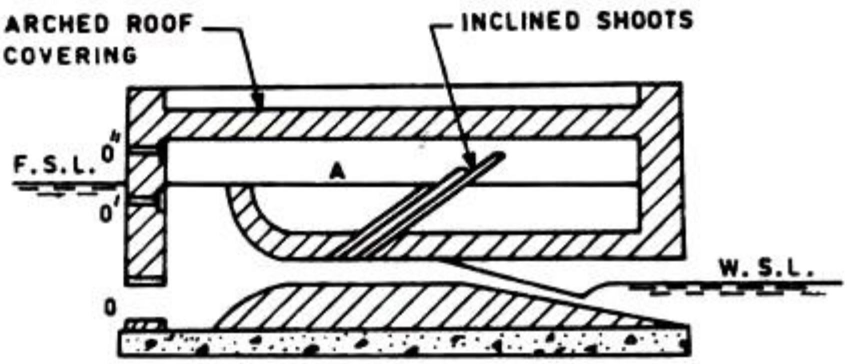


Fig. 7.14 Khanna's rigid module

This results in maintaining a constant discharge. The number of sloping shoots and their height above the normal level can vary to suit local requirements. The shoots are housed in a chamber so that these cannot be tampered with. If the shoots are blocked, the outlet continues to function as a semi-module.

INTERNATIONAL INSTITUTE OF TECHNOLOGY & MANAGEMENT, MURTHAL SONEPAT

E-NOTES

SUBJECT: IRRIGATION **SUBJECT CODE: -**

COURSE- DIPLOMA **BRANCH: CIVIL ENGINEERING**

SEMESTER 4TH **CHAPTER NAME: RIVER TRAINING WORKS**

(PREPARED BY: Mr. ANKUR CHAUHAN, LECTURER, CE)

11.1 RIVER TRAINING

River training includes all such measures as are taken for controlling and regulating river flow and river configuration. River training works are constructed either across a river, or along it. River training structures include levees or embankments built along the river to contain floods, and spurs and guide banks are constructed for altering the local flow conditions and guiding the flow. Besides, a river can be dredged to train it for navigation purposes. A river can also be trained by diverting its flow into a secondary channel or by executing artificial cutoffs on the main river so as to cause reduction in flood levels. Bank protection measures are also included in river training methods.

11.2 Objectives of River Training

River training measures aim at achieving one or more of the following objectives:

(i) *Flood Protection*

River floods of very small frequency inundate the fertile and thickly-populated plains adjacent to the river, and, thus, cause considerable loss to human life, property, agriculture, and public and private utilities.

During the years of large floods, damage is likely to be several times more. Flood control measures for thickly-populated flood plains, therefore, become essential, even if these measures do not assure complete protection under all conditions. River training for flood protection, also known as 'high water training' or 'training for discharge,' is achieved by one or more of the following four methods:

(a) Construction of levees or embankments to confine water in a narrower channel,

(b) Increasing the discharge capacity of natural channels by some means such as straightening, widening or deepening,

(c) Provision of escapes or diversion from the main channel into an auxiliary channel for water in excess of the carrying capacity of the main channel, and

(d) Construction of reservoirs.

***(ii)** Navigation*

For a river to be navigable, sufficient depth and width required for navigation should be available even at low water level in the river. River training for navigation is also known as 'low water training' or 'training for depth'. Measures to achieve adequate depth in a river for navigation include dredging the shallow reaches of the river and using spurs to contract the river channel, thus, increasing its depth. Sometimes, low flow is supplemented from another source to achieve the desired depth and width. Canalisation makes a non-navigable river navigable, and, is accomplished by building a series of small dams or weirs and locks. Sharp curves along the river need to be eliminated so that ships can move easily.

***(iii)** Sediment Control*

River training for sediment control is also called 'mean water training' or 'training for sediment'. This type of training aims at rectification of river bed configuration and efficient movement of
sediment load for keeping the channel in a state of equilibrium (3). River training methods for this purpose involve construction of such structures which would induce the desired local curvature to the flow. Spurs and pitched islands are normally used for training the river for sediment.

***(iv)** Guiding the Flow*

Hydraulic structures, such as canal headworks, and communication structures such as bridges, have to be protected against outflanking and the direct attack of flow. This requires training of the river over its considerable reach by building a system of guide banks, known as Bell's guide banks, on one or both sides of the stream at the bridge site. The purpose of these guide banks is to make sure that water flows between the abutments of the bridge. The spacing between these guide banks conforms to the width required for the river to pass the design flood discharge. Similarly, guide banks are provided to guide the flow at the weir site. Marginal bund and lateral spurs guide the flow through the guide banks.

Sometimes the flow in a river needs to be deflected away from a bank in order to protect some portions of the river bank or for contracting the river. This is done by constructing one or more spurs projecting into the river from its banks.

***(v)** Stabilisation of River Channel*

Weak river banks, which are likely to cave in or get eroded, need to be protected by training methods, such as stone pitching, lining, and so on. In some cases, the stability of the bed may also be endangered in some reaches due to increase in the bed shear on account of local flow conditions.

11.3 RIVER TRAINING METHODS

The planning and design of river training structures is accomplished by using empirical methods and reliance has to be placed on the intuition and judgement of experienced engineers. Model investigations are also resorted to for finalising the plans and design of river training structures. Commonly used methods of river training have been briefly described in the following sections.

11.3.1 Levees

A levee (also known as an embankment, bund, marginal bunds or dike) is an embankment running parallel (or nearly so) to the river and is constructed to protect the area on one side of it from flooding. The method of constructing levees on one or both sides of a river to contain the flood within the leveed portion is the oldest and most commonly used method of flood control. Levees along the Nile river in Egypt were constructed prior to 600 BC. Levees have been constructed recently on many important rivers of the world such as the Ganga, the Kosi, the Mahanadi and the Gandak in India, the Yellow, the Pearl, the Yangtze and the Huai in China, the Mississippi in the USA, and the Danube and the Rhine in Europe.

The alignment of levees for a river is decided by the location of important cities, industries, and other areas along the river which need to be protected against floods. Closely-spaced levees will be very high and, hence, massive and uneconomic. Hence, levee spacing is also governed by economic considerations. Levees should be located farther apart considering: (*i*) the desirability of having high discharge capacity of river for a given stage, and (*ii*) the requirement that the entire meander belt be within the levees so that they are not strongly attacked by the river. The levees should, obviously, have the general curvature of the river so that the river does not attack the levees.

The design of a levee is similar to that of an earth dam. It should, however, be noted that while the upstream face of an earth dam is exposed to water most of the time, that of a levee is exposed to water for a very short period during the flood season only. The top width of a levee is generally kept between 3 to 8 m or more depending upon the levee height. The levee height is decided such that the levee is able to contain a flood of a reasonable return period of, say about 500 years (5). The flood stage at any section of a river corresponding to such a flood can be obtained by routing the flood through the river.

