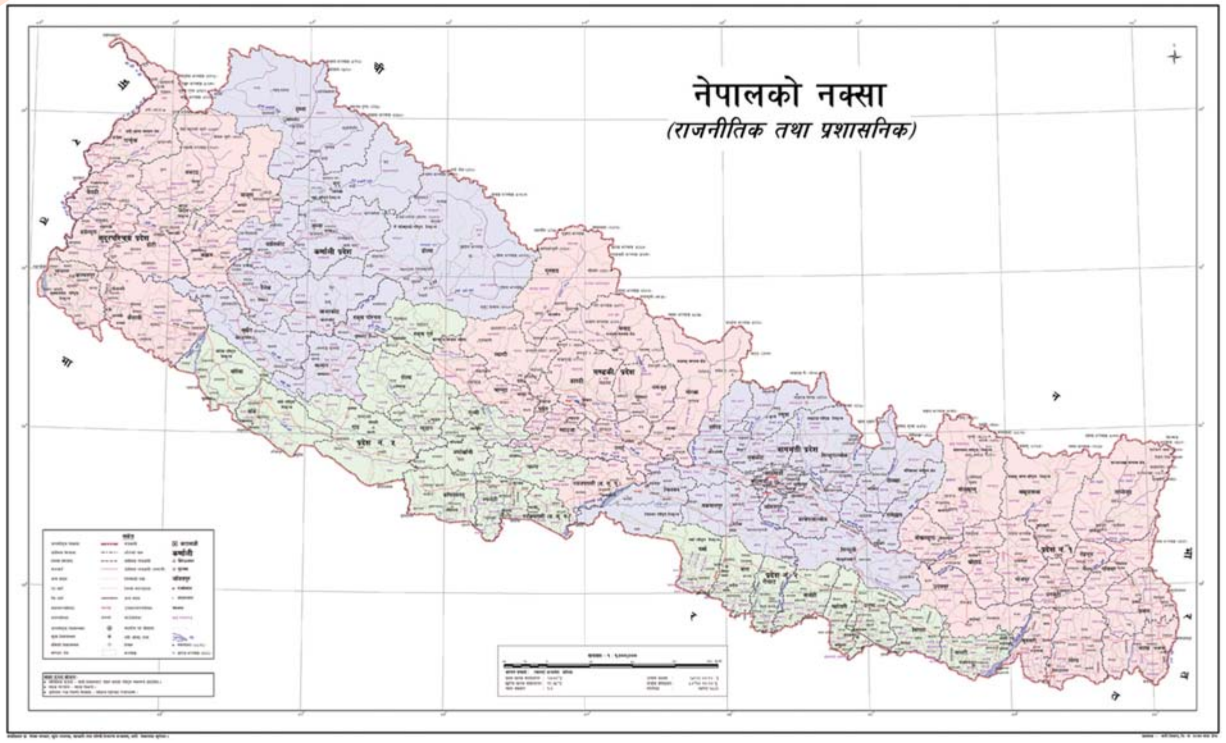
Civil Engineering



Water Resources Engineering

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Ministry of Education, Science and Technology
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Technical and Vocational Stream
Learning Resource Material

Water Resources Engineering

(Grade 10)

Secondary Level
Civil Engineering

Government of Nepal
Ministry of Education, Science and Technology
Curriculum Development Centre
Sanothimi, Bhaktapur

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Preface

The curriculum and curricular materials have been developed and revised on a regular basis with the aim of making education objective-oriented, practical, relevant and job oriented. It is necessary to instill the feelings of nationalism, national integrity and democratic spirit in students and equip them with morality, discipline and self-reliance, creativity and thoughtfulness. It is essential to develop in them the linguistic and mathematical skills, knowledge of science, information and communication technology, environment, health and population and life skills. it is also necessary to bring in them the feeling of preserving and promoting arts and aesthetics, humanistic norms, values and ideals. It has become the need of the present time to make them aware of respect for ethnicity, gender, disabilities, languages, religions, cultures, regional diversity, human rights and social values so as to make them capable of playing the role of responsible citizens with applied technical and vocational knowledge and skills. This Learning Resource Material for Civil Engineering has been developed in line with the Secondary Level Civil Engineering Curriculum with an aim to facilitate the students in their study and learning on the subject by incorporating the recommendations and feedback obtained from various schools, workshops and seminars, interaction programs attended by teachers, students and parents.

In bringing out the learning resource material in this form, the contribution of the Director General of CDC Dr. Lekhnath Poudel, Dr. Jagatkumar Shrestha, Dr. Kamal Thapa, Dr. Bharat Mandal, Kedar Dahal, Harihar Ghimire, Jagadishchandra Karki, Geeta Lamichhane is highly acknowledged. The book is written by Subasha Gurung and the subject matter of the book was edited by Badrinath Timalsina and Khilanath Dhamala. CDC extends sincere thanks to all those who have contributed in developing this book in this form.

This book is a supplimentary learning resource material for students and teachrs. In addition they have to make use of other relevnt materials to ensure all the learning outcomes set in the curriculum. The teachers, students and all other stakeholders are expected to make constructive comments and suggestions to make it a more useful learning resource material.

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Unit 1
Introduction of irrigation

1. Objective

- To define irrigation
- To list out necessities of irrigation
- To compare the advantages and disadvantages of irrigation
- To list out the sources of water for irrigation
- To describe gross command area(GCA), Cultivable command area(CCA)and Net command area(NCA)

2. Content

Introduction

Plants are living beings and do require water and air for their survival, as do human beings require. Different types of plants require different quantities of water, and at different times, till they grew up completely. Water is normally supplied to these plants by nature through direct rain water. If the natural rainfall is sufficient and timely so as to satisfy the full fill the water requirements of crop, there is no need of irrigation.

1.1. Definition of irrigation

Irrigation may be defined as the science of artificial application of water to the land, in accordance with the "crop requirements" throughout the "crop period" for full-fledged nourishment of the crops.

Simply the irrigation is defined as a process of supplying water to crops artificially.

The science of planning and designing a water supply systems to the crops for their normal growth during the period of no rainfall with the help of dam weir, barrage, reservoir and canal systems with head works, cross drainage works and miscellaneous work of canal like canal fall is called irrigation engineering.

1.2. Necessity of irrigation

The following are some factors which governs the necessity of irrigation.

(i) Insufficient rain fall

Irrigation is necessary in the areas where rainfall is insufficient for the satisfactory growth of the crops and the plants.

(ii) Non uniformity of rainfall throughout the year

If the distribution of rainfall in the zone of crop area is not evenly distributed as per requirement of the crop growth, irrigation is extremely necessary.

(iii) Growing perennial crop

Perennial crops, such as sugarcane etc, which need water throughout the year, can be raised only through the provision of irrigation facilities in the area.

(iv) Controlled water supply

By the construction of proper distribution system, the yield of the crop may be increased because of controlled supply of water.

(v) Commercial crops with additional water requirement

The rainfall in a particular area may be sufficient to raise the usual crops, but more water may be necessary for raising commercial and cash crops.

(vi) Development of desert area

The dry and desert areas can be converted to a beautiful cropland if irrigation water can be supplied as per need.

1.3 Advantages and Disadvantages of irrigation

Advantages of irrigation

1. **Increase in food production:**

   Irrigation helps in increasing crop yields, and hence to attain self-sufficiency in food.

2. **Optimum benefits:**

   Optimum utilization of water is made possible by irrigation. Yield will be smaller for any quantity less or more than this optimum quantity

3. **Generation of hydroelectric power:**

   Canal fall may sometimes be utilized for generation of power.

4. **Domestic water supply:**

At many places, irrigation canals are the only source of supply for domestic water.

5. Facilities of communication:

Roads provided alongside the important canals primarily for inspections, are utilized for general communication also.

6. Inland navigation:

It is possible that some large irrigation canals may be developed for navigation purposes.

7. Afforestation:

Trees are generally grown along the banks of the channels which increases the timber wealth of the country.

8. Elimination of mixed cropping :

In the areas, where irrigation is not assured, generally mixed cropping is adopted. By mixed cropping, we mean, sowing together of two or more crops in the same field. If the weather conditions are not favorable to one of the crops, they may be better suitable for the other and thus, the framer may get at least some yield. But, if the irrigation is assured mixed cropping can be eliminated. Elimination of mixed cropping increases the yield of the crops,

Disadvantages of irrigation

1. Irrigation may result in colder and damper climate, resulting in marshy lands and breeding of mosquitoes, causing outbreak of diseases like malaria and dengue.
2. Over irrigation may lead to water logging and may reduce crop yield
3. Irrigation projects are complex and expensive. Requires regular supervision and maintenance.
4. Loss of valuable land by submergence due to construction of reservoir by dam, weir, and barrages.
5. Irrigation may causes water pollution
6. Loss of soil fertility
7. Soil erosion

1.4. Sources of water for irrigation

The sources of water for irrigation can include surface water sources, groundwater sources, municipal water supplies, grey-water sources, and other agricultural and industrial process wastewaters.