One of the major effects on regime of river due to levee construction is the reduction in the river width and, hence, increase in velocity of flow. As such, the sediment, which would have deposited on the river bed/flood plains in the absence of levees, is now carried downstream and deposited either in an unleveled portion or in the sea. Other effects of confining the flood within levees are as follows:

- Increase in the rate of travel of flood wave in the downstream direction,
- Rise in the water surface elevation in the river during flood,
- Reduction of storage and, hence, an increase in the maximum discharge downstream, and
- Decrease in the water surface slope of the stream above the leveed portion as a result of which aggradation occurs upstream of the leveed reach.

Failure of levees can be due to one or more of the following causes:

(i) Overtopping,
(ii) Erosion of riverside slope by river current,
(iii) Caving in of the banks,
(iv) Infiltration through the foundation,
(v) Infiltration through the embankment,

(vi) Leaks as a result of holes dug by rats, crabs, and white ants, or from rotten roots and cracks due to shrinkage of soil,

(vii) Loosening of the embankment by wind action on large trees planted on it, and

(viii) Human action.

11.3.2 Spurs

Spurs (also known as groynes, spur dikes, or transverse dikes) are structures constructed in a river transverse to the river flow, extending from the bank into the river (3). Spurs guide the river flow, promote scour and deposition of the sediment where desired, and trap the sediment load to build up new river banks. Spurs are generally made from locally available earth. The nose (or head) and the sloping faces of the spurs must be protected against wave action by hand-placed rubble facing. Stone apron is provided to prevent the failure of spurs due to excessive scour at the nose and sides. Spurs are probably the most widely used river training structures and serve the following function in river regulation:

(i) Training a river along the desired course by attracting, deflecting or repelling the flow in the river channel,

(ii) Creating a slack flow with the object of silting up the area in the vicinity of spur,

(iii) Protecting the river bank by keeping the flow away from it, and

(iv) Contracting a wide river channel for the improvement of depth for navigation.

Spurs can be used either singly or in series or in combination with other river training measures. The design of spur depends on the following:

(i) River discharge,

(ii) Angle of attack,

(iii) Sediment load,

(iv) Meander length,

(v) Curvature of the river, and

(vi) Upstream and downstream river training measures.

Spur length is usually restricted to less than 20% of the river width to avoid adverse effects on the opposite bank and, at the same time, the spur length is kept longer than 1.5 to 2 times the depth of flow (13). Shorter spur length in deeper rivers induces swirling motion on both the upstream and downstream sides of the spur. This swirling motion may extend up to the adjacent river bank and cause the bank erosion necessitating bank protection measures. The spacing of spurs in a wide river is larger than that in a narrower river for similar conditions. A larger spacing can be satisfactory for convex banks and a smaller spacing is desirable at concave banks. At crossings (*i.e.*, the straight reach between two consecutive bends of a river), an intermediate spacing can be adopted. Spacing between adjacent spurs is generally kept between 2 and 2.5 times the spur length (14). Ahmad (15) has suggested that spurs used for bank protection be spaced at five times their length. However, spurs used in navigation channels are generally spaced at 0.75 to 2 times their length (16). Maintenance of the nose of longer spurs during floods would generally be difficult as has been experienced in the past on the rivers Kosi and Gandak. Moreover, a longer spur would result in relatively higher afflux on the upstream side of the spur and may induce excessive seepage through the spur which may lead to piping and breach in the spur. Such breaches have indeed occurred in the rivers Kosi and Gandak.

It is always advisable to finalise the spur designs only after conducting model studies.

Spurs can be classified as follows:

(i) Classification based on the methods and material of construction : permeable and impermeable.
(ii) Classification based on the height of the spur with respect to high flood level : Sub- merged and non-submerged.
(iii) Classification based on the functions : attracting, deflecting, repelling and sedimenting, and
(iv) Special types : Denehy's T-headed groynes, hockey type, *etc.*

11.3.3 Pitched Islands

A pitched island is an artificially created island in the river bed. It is protected by stone pitching on all sides. A pitched island is constructed with sand core and boulder lining. To protect it from scouring, a launching apron is also provided. The location, size, and shape of pitched islands are usually decided on the basis of model studies. Pitched islands serve the following purposes:

- Correcting an oblique approach upstream of weirs, barrages, and bridges by training the river to be axial,
- Rectifying adverse curvature for effective sediment exclusion,
- Redistributing harmful concentration of flow for relieving attack on marginal bunds, guide banks, river bends, *etc.*, and
- Improving the channel for navigation.

A pitched island causes scour around it and, thus, redistributes the discharge on its two sides. Pitched islands upstream of barrages and weirs have been found to be quite effective.

11.3.4 Cutoffs

Cutoffs can be defined as a process by which an alluvial river flowing along curves or bends abandons a particular bend and establishes its main flow along a comparatively straighter and shorter channel. During the development of meanders, there is always a lateral movement of the meanders due to their gradual lengthening. Increased frictional losses and bank resistance tend to stop this lateral movement. When the bend and the bank resistance become too large for continued stretching of the loop, the flow finds it easier to cut across the neck than to flow along the loop. This results in a cutoff. Cutoff is, thus, a natural way of counter- balancing the effect of the ever-increasing length of a river course due to the development of meanders. Usually, a river has shallow side channels within the neck of the meander loop. These side channels may either be part of the main channel of an earlier river course or are formed by floods spilling over the banks of the river channel. Cutoffs can develop along these shallow side channels. Alternatively, cutoff may be artificially induced for some other purpose.

Whenever a river succeeds in establishing a cutoff, there follows a period of non- equilibrium for long distances upstream and downstream of the newly-formed channel. Banks start caving in and new channels are formed while some other channels get silted up. Only after a couple of floods, the equilibrium is, once again, established.

Sometimes it is advantageous to make a controlled artificial cutoff to avoid the chaotic or non-equilibrium conditions when a natural cutoff develops. An artificial cutoff reduces flood levels and flood periods. Artificial cutoffs have been used to shorten the travel distance and increased ease of manoeuvring of boats along the bend during navigation. In such situations, use of training measures like groynes and revetment on banks usually becomes necessary to prevent bank erosion and arrest the natural tendency of the river to meander.

For inducting an artificial cutoff, a suitable pilot cut (or pilot channel) of small cross- section is initially made so as to carry 8 to 10 per cent of the flood discharge. The pilot channel is then allowed to develop by itself and sometimes such gradual development is assisted by dredging. Pickles (8) has made the following recommendations for design and execution of artificial cutoffs:

(i) The pilot channel should be tangential to the main direction of river flow approaching and leaving the cutoff.

(ii) The pilot channel is usually made on a mild curve, the curvature being less than the dominant curvature of the river itself.