Surface water sources include 'flowing' water supplies (i.e., creeks, streams, canals) and 'standing' or stored water supplies (i.e., ponds, reservoirs, lakes).

Groundwater supplies may come from springs and wells, and although the quality is usually good, the available quantity that can be pumped at any time may again limit the irrigation method.

Grey-water is domestic wastewater, other than those containing human excreta, such as sink drainage, washing machine discharge or bath water.

1.5 Gross Command Area (GCA)

Gross Command Area is the total area bounded within the irrigation boundary of the project which can be economically irrigated without considering the limitation of the quantity of available water. It includes the cultivable as well as the uncultivable area. For example, ponds, Residential areas, roads, etc. are the uncultivable areas of the gross command area.

1.6 Cultivable command area (CCA)

Cultivable command area is the gross command area less the area of uncultivable land included in the gross command area. Thus residential area, ponds, forests etc. are excluded. In the absence of detailed data, CCA may be assumed to be equal to 80% of GCA.

1.7 Net Command Area (NCA)

Net command area is the cultivable command area less the area of canal networks, supply ditches, bunds constructed in the field etc.

3. Learning process and support materials

Following are the learning process of this unit:

-theoretical notes
-presentation

-group work

4. Assessment

A. Very short answer question.

1. Define irrigation.
2. What are the sources of water for irrigation?
3. What is the full form of GCA?
4. Write about the net command area.

B. Short answer question.

1. What are the advantages and disadvantages of irrigation?
2. Compare between GCA and NCA.
3. Differentiate CCA and NCA.

Glossary:

Fledge- to grow

Nourishment- the act of supplying the means of support and increase

Yield- to afford, to give as required

Navigation- the theory, practice and technology of charting a course for a ship, aircraft or spaceship

Marshy- of, or resembling an area of low, wet land

Creek- a stream of water (often freshwater) smaller than a river and larger than a brook

Reference materials

Suggested texts and references

Irrigation Engineering and Hydraulic Structures –Santosh Kumar Garg

Irrigation and Water Power Engineering- Dr. B.C. Punmia, Dr. Pande B.B. Lal, Ashok Kumar Jain and Arun Kumar Jain

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Unit 2
Water Requirement

1. Objective

- To define crop season
- To describe crop types
- To compare the base period and crop period
- To explain Kor period and Kor depth
- To identify duty delta relationship
- To describe the factors affecting duty

2. Content

The term 'water requirements of a crop' means the total quantity and the way in which a crop requires water, from time it is sown to the time it is harvested. Different crops will have different water requirements and the same crop may have different water requirements at different places of the same country; depending upon the variations in climate, type of soils, method of cultivation and useful rainfall, etc.

2.1 Crop Seasons

The period during which some particular types of crop can be grown every year in the same field is known as crop season. From the agricultural point of view, the year can be divided into two principal cropping seasons i.e. Rabi and Kharif; based on the monsoon.

Kharif season

Kharif starts from 1st April and ends on 30th September. The kharif crops include rice, maize, cotton, tobacco, groundnut, soybean, etc. Kharif crops are also called 'summer crops'.

Rabi season

Rabi starts from 1st October and ends on 31st March. The Rabi crops include wheat, barley, mustard, potatoes, gram, etc. Rabi crops are also called 'winter crops'.

These dates are not rigid deadlines and the time may vary from 1 to 3 months on either side.

Kharif crops require about two or three times the quantity of water required by the Rabi crops.

Crops like cotton and sugarcane require almost both of the seasons. Cotton is a 8 months crop. But sugarcane which requires almost a year is called perennial crop.

2.2. Crop Types

1. Based on irrigation method

- **a. Wet crop:** A wet crop is that which requires water by irrigation. Such crop cannot grow without irrigation. E.g. Rice, wheat, etc.
- b. **Dry crop:** Dry crop is that which does not require water for irrigation. It utilizes moisture in soil during rainfall. E.g. Millet

2. Based on season

- a. **Rabi crops:** Rabi crops are sown in autumn and harvested in spring. E.g. wheat, tobacco, mustard, barley, potato, etc.
- b. **Kharif crop:** Kharif crops are sown by the beginning of monsoon and are harvested in the autumn. E.g. maize, groundnut, rice, cotton, millet, etc.

2.3. Base Period (B)

The time between the first watering of a crop at the time of its sowing to its last watering before harvesting is called base period or the base of the crop. It is total period during which irrigation is done and generally expressed in days and denoted by B.

2.4. Kor period and Kor depth

The first watering which is given to the crop, when the crop is few centimeters high, is called Kor-watering. It is usually the maximum single watering followed by other watering at regular intervals.

Kor period

The Kor period is the critical growth period of crop during which the water demand is maximum. If the plant fails to receive sufficient water in this period, they suffer from significant loss.

Kor depth

The depth of water applied for the Kor period is known as Kor depth.

Crop	Kor depth	Kor period
Rice	19 cm	2 to 4 weeks
Wheat	13.5 cm	3 to 8 weeks

2.5. Crop Period

The time period that elapses from the instant of sowing to the instant of harvesting of crop is called crop period. It is the total period during which the crop remains in the field. It is generally expressed in days. Crop period is slightly more than base period.

2.6 Delta and Duty

Delta

Total depth of water supplied to the crop during the entire base period for full growth of that crop is called its delta. It is denoted by Δ (in cm). For e.g. wheat requires 10 cm depth of water, if 5 watering are provided during entire base period then,

Δ (Delta for wheat) $=10\times5$cm $=50$ cm

Duty

Duty of water represents irrigating capacity of a unit water. It is defined as the number of hectares of land irrigated for full growth of a given crop by supply of 1m3/sec of water continuously during the entire base period of that crop. It is generally represented by 'D' and expressed in hectares/cumec. E.g. If 600 hectares of land is irrigated by 2 cumecs of water, the duty of water (D) =600/2 =300 hectares/cumec

2.7. Duty delta Relationship

Let there be a crop of base period B days. Let, one cumec of water be applied to this crop on the field for B days,

Now, volume of water applied to this crop during B days,

$$V = (1\times60\times60\times24\times B)m^3$$

$$=86400B\ m^3$$

By definition of duty (D), one cubic meter supplied for B days matures D hectares of land.

Therefore, this quantity of water (V) matures D hectares of land or 10^4 D sq.m. of area.

Total depth of water applied on this land = Volume/ Area

$= 86400B/10^4D$

$= 8.64B/D$ meters

By definition, this total depth of water is called delta (Δ).

Therefore, $\Delta=8.64B/D$ m

$$\boxed{\Delta=864B/D \text{ cm}}$$

Where Δ is in cm, B is in days and D is duty in hectares/cumec

Which is the required relationship between duty and delta for a given base period.

2.8. Factors affecting duty

Factors affecting duty of irrigation water are as follows:

1. Types of crop

Different crop requires different amount of water and hence the duties for them are also different. The duty of water will be less for a crop requiring more water and vice-versa.

2. Climate and season

Duty includes water lost in evaporation and percolation. These losses will vary with the season. Hence, duty varies from season to season and also from time to time in the same season.

3. Useful Rainfall

If rain falling directly over the irrigated land, is useful for the growth of crops, then lesser irrigation water will be required to mature the crop.(More the useful rainfall, less will be the requirement of irrigation water) and hence, more will be the duty of irrigation water.

4. Type of soil

If the permeability of soil is high, the water loss due to percolation will be more and hence duty will be less.

5. Efficiency of cultivation method

In faulty and less efficient cultivation method(including tillage and irrigation), duty of water will be less due to wastage while improved duty of water can be gained with same quantity of water if used economically as it irrigates more area.

6. Base period of the crop

If the base period of the crop is more, the amount of water required will be high and duty will be low and vice-versa.

2.9 Water requirement of different crops

	Crop	**Period of growth**	**Average water depth required (in cm)**	**Irrigation requirement and remarks**
	Kharif crops			
1	Maize	June to Sept./Oct.	45	4 or 5 watering
2	Rice	July to Nov.	125-150	Standing water of 5 to 8 cm gives best result
3	Groundnut	May to Nov./Dec.	45	Soil is moistened before sowing(Paleo required before sowing)
4	Cotton	May/June to Nov./Jan.	25-40	3 or 4 watering are required

5	Millet	July to Nov.	30	Water shouldn't stand still. Irrigation as required.
6	Til	July/Aug. to Oct./Nov.	-	Generally not irrigated but better to irrigate once.

Rabi crops

1	Wheat(ordinary)	Oct. to Mar./Apr.	37.5	3-4 watering of 7-10cm depth
2	High yielding wheat	"	45	5-6 watering of 7-10cm depth
3	Barley	Oct. to Mar./Apr.	30	Irrigated when leaves get dry
4	Potato	Sept./Oct. to Feb.	60-90	Usually irrigated.
5	Tobacco	Oct./Feb. to Feb./May	60	4-5 watering
6	Mustard	Oct. to Feb./Mar.	45	Watered at intervals of 7-10 days

Overlapping Crop (Generally Rabi Crop)

1	Sugarcane	Feb. /Mar. To Dec./Mar.	90	5 or 6 watering of 10 cm or more

*Paleo Irrigation:

Sometimes in the initial stage, before the crop is sown, the land is very dry. When the soil is too dry to be sown, the soil is moistened with water so as to help in sowing the crop. This is known as paleo irrigation. For e.g. for groundnut, paleo irrigation is required.

Note:

1) Field crop: Rice, Wheat, Maize, Potato
2) Plantation crop: coffee, tea, rubber
3) Commercial crop: Cotton, sugarcane, mustard

3. Learning process and support materials

Following are the learning process of this unit:

-theoretical notes

-presentation

-group work

4. Assessment

A. Very short answer questions.

1. What is base period?
2. What is duty?
3. Define delta.
4. What is crop period?
5. What are crop season?

B. Short answer questions.

1. A crop needs 10 cm water during its base period of 100 days. Calculate the duty required for that crop.
2. What is kor period and kor depth?
3. Explain kharif crop with examples.

C. Long Questions

1. Derive the relationship between duty, base period and delta.
2. Describe the factors affecting duty.

Glossary

Significant=important, notable

Percolation=the seepage or filtration of a liquid through a porous substance

Tillage=the cultivation of plowable land

Reference materials

Suggested texts and references

Irrigation Engineering and Hydraulic Structures –Santosh Kumar Garg

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Unit 3
Method of Irrigation

1. Objective

- To define surface irrigation
- To list out the types of surface irrigation
- To define sub surface irrigation
- To identify drip and sprinkler irrigation
- To identify advantages and disadvantages of drip and sprinkler irrigation

2. Contents

3.1. Surface irrigation

The method of irrigation in which water is applied directly to soil surface from a channel located at the upper reach of the field, is called surface irrigation. Surface irrigation can be further classified into

a. Flow irrigation

b. Lift irrigation

a. Flow irrigation

When the water is available at higher level, and it is supplied to the lower level, by action of gravity, then it is called flow irrigation. Flow irrigation can further be sub –divided into

(i) Perennial irrigation

(ii) Flood irrigation

i. Perennial irrigation

In perennial system of irrigation, constant and continuous water supply is assured to the crops throughout the crop period.

- When irrigation is done by diverting the river runoff into the canal by constructing the diversion headwork across the river, then it is called direct irrigation.
- But, if a dam is constructed across the river to store water during monsoons,

so as to supply water in the off-taking channel during period of low flow, it is termed as storage irrigation.

ii. Flood irrigation

This type of irrigation is also called inundation irrigation. In this method of irrigation, soil is kept submerged and thoroughly flooded with water, so as to causes through saturation of land. The moisture soaked by the soil, brings the crops to maturity.

a. Lift irrigation

If water is lifted up by some mechanical means, such as by pumps and then supplied for irrigation, it is called lift irrigation. Use of well and tube wells comes under these categories.

3.1.1. Uncontrolled flooding

In uncontrolled flooding, the water is applied by spreading it over the land but prior to the application of water; no land preparation is done in the form of border or field ditches. There is no control over the flow of water by levees and bunds in this method.

3.1.2. Check flooding

In this method, the field is divided into number of compartments by low and flat levees. The confined plot area varies from 0.2 to 0.8 hectare. The irrigation water is admitted into each in turn from the farmer's water course running alongside. Each compartment is essentially level. This result in more even spread of water and avoids wastage.

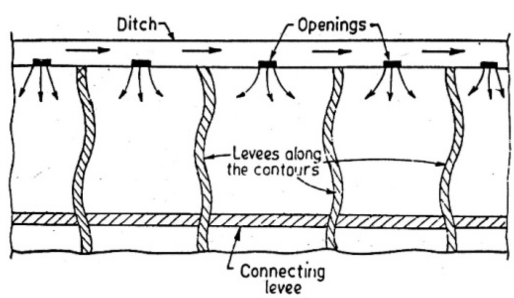
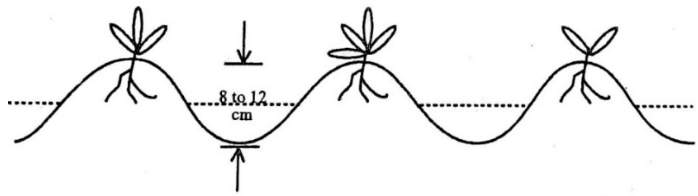


Fig. Check Flooding (Plan View)

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

3.1.3. Furrow irrigation

It consists of applying water to the furrows (a series of long and narrow channels) in between the rows of plants to be irrigated. The water reaches to the root of the plants by percolation. In this irrigation method, only 1/5 to 1/2 of the land surface is wetted by water. As water is not applied to the entire surface area of field, evaporation losses are also less. This method is an excellent method for row crop like potatoes, cauliflowers etc.



Furrow irrigation

3.1.4. Zig Zag Method

- In this method, the agricultural area is sub-divided into small plots by low bunds, where opening for water are kept on zigzag way as shown in figure below.
- The water is applied to the plots from the field channel through the opening
- The water flows in a zigzag way to cover the entire area

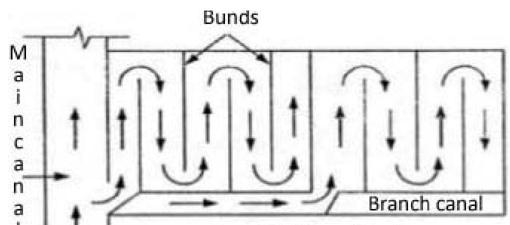


Fig. Zig-Zag method

3.1.5. Contour farming

This method is commonly adopted in hilly areas with steep slope. Counter farming involves aligning the plants rows and tillage line at right angles to natural flow of runoff (i.e. in direction of contour line or perpendicular to slope of land)

In this method the land is divided into series of horizontal strips called terraces as shown in figure below. Small bunds are constructed at the end of each terrace to hold water up to required height.

This method minimizes the soil erosion by reducing the rate of run-off and helps to irrigate the field by applied water more effectively.

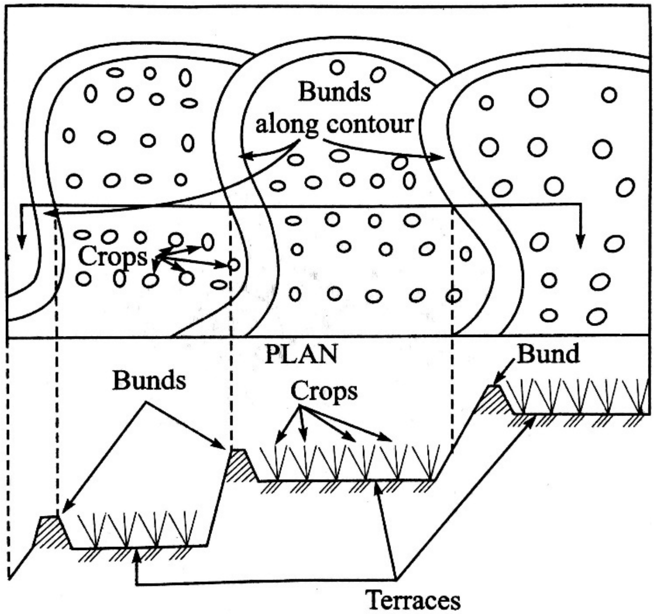


fig. Plan and section of contoour farming

3.1.6. Basin flooding

This method is a special type of check flooding and is adopted specially for orchard trees. One tree is generally placed in the basin, and the irrigation water is applied to these basins as in check method.

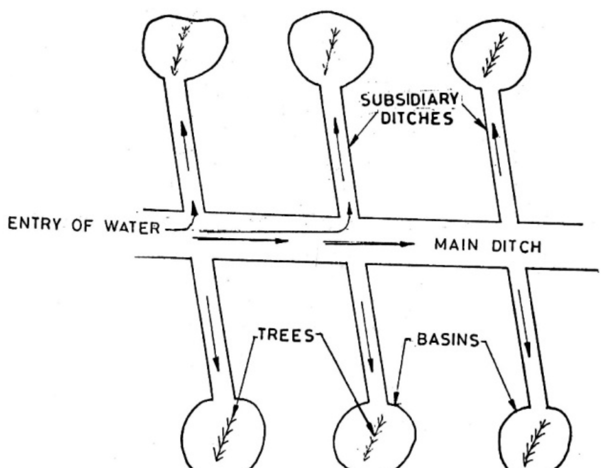


Fig. Basin Flooding (Plan View)

1.1.7. Contour laterals

In steeper terrain, this method is useful. Small contour laterals are constructed to divert water towards the sloping areas.