(iii) Entrance to the pilot channel is made bell-mouthed. Such transition at the exit is considered unnecessary because the cut develops first at the lower end and works progressively upstream.

(iv) The cut, when unlikely to develop because of either coarseness of the material or low shear stress, should be excavated to average river cross-section.

(v) The width of the pilot cut is unimportant as the cut ultimately widens due to scouring. Hence, in practice, the width is determined by consideration of the type and size of the dredging equipment used.

(vi) When a series of cutoffs is to be made, the work should progress from the down- stream to upstream.

11.4 Embankments:

The floods may be prevented from submerging the country by constructing earth embankments. They are generally constructed up to a height of 12 m. They are designed and constructed in the same way as an earth dam. The embankments are generally constructed parallel to the river channel.

Depending upon the position of the embankments subdivisions made are:

i. Marginal embankments or dykes or levees,

ii. Retired embankments.

The marginal embankments are constructed as close to the banks as possible to restrict the flood water from submerging the area behind them. Figure shows the position of marginal embankments.

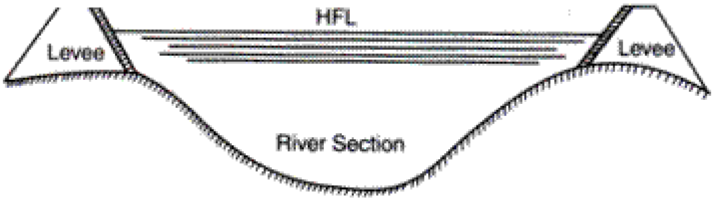


Fig. 14.4. Marginal embankments or levees

They are designed to hold up the water up to a maximum anticipated HFL without the possibility of overtopping and with a view to withstand all external pressures. This condition is met with by providing sufficient freeboard, bed width, top width and stone protection on adequate slopes.

As the height of the embankment increases it becomes necessary to provide key treach, zoned section etc., to make the embankment stable. Like earth dams embankments are also likely to fail due to overtopping, piping, rat holes, seepage and caving in of river side sloping face. It is therefore necessary to adopt adequate sections for various heights.

The following sections are generally adopted for various heights. (Fig):

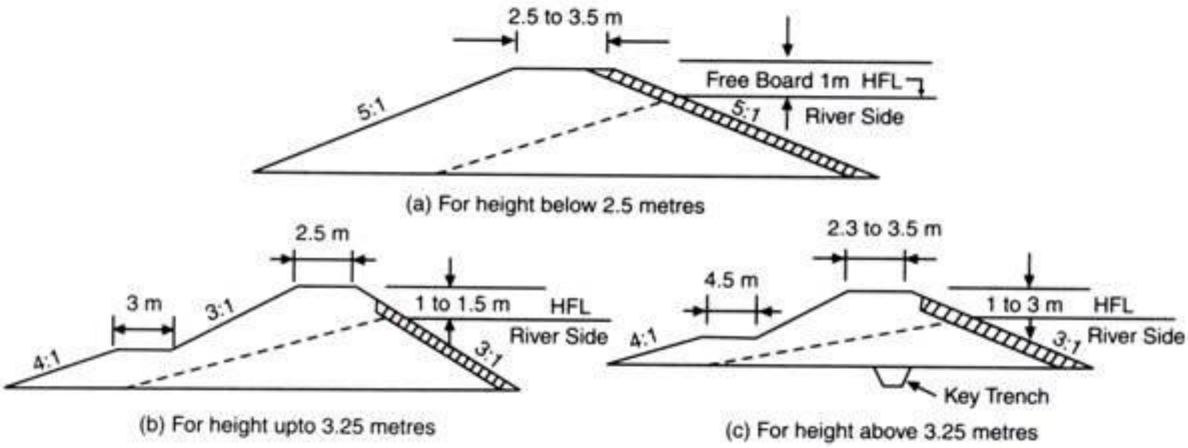


Fig. 14.5. Sections of marginal embankments

11.4.1 Advantages of Embankments:

(i) They are very widely used river training work.

(ii) It is cheaper and quick as well as simple in construction. They can be constructed with locally available material.

(iii) Maintenance of embankments is similar to canal bank maintenance and does not involve intricate methods.

(iv) Embankment can be constructed reach by reach to extend extent of protection.

(v) They protect large areas by comparatively small investment.

11.4.2 Disadvantages of Embankments:

(i) By restricting the waterway it raises the flood levels.

(ii) Unpredictable flood flows attack the embankment and hence chances of its failure are quite high.

(iii) During flood constant vigil is required on the embankments. It increases cost of maintenance.

(iv) They interfere in laying irrigation canal system and also reduce cultivable area.

Retired embankments are constructed at a distance from the river banks. Thus retired embankments are the intermediate type between the case of marginal embankments and river with no embankments. Retired embankments are generally constructed on a lower ground away from the banks.

Though they are costly due to increased height and risky, they have some mentionable advantages:

i. They do not interfere in the process of raising of the ground by deposition of silt.

ii. They make it possible to store more water for longer period.

iii. They provide wider waterway in times of high floods.

11.5 Guide Banks or Bell's Bunds:

Rivers in flood plains submerge very large areas during flood periods. Naturally when some structure is to be constructed across such a river (for example, bridge, weir, etc.), it is very expensive to construct the work spanning whole width of the river. To economies some training work may be constructed to confine the flow of water within a reasonable waterway.

Guide banks are meant for guiding and confining the flow in a reasonable waterway at the site of the structure. The design of the guide banks is based on the theory developed by Mr. Bells. Hence, guide banks are also known as Bell's bunds. This river training work has been devised from a study of the natural river channel in alluvial reach.

The river has a tendency to meander over large width of low lying land thereby flooding it occasionally. But it was observed that the same stream passes through narrow and deep sections where high and stiff permanent banks are available on either side without appreciable afflux or abnormal velocity.

The guide banks guide the river flow past a bridge or any other hydraulic structure without causing damage to the work and its approaches. The guide banks are constructed parallel or approximately parallel to the direction of flow. They extend both upstream and downstream of the abutments of the hydraulic structure. The guide banks may be provided on either side of the hydraulic structure or on one side as required.

The guide banks consist of four parts mainly:

i. Upstream curved head or impregnable head,

ii. Downstream curved head,

iii. Shank or a straight portion which joins the two curved heads, and

iv. Slope and bed protection, it includes apron.

Generally the core of the bund is built with sand. The sloping faces are protected with stones. An apron is also provided for protecting the bed against scouring. Sufficient freeboard and top width are also provided. The curved heads are laid with adequate curvature.

Guide banks mainly serve two purposes:

i. They protect the approach embankment for the bridge from attack of the water. Approach embankments extend from the bank of the river to the guide banks generally in perpendicular direction to both.

ii. They control the river and induce it to flow through the bridge more or less axially.