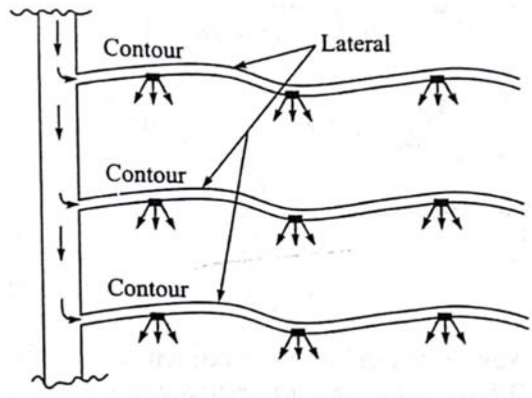


Fig. Contour Laterals

3.2. Sub surface irrigation

The method of irrigation in which water is directly supplied to the root zone of the crop, is called sub surface irrigation. The underground water nourishes the plant roots by capillary action. Artificial water table is created and maintained at some depth, usually 30 to 75 cm below the ground surface. It may be divided into two types

a. Natural sub-surface irrigation

Leakage water from canal, ponds, river etc. goes underground, and during passage through the sub-soil, it may irrigate the crops. Sometimes, leakage water causes the water table to rise up, which helps in irrigation of crops by capillarity.

b. Artificial sub-surface irrigation

When a system of open jointed drains is artificially laid below the soil, so as to supply water to the crops by capillarity, then it is called artificial sub- surface irrigation.

3.3. Drip irrigation

Drip irrigation is also known as the trickle irrigation. It is the latest field irrigation technique, and is adopted at the places, where there exists scarcity of irrigation water. In this method, water is slowly and directly applied to the root zone of the plants, thereby minimizing the losses by evaporation and percolation with the help of networks of pipe fitted with special type of nozzle called emitters.

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

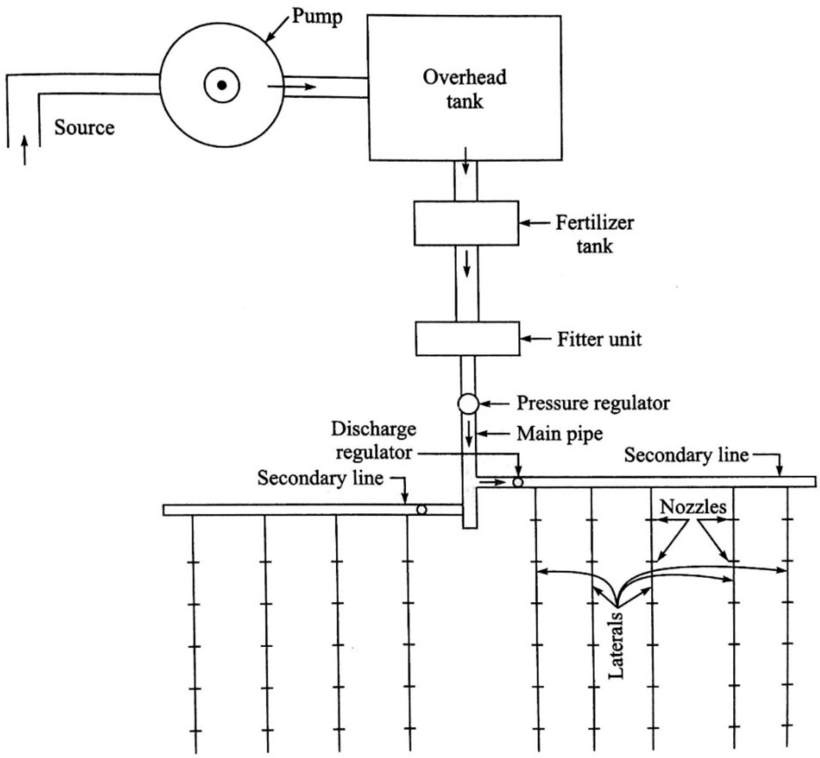


Fig. Component of Drip irrigation

Advantages of Drip irrigation system

a. Less amount of irrigation water is required
b. Water logging is avoided
c. Less loss of applied water
d. Control of weed growth
e. No over irrigation
f. Reduction in labor cost

Factors affecting choice of irrigation method

1. Soil characteristic of land to be irrigated
2. Topography of the area
3. The quantity of water available
4. Types of crops and its requirements
5. Size of stream supplying irrigation water

Disadvantages

a. Initial cost of instillation is high

b. Problem of clogging nozzle

3.4. Sprinkler irrigation

In this method of irrigation, water is applied to the soil in the form of spray through a network of pipes, pump and a special device called sprinkle. It is a kind of artificial rain and therefore, gives very good results.

This method of irrigation avoids the necessity of leveling of undulating land, eliminates deep percolation loss and ensures even spread of applied water. In this method, fertilizers can be uniformly applied because they are mixed uniformly with irrigation water itself. This method is favorably adopted when the land topography is irregular, the land gradient is steeper and the land soil is excessively permeable. But method is expensive and the water used should be of good quality.

Suitability of sprinkler irrigation

This method is suitable where,

1. Where the land topography is irregular, and hence unsuitable for surface irrigation
2. When land slope is steeper, and soil is easily erodible
3. When the land is excessively permeable or when the soil is highly impermeable
4. When the water is available with difficulty and is scarce.

Advantages of sprinkler irrigation

1. Seepage losses like in the earthen channel are eliminated.
2. Land leveling is not required, thus avoiding removing of top fertile soil.
3. No cultivation area is lost for making ditches, levees etc. (increase in about 18 % cultivation area)
4. In sprinkler system, water is to be applied at a rate lesser than the infiltration capacity of the soil, and thus avoiding surface run-off.

5. Fertilizer can be uniformly applied, because they are mixed with irrigation water itself.
6. Less labor is required
7. Up to 80% efficiency can be achieved.
8. Erosion of soil is avoided or controlled

Disadvantage of sprinkler irrigation

1. High wind may cause non-uniform spreading of water on the crops,
2. More evaporation loss of applied water
3. Requires high electrical power to operate pumps.
4. Only sand and silt free water can be used.
5. They are not suited to crops requiring frequent and larger depth of irrigation water.
6. Maintenance cost is high and also requires regular supervision.

3. Learning process and support materials

Following are the learning process of this unit:

-theoretical notes
-presentation
-group work
-prepare field visit to farmer's farm

4. Assessment

A. Very Short Questions.

1. Define surface irrigation?
2. What is sub-surface irrigation?
3. What is contour farming?
4. What is drip irrigation?

B. Short Questions.

1. Describe about the sprinkler irrigation.
2. Write about the contour lateral irrigation.

3. Why is zig zag method not a good method?
4. Why basin flooding is better than other flooding of water?
5. Write any four advantages of drip irrigation method.

C. Long Questions.

1. Explain about the surface irrigation in detail.
2. Explain about the uncontrolled and check flooding with figure.

Glossary

Divert- to turn aside from a course

Saturation- the act of being soaked with moisture

Levees- the border of an irrigated field, an embankment to prevent overflowing

Compartment- one of the parts into which an area is subdivided

Capillary action- the drawing of a liquid (often against gravity) into or up narrow opening due to surface tension

Undulating- moving up and down like waves; wavy

Reference materials

Suggested texts and references

Irrigation Engineering and Hydraulic Structures –Santosh Kumar Garg

Irrigation and Water Power Engineering- Dr. B.C. Punmia, Dr. Pande B.B. Lal, Ashok Kumar Jain and Arun Kumar Jain

Irrigation and Water Power Engineering- Madan Mohan Das and Mimi Das Saikia

Irrigation Engineering(Including Hydrology)-R.K. Sharma and T.K. Sharma

Irrigation Engineering and Hydraulic Structures-Dr. V.C. Agarwal

Engineering hydrology-K. Subramanya

Engineering hydrology-Dr. K.N. Dulal and Er. Sanjeeb Baral

Unit 4
Various Irrigation Structures

1. Objective

- To define head works
- To list out types of head works
- To familiar with canal head regulator and cross regulator
- To familiar with canal fall
- To compare weir and barrage
- To identify different cross-drainage works

2. Contents

2.1. Headworks: Definition and types

Any structure at the head or diversion point of a waterway is said to be headwork. It is used to divert water from a river into a canal or from a large canal into a smaller canal.

Functions of a headwork:

A headwork serves the following purposes:

(i) A headwork raises the water level in the river.

(ii) It regulates the intake of water into the canal.

(iii) It also controls the entry of silt into the canal.

(iv) A headwork can also store water for small periods of time.

(v) It reduces fluctuation in the level of water in river.