11.5.1 Selection of Site and Section of Guide Banks:

The site for guide banks should be selected in such a way that there is no side channel flowing parallel to the guide banks. The side channel if present may breach the approach embankment. The guide banks should be so designed that no swirls are produced.

The top width of bank should not be less than 3 m. Side slopes should be 2:1 and free board 1.25 to 1.50 meters. While providing the free board due weightage should be given for heading up of the water and also for settlement of banks (generally 10 per cent of height). The inside slope should be protected with stone pitching and outside slope with good earth.

The radius of curvature of the upstream curved head should be such as not to cause intense eddies. The radius of downstream curved head may be kept half that of upstream curved head. The heads should be curved well round to the back of the guide bank. Upstream curved head generally subtends an angle from 120° to 145° to the centre and downstream head from 45° to 90°. The upstream curved head is also called “impregnable head”.

To protect the face of the guide bank at the river bed level a thick stone cover is laid on the bed. It is called an apron. When the scour undermines the river bed the apron comes down or launches to cover the face of the scour. Hence it is called Launching apron also. The quantity of stone in the apron should be adequate to insure complete protection of the scoured face. Figure shows the details of a guide bank. After launching, the apron does not remain uniform in thickness.

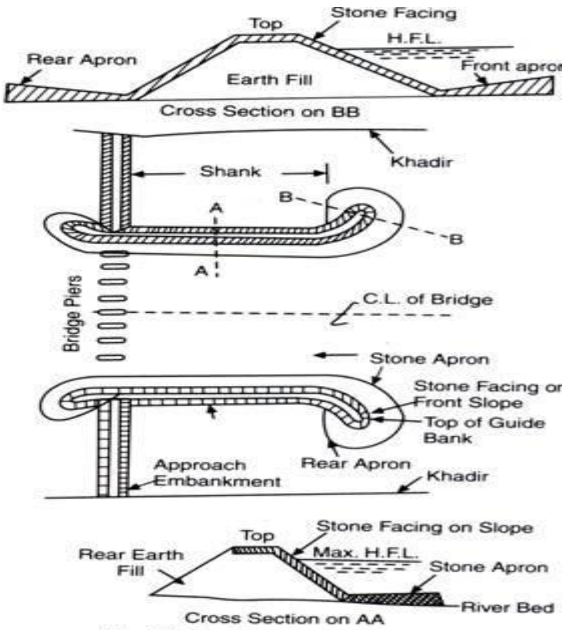


Fig. 14.7. Details of guide bank

11.6 Spurs or Groynes:

They are the structures constructed transverse to the river flow. They extend from the bank into the river.

Groynes serve following purposes:

a. They protect the river bank by keeping the flow away from it.

b. They create still pond along a particular bank with the aim of silting up the area in the vicinity.

c. They train the river to flow along a desired course by attracting, deflecting or repelling the flow.

d. They contract the wide river channel for improving the navigation depth.

Classification of Groynes:

Various classifications of spurs or groynes may be given as mentioned below:

1. Classification according to the method of construction.

(a) Permeable, and

(b) Impermeable.

2. Classification according to the height of the spur below high water.

(a) Submersible, and

(b) Non-submersible.

3. Classification according to the functions served.

(a) Attracting type,

(b) Deflecting type,

(c) Repelling type, and

(d) Sedimenting type.

4. Special type:

For example, Denehy's "T" headed groynes. Hockey spurs, etc. When a river is to be confined to a definite channel impermeable type of groyne is most suitable. For excessively silt-laden rivers permeable groynes are suitable. The groynes may be used singly or in series or in combination with other training work depending upon the problem in hand.

When training or protection is to be given over a long and straight river reach groynes are used in series. Spacing of 2 to 2.5 times the length of groynes is a general practice. In a curved reach river can be trained by limited number of spurs. They can also be used in combination with other training measures.

11.6.1 Impermeable Groynes:

The groynes may be aligned either perpendicular to the bank or inclined, pointing upstream or downstream. When a groyne points upstream then it is called a repelling groyne. The reason being, this type has a property of repelling the river flow away from the bank. This is accomplished by creation of a still pond on the upstream. Obviously the river starts following beyond the still pond and in the process the river flow goes away from the bank.

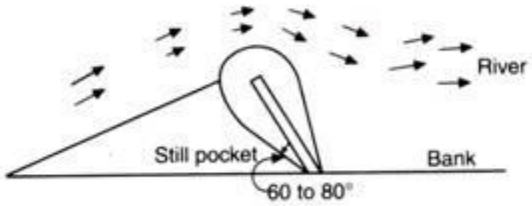


Fig. 14.8. Repelling groyne

On the contrary, when a groyne points downstream it is called an attracting groyne as. It attracts the river flow towards the bank from which it takes off.

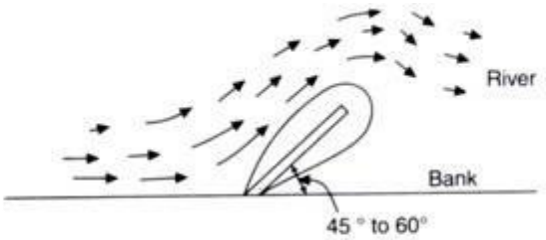


Fig. 14.9. Attracting groyne

In this case the groyne actually provides a body against which the river current keeps hugging. The river flow thus remains along the bank permanently. When a groyne of short length is taken perpendicular to the bank, it only deflects the flow locally. Hence, it is called deflecting groyne.

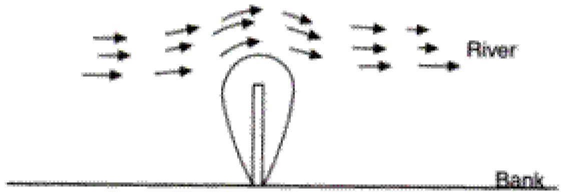


Fig. 14.10. Deflecting groyne

After successfully conducting model experiments various designs for groyne heads have been evolved. A groyne with head normal to the groyne direction of called 'T' headed groyne.

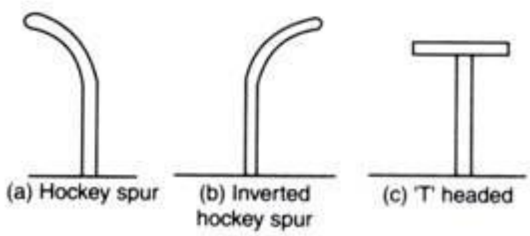


Fig. 14.11. Special types of spurs or groynes

From this it is clear that deflecting, repelling, attracting, T headed, hockey type, etc., all come under the impermeable type of groynes. The section of groyne is like a guide bund or an embankment. It is protected on both sides by stone pitching or concrete blocks etc. At the river bed launching apron is also provided. Top of spur is generally kept 3 m wide. Side slopes of 2:1 is general practice. The spurs are built by sand, gravel and boulders.