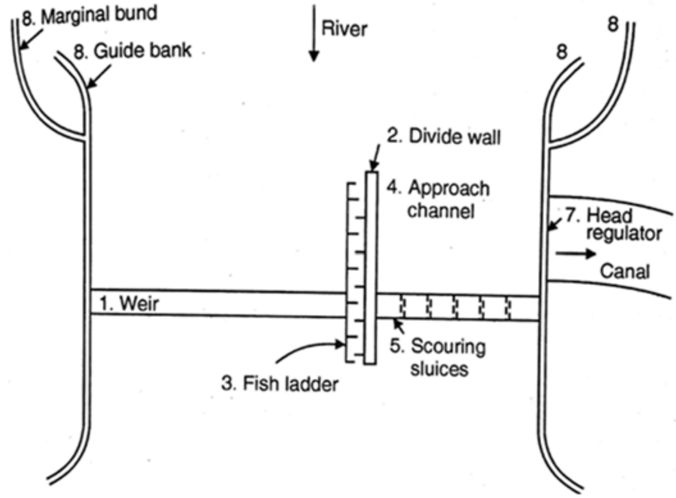


Fig. Component parts of a headwork

There are two types of headwork:

1. Storage headwork
2. Diversion headwork

1. Storage headwork: The structure constructed across the river valley to form the storage reservoir is called storage headwork. The water is supplied to the canal from the reservoir through the canal head regulator. It stores the water during the period of excess supply in the river and releases it when demanded. This serves as multipurpose function like hydroelectric power generation, flood control, fishery, etc.

The following points should be considered while selecting site for storage headwork:

(i) The hill area is preferred for the storage headwork where the river valley is available from a deep reservoir with minimum surface area.

(ii) In the dam site, good foundation should be available.

(iii) In the reservoir area, there should be no cracks or permeable foundation.

(iv) Road or railway communication to the site should be easy.

(v) The river should not carry much sediment because this will form reservoir sediment.

(vi) The required capacity of reservoir is fulfilled if the catchment area is wide.

2. **Diversion headwork:** The diversion headwork provides an obstruction across a river so that the level of water is raised and water is diverted to the channel at required level. The flow of water in the canal is controlled by canal head regulator. This increased water level helps to flow water by gravity and increase the command area while reducing the fluctuation in the river,

Following points should be kept in mind while selecting site for diversion headwork:

(i) The river should be narrow and straight at the sight.

(ii) The river bank should be well defined.

(iii) The altitude of the site should be higher than the area to be irrigated.

(iv) Road and railway communication to the site should be easy.

(v) For avoiding transmission loss, the site should not be far away from the command area of the project.

Diversion headwork is further classified into two types. They are:

1) Temporary spurs or bunds and

2) Permanent weir and barrages

(1) Temporary spurs or bunds

They are temporary in nature and are constructed every year after the floods.

(2) Permanent weir and barrages

They are constructed for important works and they are permanent in nature.

Components of diversion headwork:

(1)	Weir or barrage	(5)	Canal head regulator
(2)	Divide wall	(6)	Guide bank
(3)	Fish ladder	(7)	Marginal bund
(4)	Scouring sluice	(8)	Silt regulation works

4.1.1. Canal head regulator

A canal head regulator is provided at the head of off-taking canal. It provides the following functions:

(1) It regulates the supply of water entering the canal.

(2) It controls the entry of silt in the canal.

(3) It prevents the river floods from entering the canal.

The regulator is generally aligned at right angle to the weir, but slightly greater angles (between 90° to 110°) are now considered preferable for providing smooth entry of water into the regulator. The regulator is provided with gates.

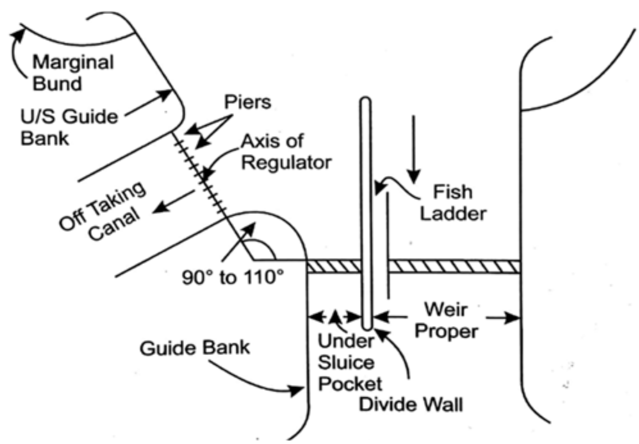


Fig. Alignment of canal head regulator

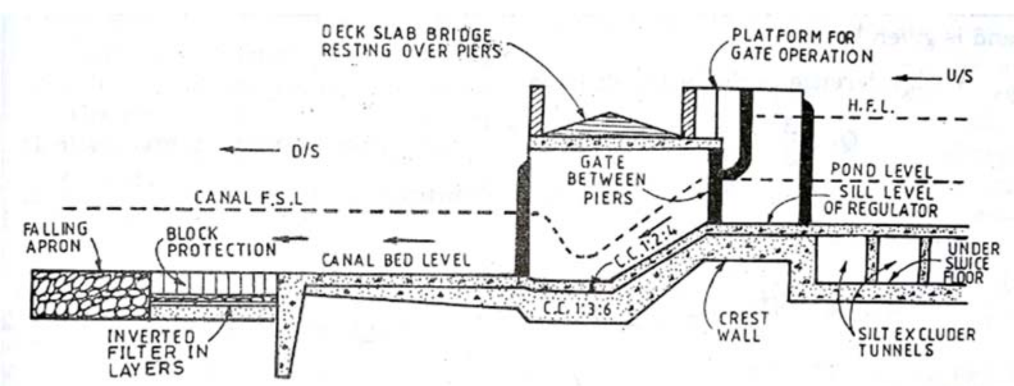


Fig. Typical section through a canal head regulator

4.1.2 Cross regulator

A cross regulator is a structure constructed in main canal downstream of the off-taking canal to enable the off-taking canal draw its required supply even if the main canal is carrying low supply. Its functions are:-

1) It regulates water in the whole canal system.
2) It helps in closing the supply to the downstream of the parent channel, for the purpose of repairs.
3) It raises water level to the upstream and feeds the off-taking canal during the period of low discharge in the parent canal.
4) To control water surface slopes in conjunctions with falls for bringing the canal to regime slope and section.
5) To control discharge at an outfall of a canal into another canal or lake.

The need of cross regulator is essential for all irrigation systems which supply water to distributaries and field channels by rotation and therefore, require to provide full supplies to distributaries even if the parent channel is carrying low supplies.

Differences between head regulator and cross regulator:

	Head Regulator		Cross Regulator
1)	Head regulator controls supply of off-taking channel.	1)	Cross regulator controls the supply of parent channel.
2)	It is provided at the head of the off-taking channel.	2)	It is provided at the downstream of the off-taking channel.
3)	It controls silt entry in the off-taking canal.	3)	It controls silt entry in the parent channel.
4)	It helps in closing the supply to the upstream of the off-taking channels.	4)	It helps in closing the supply to the downstream of the parent channels.

4.1.3. Canal fall or drops

A canal fall is an irrigation structure constructed across a canal to lower down its water level to maintain the designed slope when there is change of ground level and destroy the surplus energy liberated from the falling water which may otherwise scour the bank and bed of canal.

Necessity of construction of fall:

The slope of ground is not uniform in all places, especially in mountainous regions or regions with steep gradient. The velocity of flow will be much more than required. Thus, in order to control the energy of water flow, structures known as canal fall or drop is constructed across the canal.

Consideration for location of falls:

1. As far as possible, it should be located where it may serve the combining service of regulator and bridge.
2. In case of branch and distributary channels, falls are located with consideration to commanded areas.
3. For the canal which does not irrigate the area directly, the fall should be located from the consideration of economy in cost of excavation and cost of the fall itself.

Types of canal fall:

1) Ogee fall 2) Rapid fall 3) Stepped fall

4) Trapezoidal notch fall 5) Vertical drop fall

1) Ogee fall

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

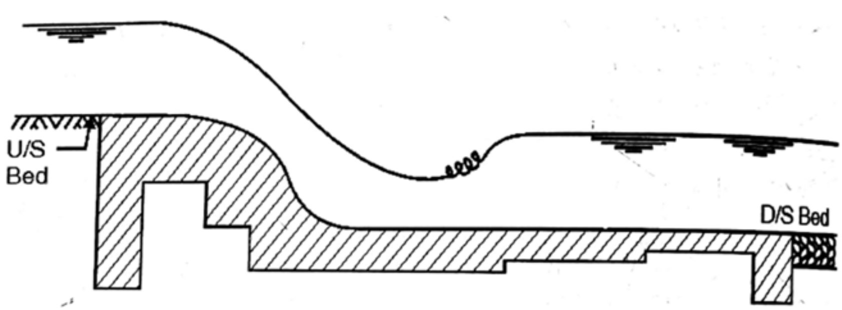


Fig. Ogee fall

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.

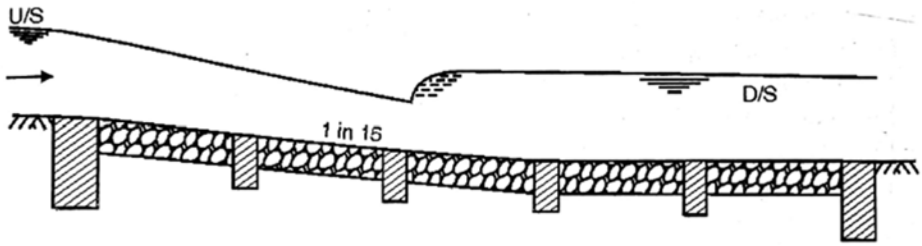


Fig. Rapid fall

3) Stepped fall

Stepped fall consists of a series 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 level with lower bed level.

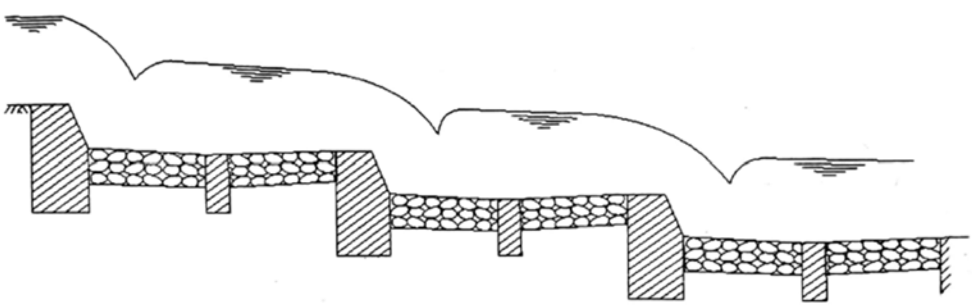


Fig. Stepped fall

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 sill of the notches are kept at the upstream bed level of the canal.

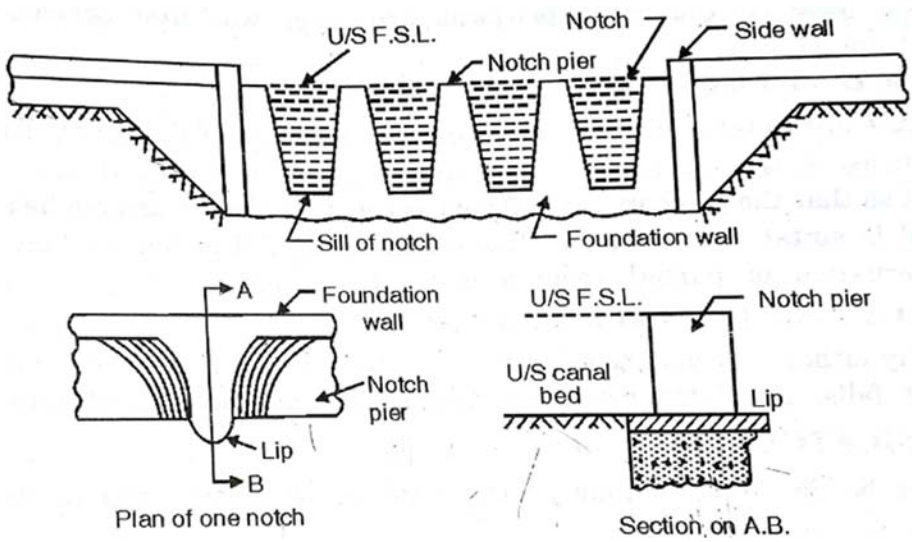


Fig. Plan and sectional view of trapezoidal notch fall

5) Vertical drop fall

In a vertical drop fall, the energy of the flowing water is dissipated by means of impact and by sudden deflection of velocity from vertical to horizontal direction. A water cushion is provided at the toe of the drop so as to reduce the impact of falling jet and thus to save the downstream floor from scour.

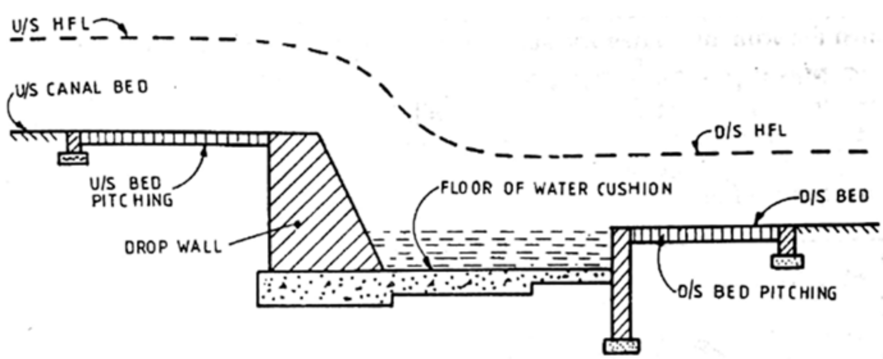


Fig. Simple vertical drop fall

4.1.4. Weir and Barrage

A solid obstruction placed across the river to raise water level on upstream side of the obstruction is called weir or barrage.

Weir: if the major part or the entire ponding of water is achieved by a raised crest and a smaller or nil part of it is achieved by the shutters, then this barrier is called weir.

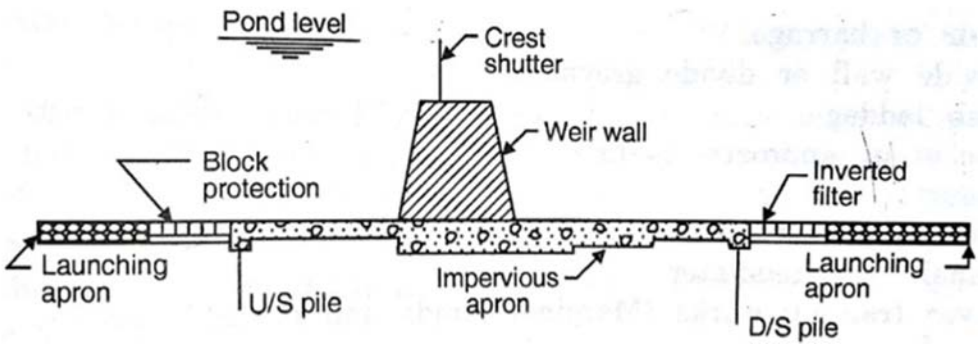


Fig. Weir

Barrage: If most of the ponding is done by gates and smaller or nil part of it is done by raised crest, then this barrier is known as barrage or a river regulator.

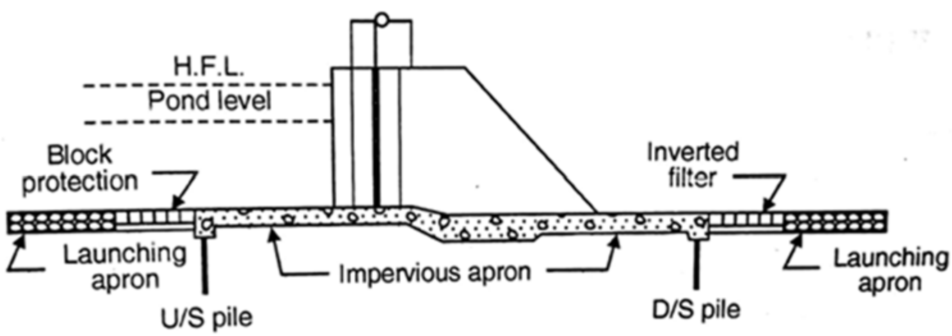


Fig. Barrage

They are commonly used to prevent flooding, measure water discharge and make rivers navigable.

Location of weir

1. A weir should be located in a suitable part of the river where there is unlikely to change its course.
2. The weir has to be built high enough to fulfill command requirements. During high floods, the river could overtop its embankment and change its course. Thus, a location with firm, well-defined banks should be selected for construction of the weir.
3. Where possible, the site should have good rock bed condition.

4. Alternatively, the weir should be kept as low as possible.

Difference between weir and barrage

	Weir		Barrage
1)	Crest level is set high.	1)	Crest level is set low.
2)	Shutters are in part length.	2)	Gates are over entire length.
3)	No control of flow. water	3)	Relatively high control on flow and levels by operation of gates.
4)	Chances of silting on the upstream is more due to raised crest.	4)	Chances of silting on the upstream is less due to low set crest.
5)	Afflux created is high due to relatively high high floods is low.	5)	Due to low crest of weirs, the afflux during weir crest.
6)	No possibility to provide road or rail-bridge.	6)	Road or rail-bridge can be constructed at low cost.
7)	Low cost in construction.	7)	High cost in construction.

4.1.5 Under sluice and silt excluder

Under sluice (Scouring sluice)

Under sluice maintain deep channels in front of canal head regulator and dispose off heavy silt and part of flood to the downstream side of weir or barrage.

A divide wall separates the main weir portion from the under sluice portion of weir. The crest of under sluice portion is kept at lower level than the crest of normal portion of weir. The under sluice length of barrage is divided into numbers of ways by piers and separate gates are installed on each ways. Thus, each way acts as gate controlled opening and will help in bypassing the excess supplies to downstream of rivers. This opening also help in scouring and removing deposited silt from under sluice pocket and hence are also called scouring valve.