11.6.2 Permeable Groynes:

Common type of permeable groynes are tree groynes and pile groynes. They are temporary in nature and get washed away during floods. Therefore they are constructed every time before floods. A tree groyne consists of a thick wire rope (2.5 cm dia) firmly anchored at one end to the bank and tied at the other to a heavy buoy. Sometimes this wire may be stretched across the river and anchored at its ends. It may be supported at intermediate points on tripods.

Entire leafy trees are taken and about 30 cm up the stem a hole is drilled through each tree. Then an iron ring is drawn through the whole and attached to the wire rope. Dimensions of trees may vary from 6 to 12 m in height and 0.50 to 1.2 m in girth.

A pile groyne consists of a series of piles driven 6 to 9 m into the bed 2.5 m to 3 m apart. There may be two or three rows. The rows are spaced 1 to 2 m apart. Each row is closely intertwined by brushwood branches. For stability upstream row is braced to the downstream row by transverse laterals and diagonals.

The permeable groynes lower the velocity of flow. As a result sedimentation occurs. Hence permeable groynes may be said to be of segmenting type according to the function served. The cost of construction of this type is about 40 per cent that of impermeable type of same length. This type of groynes may be constructed even if there is flow in the river. Thus construction is easy and rapid.

To summarise, the factors which influence the choice and design of groynes are:

i. Fall and velocity of flow in the river.

ii. Character of bed load carried by the river.

iii. Depth of waterway, maximum HFL and nature of flood hydrograph.

iv. Width of waterway, at high water, low water, and mean water.

INTERNATIONAL INSTITUTE OF TECHNOLOGY & MANAGEMENT, MURTHAL SONEPAT

E-NOTES

SUBJECT: IRRIGATION **SUBJECT CODE: -**

COURSE- DIPLOMA **BRANCH: CIVIL ENGINEERING**

SEMESTER 4TH **CHAPTER NAME: WATER LOGGING**

(PREPARED BY: Mr. ANKUR CHAUHAN, LECTURER, CE)

WATER LOGGING

12.1 INTRODUCTION:

Water logging and salinity are a twin menace to agriculture.

12.2 WATER LOGGING:

It is the presence of water in the zone of roots of plants up to 5 ft depth by raising the water table due to which growth of crops stop. Its best example in Southern Punjab the land in the surrounding of Indus River at Ghazi Ghat which is nearly up to 0.5 km from the banks of the Indus River.

12.3 CAUSES OF WATER LOGGING:

Following are the main reasons of losses in irrigation due to water logging.

- Over irrigation
- Seepage from canals
- Inadequate surface drainage
- Obstruction in natural water course
- Obstruction in sub-soil drainage
- Nature of soil
- Incorrect method of cultivation
- Seepage from reservoir
- Poor irrigation management
- Excessive rain fall
- Flat country slope
- Topography of land
-

These reasons are discussed one by one.

1. **Over Irrigation:**

It means more water is provided then required due to which proper growth of crop is not possible.

2. **Seepage from Canal:**

Through seepage from canal on the banks, water level came to rise and the land becomes not suitable for irrigation purpose.

3. **Inadequate Surface Drainage:**

It means two types of canals, one of which is a "lined canal". It will not affect the land in surrounding. On the other hand "an unlined canal" will fully affect the land in surrounding in the form of seepage due to which this effected land provides fewer crops.

1. **Obstruction In Natural Water Course:**

If obstruction in natural water course (rivers) is present, blockage condition of rain water or other water created are produced and water store on the surface in the form of pounds. It affects the human health along with cultivation of crops on this land.

2. **Obstruction in sub-soil drainage:**

Sometime in sub-soil, a hard impervious layer acts as an obstacle due to which water table rises up to roots of the crops. As a result water logging conditions are generated.

3. **Nature of Soil:**

A pervious soil provides more water to the crops due to which water logging conditions are generated. On the other hand impervious soil strata provide more friction in the way of water flow due to less openings or voids.

4. **Incorrect Method of Cultivation:**

It means a farmer must have full knowledge about the crop which is to be cultivated. As a result of which he irrigates his crop according to the requirement. On the other hand a non-expert farmer provide more water or not according to the requirement which results in water logging.

5. **Seepage from Reservoir:**

Due to storage of water with high head seepage conditions are created not usually in hilly areas.

6. **Poor Irrigation Management:**

It means management of irrigation supplies a large quantity of water for irrigation to a small area.

7. **Excessive Rain Fall:**

It is another reason of water logging. In area which is fully flat and has no proper drainage system for excessive rain fall, water starts to store on the surface. As a result water logging conditions are generated.

8. **Flat Country Slope:**

Some areas have very less slope (flat) due to which flowing speed of water becomes very slow. As a result, a large quantity of water penetrates into soil and water table rises which creates water logging conditions.

9. **Topography of Land:**

Topography of land also affects the water table. In hilly areas conditions of water table are different as compared to the plane areas.

12.4 EFFECTS OF WATER LOGGING:

The waterlogging affects the land in various ways. The various after effects are the following:

1. Creation of Anaerobic Condition in the Crop Root-Zone:

When the aeration of the soil is satisfactory bacteriological activities produce the required nitrates from the nitrogenous compounds present in the soil. It helps the crop growth. Excessive moisture content creates anaerobic condition in the soil. The plant roots do not get the required nourishing food or nutrients. As a result crop growth is badly affected.

2. Growth of Water Loving Wild Plants:

When the soil is waterlogged water loving wild plant life grows abundantly. The growth of wild plants totally prevent the growth of useful crops.

3. Impossibility of Tillage Operations:

Waterlogged fields cannot be tilled properly. The reason is that the soil contains excessive moisture content and it does not give proper tilth.

4. Accumulation of Harmful Salts:

The upward water movement brings the toxic salts in the crop root-zone. Excess accumulation of these salts may turn the soil alkaline. It may hamper the crop growth.

5. Lowering of Soil Temperature:

The presence of excessive moisture content lowers the temperature of the soil. In low temperature the bacteriological activities are retarded which affects the crop growth badly.

6. Reduction in Time of Maturity:

Untimely maturity of the crops is the characteristic of waterlogged lands. Due to this shortening of crop period the crop yield is reduced considerably.

12.5 Detection of Waterlogging:

From the subject matter discussed above it is clear that the waterlogging is indicated when the ground water reservoir goes on building up continuously. When the storage starts building up in the initial stages the crop growth is actually increased because more water is made available for the crop growth. But after some time the waters table rises very high and the land gets waterlogged. Finally the land is rendered unproductive and infertile.