Functions of under sluice are:

a) To maintain a well-defined deep channel approaching the canal head regulator.

b) To ensure ease diversion of water into canal through canal head regulator even during low flow (dry period).

c) To control the entry of silt into the canal.

d) To help in scouring the silt deposited over the under sluice floor and removing towards the downstream side.

Divide wall

Divide walls is long wall made up of stone masonry and cement concrete placed perpendicular to the weir and separates the weir portion from under sluice. It extends little beyond the canal head regulator and downstream upto launching apron.

Function of divide wall:

a) It separates under sluice from the weir portion.

b) It serves as support wall of the fish ladder.

c) Divide wall may keep the cross current, if they are formed, away from the weir. Cross current leads to vortices and deep scour.

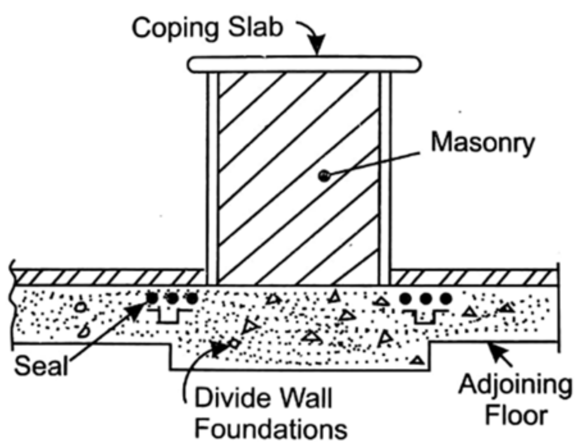


Fig. Cross section of divide wall on pucca floor

Fish ladder

In the river, the migrating fishes moves from upstream to downstream during winter in search of warm water and downstream to upstream in search of clear water during monsoon. These migrating fishes cannot pass across barrier to upstream if weir is high and velocity of flow exceeds 3 m/s. In order to cope this problem, a device is constructed by which flow energy is reduced and velocity remains below 3 m/s.

A structure which enables the fish to pass upstream is called fish ladder. It is constructed by providing a narrow opening adjacent to divide wall and provided with suitable baffle walls in it so as to control flow velocity.

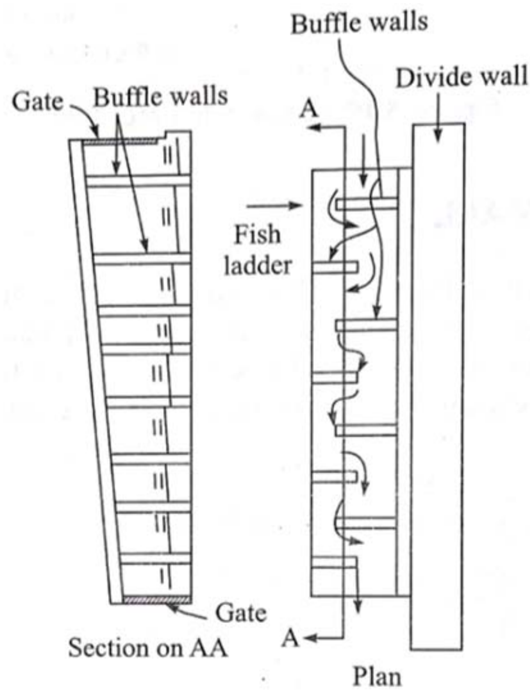


Fig. Plan and sectional view of fish ladder

Silt excluder

Silt excluder is a device installed in front of canal head regulator to exclude entry of silt into off-taking canal. It is designed such that the top and bottom layer of flow are separated with least disturbance. Top clear water enters to the canal through canal head regulator and silt laden water escape through under sluice.

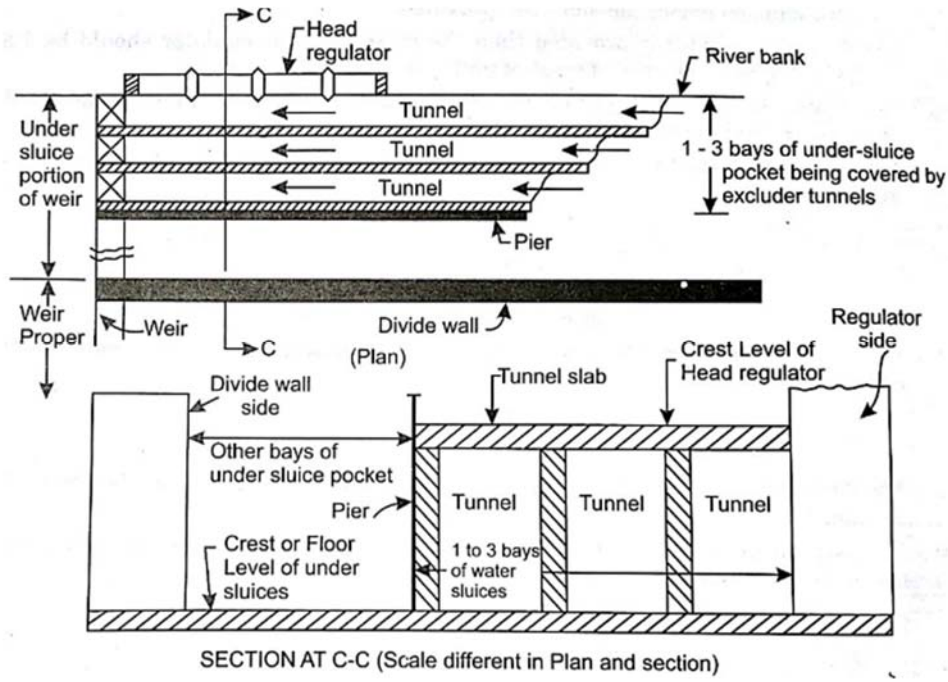


Fig. Silt excluder

Guide Bank

Guide banks are constructed on both sides of river banks to protect hydraulic structure and to guide the flow, so as to confine it in a reasonable width of river. It consists of massive embankment in shape of bell mouth on both sides which prevents the river from changing its course and out flanking the engineering work constructed in river.

4.2. Cross-Drainage Works

A cross-drainage work is a structure which is constructed at the crossing of a canal and a natural drain so as to dispose off the drainage water without interrupting the continuous canal supply. A cross drainage work is generally a costly construction and must be avoided as far as possible by aligning artificial canals along the ridge lines. It can also be reduced by diverting one drain to another.

Types of cross-drainage work

The drainage water intercepting the canal can be disposed off in either of following ways:

1. By passing the canal over the drainage

   This may be accomplished either through

   a) An aqueduct

   b) Siphon aqueduct

2. By passing the canal below the drainage

   This may be accomplished either through

   a) A super-passage

   b) Canal siphon

3. By passing the drain through the canal, so that the canal water and drainage water are allowed to intermingle with each other. This may be accomplished either through

   a) A level crossing

   b) Inlet and outlet

Aqueduct and siphon aqueduct: In these works, the canal is taken over the natural drain such that drainage water runs below the canal either freely or under siphonic pressure.

4.2.1. Aqueducts

When the high flood level (HFL) of the drain is sufficiently below the bottom of the canal so that the drainage water flows freely under gravity, the structure is known as aqueduct. In aqueduct the canal water is taken across the drainage in trough supported in piers. An inspection road is generally provided along with the trough.

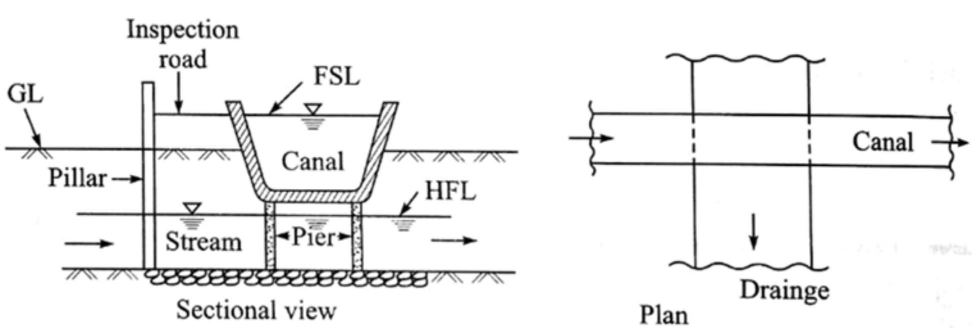


Fig. Plan and sectional view of aqueduct

4.2.2. Siphon aqueducts

When the high flood level of the drain is higher than the canal bed and the drain water passes the aqueduct barrels under siphonic action, the structure is known as siphon aqueduct.in case of siphon aqueduct, the drain bed is generally depressed and provided with pucca floor.