The problem of waterlogging develops in its full form slowly. Therefore its early detection is possible by keeping a close watch over the yields and also on the variations in the groundwater level. A comparative reduction in crop yields in spite of irrigation and fertilisation and early maturity of crops indicate the symptoms of waterlogging. Also when harmful salts start appearing on the fields as white incrustation or deposit it indicates that waterlogging is likely to follow. In worst cases the water-table rises so high and close to the ground surface that the fields turn into swamps and marshes.

The best way of keeping watch over the problem of waterlogging is by observing variations in the groundwater level. It can be done by measuring the depth of water levels at regular interval in the wells dug in the area. Continuous high water levels indicate that the groundwater storage is building up which may create waterlogging in the area.

12.6 PREVENTION OF WATER LOGGING:

Following are the methods through which we can prevent our lands from water logging.

- Canal Closures
- Lowering Full Supply
- Lining of Canal & Water Courses
- Provision of Intercepting Drainage
- Provision of Surface Drainage
- Pumping
- Plantation
- Restricted Irrigation
- Crop Rotation
- Methods of Irrigation with Less Water

1. **Canal Closures:**

Water logging can be controlled by stopping supply of water for certain day for irrigation purpose from the canals.

2. **Lowering Full Supply Level:**

By lowering of water level from full supply to reasonable head in canals, seepage can be controlled.

3. **Lining of Canals & Water Courses:**

By providing concrete or brick lining, “water logging due to seepage” can also be controlled.

4. **Provision of Intercepting Drains:**

By providing intercepting drains on the banks parallel to canal, water logging due to seepage can be controlled.

5. **Provision of Surface Drains:**

Surface drains are provided in open flat areas to drain off extra irrigation water and rain water into stream or nala.

6. **Pumping:**

By pumping we can also lower the water table with pumping pipe at a certain distance from water logged area.

7. **Plantation:**

By providing trees and other plants on the banks of the canal or river a large quantity of seepage water can be controlled. This results in growth of crops in surrounding area.

8. **Restricted Irrigation:**

Due to large supply or more then required supply of water to the area to be irrigated, water logging conditions are created.

9. **Crop Rotation:**

In different seasons, different types of crops should be planted to control the water logging.

10. **Methods of Irrigation with Less Water:**

To prevent the land from water logging, those methods of irrigation should be adopted in which less water is used for proper growth of crops. For this purpose Drip Irrigation & Sprinkling Irrigation method are used.

12.7 Surface Drainage

Surface drainage is the shaping, grading, or management of the land surface to provide gradual removal or diversion of water off of the land surface. Surface drainage is accomplished by smoothing out small depressions (land smoothing) or regrading an undulating land surface to a uniform slope, and directing water to a natural or improved, constructed channel. Ridge tillage is a form of surface drainage, providing excess water that accumulates between the ridges can flow away. Soil aeration or coring is also a form of surface drainage if it facilitates infiltration of water into an unsaturated subsoil. Surface drainage refers to the orderly removal of water, both within a field or to the removal of excess water off site.

Advantages of surface drainage are to minimize the duration of ponded water that inundates crops, and to minimize the prolonged saturation of soil which restricts gas (oxygen and carbon dioxide) exchange with the soil and plant root system or which prevents cultural operations. Surface drainage is most advantageous on flat lands where slow infiltration, low permeability, or restricting soil layers prevent the ready infiltration of high intensity rainfall.

A disadvantage of surface drainage is that it has a minimal affect on reducing the saturated subsoil occuring as a result of high water table conditions, especially where the source of the water is emerging from lower horizons. Other disadvantages are that if the water is not removed in an orderly manner, soil erosion may occur, and nutrient and other contaminants may be carried off in the runoff. Phosphorus and many herbicides are normally bound near the soil surface, and these may be transported in the surface drainage water.

12.8 Subsurface Drainage

Subsurface drainage is the removal of excess drainable porosity water in the subsoil, with the aim of lowering or controlling the water table depth below the crop root zone. Subsurface drainage is usually implemented with the use of buried corrugated (and perforated) plastic or clay (***tile***) conduits, but it can be done also by creating an unlined pore (***mole drain***), constructing ***blind (or French) drains***, excavating deep open drains, or by the use of ***tubewells*** (shallow groundwater wells).

A subsurface drain must be installed below the water table (so water can flow from higher to lower energy state) or it will not work. Once the water table drops to the same elevation as the drain, the drain will no longer flow. The primary advantage of subsurface drainage in humid regions is the water table can be lowered so soils classified as poorly drained can be improved to respond more like well drained soils, with the benefits of improved productivity and trafficability. In arid regions, the advantage is mainly to minimize the build up of excess salinity in the crop root zone.

A disadvantage of subsurface drainage is that its often more costly to implement per unit area compared to surface drainage, especially for fine textured soils. Also, if water ponds on the surface because of surface sealing or a shallow compact layer (plowpan, fragipan), subsurface drainage is not effective in removing this excess water.

The environmental disadvantages related to drainage implementation are poorly drained, wetland type habitats may be modified, and the drainage discharge water may carry unacceptable contaminants. Since subsurface drainage lowers the water table and facilitates aerobic soil conditions, nitrification is enhanced and high nitrate concentrations may occur in the drain discharge water.

i. Deep open drains

The excess water from the rootzone flows into the open drains (see Fig.). The disadvantage of this type of subsurface drainage is that it makes the use of machinery difficult.

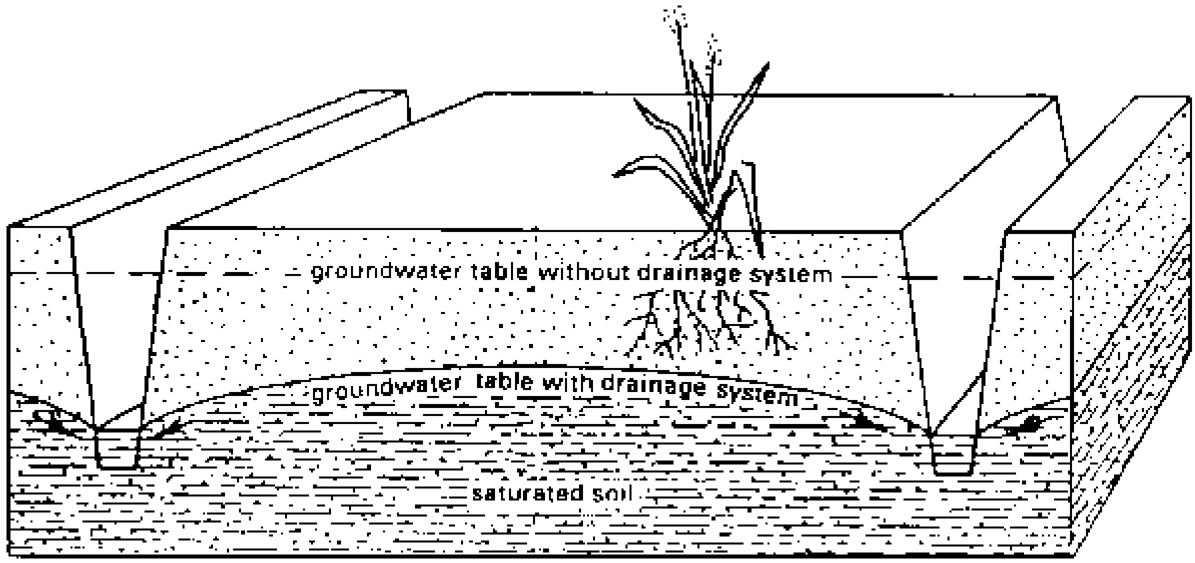


Fig. Control of the groundwater table by means of deep open drains

ii. Pipe drains

Pipe drains are buried pipes with openings through which the soil water can enter. The pipes convey the water to a collector drain (see Fig.).

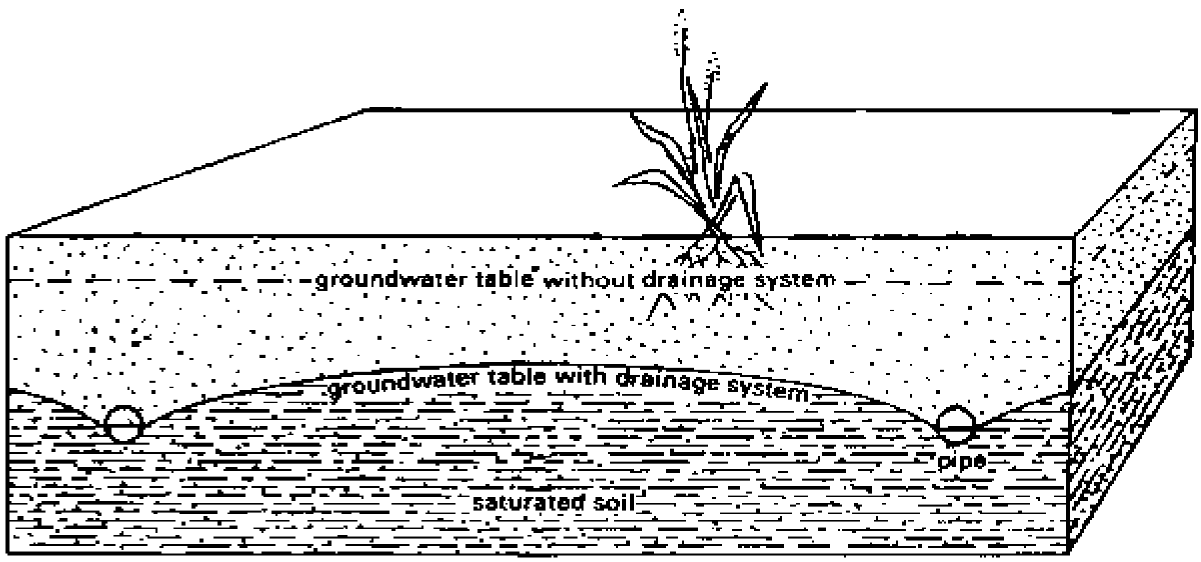


Fig. Control of the groundwater table by means of buried pipes

Drain pipes are made of clay, concrete or plastic. They are usually placed in trenches by machines. In clay and concrete pipes (usually 30 cm long and 5 - 10 cm in diameter) drainage water enters the pipes through the joints. Flexible plastic drains are much longer (up to 200 m) and the water enters through perforations distributed over the entire length of the pipe.

iii. Deep open drains versus pipe drains

Open drains use land that otherwise could be used for crops. They restrict the use of machines. They also require a large number of bridges and culverts for road crossings and access to the fields. Open drains require frequent maintenance (weed control, repairs, etc.).

In contrast to open drains, buried pipes cause no loss of cultivable land and maintenance requirements are very limited. The installation costs, however, of pipe drains may be higher due to the materials, the equipment and the skilled manpower involved.

12.9 An Introduction to Artificial Recharge

One result of the growing competition for water is increased attention to the use of artificial recharge to augment ground water supplies. Stated simply, artificial recharge is a process by which excess surface water is directed into the ground—either by spreading on the surface, by using recharge wells, or by altering natural conditions to increase infiltration—to replenish an aquifer. Artificial recharge (sometimes called planned recharge) is a way to store water underground in times of water surplus to meet demand in times of shortage. Water recovered from recharge projects can be allocated to nonpotable uses such as landscape irrigation or, less commonly, to potable use. Artificial recharge can also be used to control seawater intrusion in coastal aquifers, control land subsidence caused by declining ground water levels, maintain base flow in some streams, and raise water levels to reduce the cost of ground water pumping.

It is useful to think of the entire artificial recharge operation as a water source undergoing a series of treatment steps during which its composition changes. The constituents of potential concern depend not only on the character of the source water, but also on its treatment prior to recharge (pretreatment), changes that occur as it moves through the soil and aquifer (soil-aquifer processes), and treatment after withdrawal for use (posttreatment).

This report discusses three types of source waters having very different characteristics—treated municipal wastewater, stormwater runoff, and irrigation return flow—that have been proposed for use in artificial recharge. Normally, each of these source waters needs to be subjected to some kind of pre treatment before being introduced into the soil or aquifer. The exact pre treatment operations required depend on the type of source water, the nature of the recharge Bottom of Form process, and the intended use of the recovered water. A fundamental assumption of this report is that wastewater used to recharge the ground water must receive a sufficiently high degree of treatment prior to recharge so as to minimize the extent of any degradation of native ground water quality, as well as to minimize the need for and extent of additional treatment at the point of extraction.

After pretreatment, the water is ready for recharge, either through surface spreading and infiltration through the unsaturated zone or by direct injection into ground water. Recharge by infiltration takes advantage of the natural treatment processes, such as biodegradation of organic chemicals, that occur as water moves through soil. The quality of the water prior to recharge is of interest in assessing the possible risks associated with human exposures to chemical toxicants and pathogenic microorganisms that might be present in the source water. Although one can reasonably expect that such constituents will often be reduced during filtration through the soil, as well as subsequently in the aquifer, a conservative approach to risk assessment would assume that toxicants and microorganisms are not completely removed and some are affected only minimally prior to subsequent extraction and use. Thus, when recharge water is withdrawn later for another purpose, it may require some degree of posttreatment, depending on its intended use.

Taking a systems perspective that encompasses all steps from pre treatment, through recharge, through transformation and transport, to extraction, this report assesses the issues and uncertainties associated with the artificial recharge of ground water using source waters of impaired quality. In particular, the report focuses on the methodologies and nature of the recharge systems and the subsequent impacts on the native ground water quality, especially as those impacts may affect public health following use of the recovered water. Economic, institutional, and regulatory questions are examined as well. First, this chapter presents a primer on artificial recharge of ground water to give the reader an introduction to the philosophy and techniques of the field.

12.10 A PRIMER ON ARTIFICIAL RECHARGE

Water continually evaporates from the oceans and other open water bodies, moves across the land as water vapor in clouds, falls back on the land as rain and snow, and then returns to the oceans through rivers and underground pathways to start the cycle—the hydrologic cycle—again. Part of the water that fails on the land evaporates from the soil or is transpired from plants back into the atmosphere. Another part flows overland to stream channels, lakes, or the sea. The remainder seeps downward through the soil under the influence of gravity to enter the ground water system. Once in the ground water system, the water moves slowly in response to ground water slopes or hydraulic gradients until it re enters the surface part of the cycle. Bottom of Form contained below the land surface in saturated fractures, cracks, cavities, and pore, spaces in geologic formations. It is distinct from water in the unsaturated zone, which can be at or below atmospheric pressure and is contained in films and pores in the partially air-filled soil region between the ground water zone and the soil surface. This upper region containing soil, water, and air is called the unsaturated, or vadose, zone. The term recharge is used for water entering the ground water system and the term discharge applies to water leaving it. Geologic units permeable enough to yield appreciable amounts of ground water to wells are termed aquifers.

12.10.1 Ground Water Flow

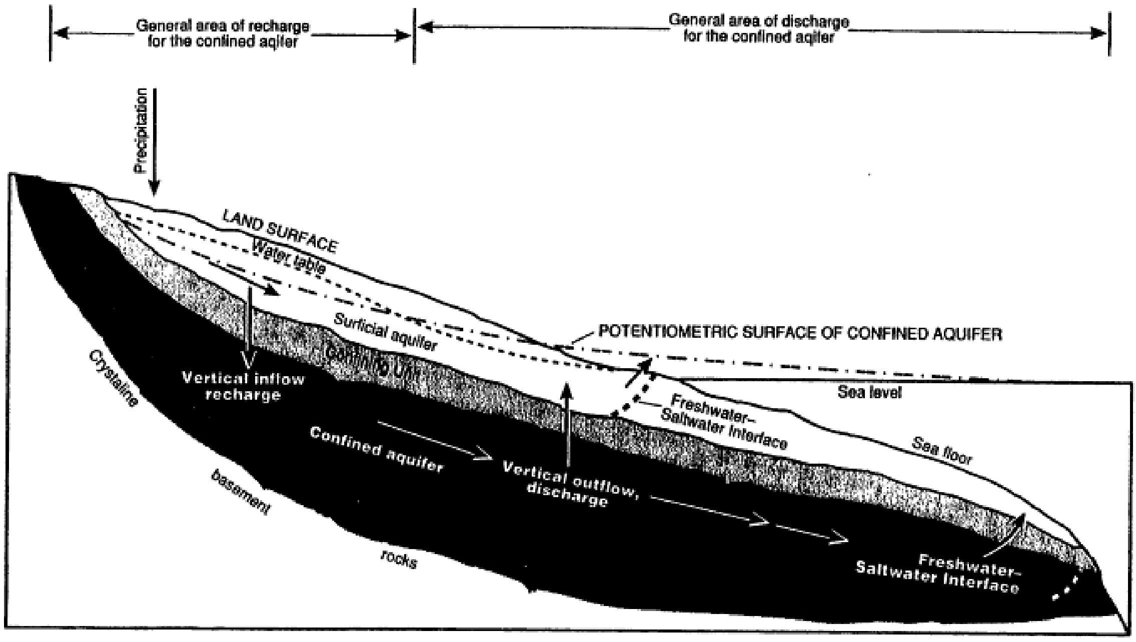
The upper surface or boundary of the zone of complete saturation in the ground water system is called the water table. In general, the water table stands higher under hills than under valleys, and these differences in water table height (also referred to as head differences) provide the hydraulic gradients that cause ground water to flow from recharge areas to areas of discharge. Ground water in the shallow geologic units containing the water table is called unconfined because the water is more or less in direct contact with the atmosphere.

Recharge to a water table aquifer occurs wherever rainfall or surface water infiltrates downward through the soil to the water table. Generally, the recharge area of an aquifer is the entire land surface overlying the aquifer, although certain portions, such as those lying under lakes or streams, may supply much of the recharge volume. Ground water in deeper geologic units separated from the water table beds by confining layers is said to be under confined, or artesian, conditions. The height of the water level in a wen open to a confined aquifer marks the position of the potentiometric surface of that aquifer. Where the height of the potentiometric surface is higher than that of the land surface, wells open to the confined aquifer will flow freely.

Recharge to a confined aquifer can occur if the pressure of its water is less than that in the overlying or underlying aquifers that adjoin it. Discharge of ground water takes place through springs, streams, wetlands, lakes, tidal waters, and pumped wells. Water tables and potentiometric surfaces fluctuate seasonally, generally by several feet, in response to natural variations in rates of recharge and discharge.

Ground water is constantly in motion, following hydraulic gradients from points of high head to points of low head in an aquifer system. Flow of ground water is always laminar, except near large springs or pumped wells, where it may be turbulent. The velocity of ground water flow in aquifers generally ranges from a few inches to a few feet per day and is determined by the porosity, permeability, and hydraulic gradient.

Ground water naturally contains concentrations of various mineral substances that have been dissolved from the local soil and geologic formations.



12.11 Artificial Recharge

Artificial recharge is the process of spreading or impounding water on the land to increase the infiltration through the soil and percolation to the aquifer or of injecting water by wells directly into the aquifer. Surface infiltration systems can be used to recharge unconfined aquifers only. Confined aquifers can be recharged with wells that penetrate the aquifer. Well recharge is also used for unconfined aquifers if suitable land for infiltration systems is not available.

Artificial recharge can be done using any surplus surface water. When low quality water is used for recharge, the underground formations can act as natural filters to remove many physical, biological, and chemical pollutants from the water as it moves through. Often, the quality improvement of the water is actually the main objective of recharge, and the system is operated specifically using the soil and the aquifer to provide additional treatment to the source water. Systems used in this way are called soil-aquifer treatment (SAT), or geo purification, systems.

The water extracted from SAT systems often can be used without further treatment to support recreation, landscape irrigation, and other nonportable purposes. Potable use may require more treatment. Because aquifers usually are much comer than vadose zones, the quality improvement of the water is much less in the aquifer than in the vadose zone. Thus, recharge using wells in confined aquifers cannot be expected to produce major improvements in the quality of the water. If low-quality water is to be used for well injection, it must be treated to meet the desired reuse qualities before injection. In addition, adequate treatment of the water before recharge is necessary to reduce clogging of the recharge wells. An overview of sources of water, treatment options, recharge systems, recovery techniques.