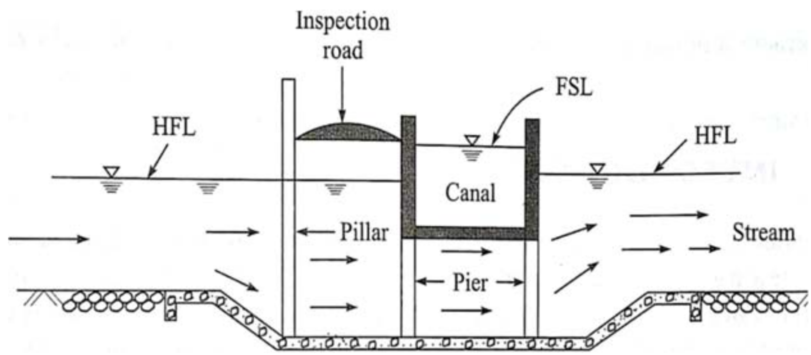


Fig. Sectional view of siphon aqueducts

Super passage and canal siphon: In these works, the drain is taken over the canal such that canal water runs below the drain either freely or under siphonic action.

4.2.3. Super passage

When the full supply level (FSL) of the canal is sufficiently below the bottom of drain through, so that the canal water runs freely under gravity, the structure is known as a super passage. A super passage is thus the reverse of an aqueduct.

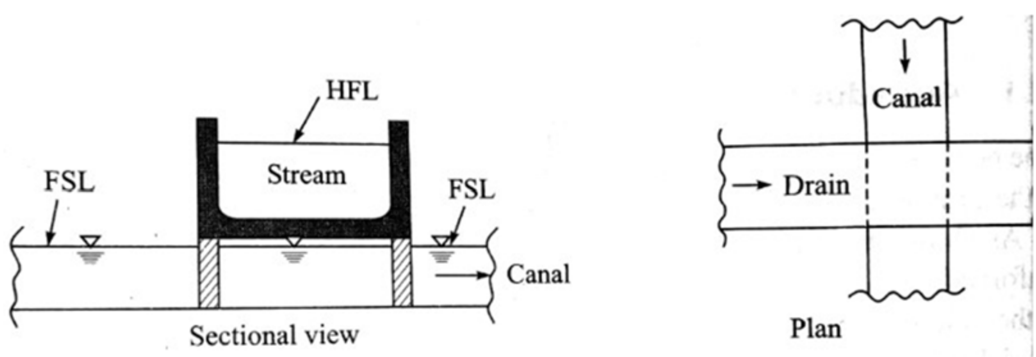


Fig. Plan and sectional view super passage

4.2.4. Siphon or canal siphon

When the FSL of the canal is above the bed level of the drainage trough, so that canal flows under siphonic action under the trough, the structure is known as a siphon or a canal siphon.

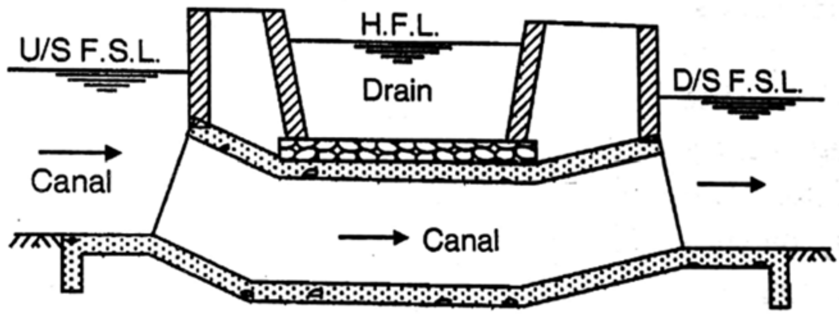


Fig. Siphon or canal siphon

4.2.5. Level crossing

In this type of cross drainage work, the canal water and drain water are allowed to intermingle with each other. A level crossing is generally provided when a large canal and huge drainage meets each other practically at the same level. A typical layout of level crossing is shown below:-

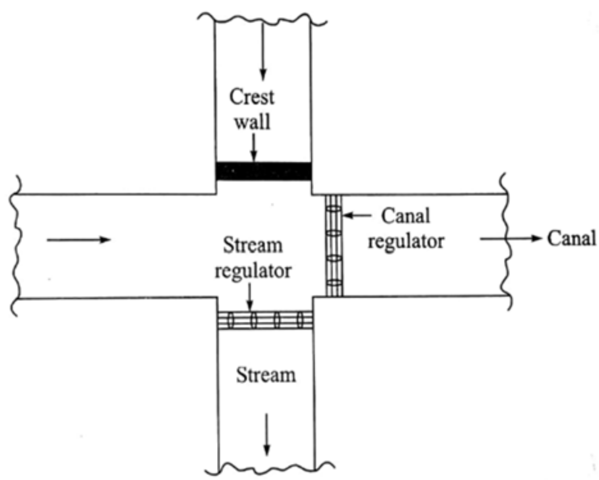


Fig: Typical layout of a level crossing

4.2.6. Inlet and outlet

When large irrigation canal meets a small stream or drain at approximately at same level, drain water is allowed to enter the canal as inlet. At some distance from this inlet point, a part of water is allowed to dispose off in stream in required quantity.

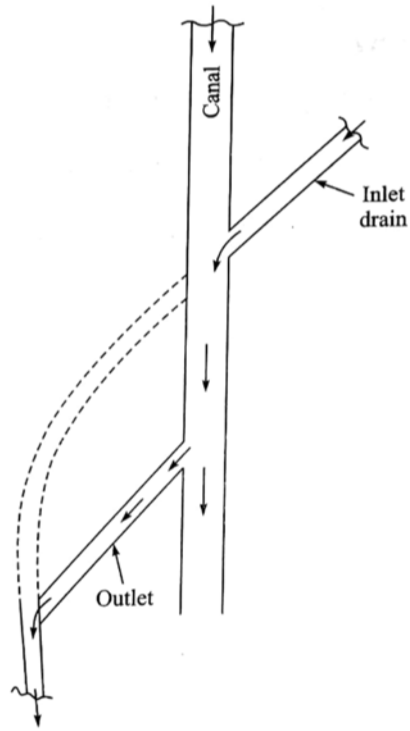


Fig. Inlet and outlet

3. Learning process and support materials

Following are the learning process of this unit:

-theoretical notes

-presentation

-group work

-prepare field trip for the observation of various irrigation structures

1. Assessment

A. Very short answer question

1. What is canal head regulator?

2. What is aqueduct?

3. What is the main difference between weir and barrage?

4. Draw a cross drainage structure aqueduct.

5. Define canal fall.

B. Short answer question.

1. Describe weir and barrage with figures.
2. Differentiate between aqueduct and super passage.
3. Compare clearly between aqueduct and siphon aqueduct with neat sketches.

C. Long Questions.

1. Explain the under sluice and silt excluder.
2. Describe the different cross drainage works.

Glossary

Surplus- excess

Recommended- to suggest or encourage as an appropriate choice

Deflection- the act of deviating from its original path

Cope- to deal effectively with something difficult

Intermingle- to mix or become mixed together

Reference materials

Suggested texts and references

Irrigation Engineering and Hydraulic Structures – Santosh Kumar Garg

Irrigation and Water Power Engineering- Dr. B.C. Punmia, Dr. Pande B.B. Lal, Ashok Kumar Jain and Arun Kumar Jain

Irrigation and Water Power Engineering- Madan Mohan Das and Mimi Das Saikia

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Engineering hydrology-K. Subramanya

Engineering hydrology-Dr. K.N. Dulal and Er. Sanjeeb Baral

Unit 5
Canal Design Concept

1. Objective

- To define canal
- To list out classification of canal
- To identify types of canal based on alignment
- To familiar with canal losses and canal lining
- To familiar with river training works

2. Contents

Canal

A canal is an artificial channel, generally trapezoidal in shape constructed on the grounds to carry water to the fields either from the river or from a tank or reservoir.

2.1. Classification of canal and their alignment

1. Based on function

The following are the names given to canals based on function as:

a. Irrigation canal

The canal, which is constructed to carry water to the agricultural field, is called irrigation canal.

b. Navigation canal

The canal, which is mainly used for navigation besides irrigation, is called navigation canal.

c. Power canal

The canal, which carries water mainly for power generation besides irrigation, is called power canal.

d. Feeder canal

The canal, which feeds water to one or more canals for irrigation and other purposes, is called feeder canal.

e. Carrier canal

A carrier canal besides doing irrigation carries water for another canal.

2. Based on nature of source of supply

The canals are classified in following categories based on source of supply and system of supply as:

a. Permanent canal

Permanent canals are those, which are fed by permanent source of supply such as, ice feed river or reservoir. It is well-graded canal and provided with permanent head works, regulator and distribution system.

b. Inundation canal

These are earliest type of irrigation canals and the supply of water is dependable on periodical rise of water level in the river during flood period. Construction of permanent regulatory work is rare in those channels.

3. Based on financial aspect and output

a. Productive canal

b. Protective canal

a. Productive canal

These canals when fully developed produce enough revenue from the cultivators to cover up all the expenditures for construction and maintenance. Thus, the canals, which add wealth of nation directly from their water, are called productive canals.

b. Protective canal

The canal, which is constructed with the idea of protecting particular area from famine, is called, protective canal. This gives employment for food to the famine stricken framer. Thus, this canal is sort of relief work.

1. Based on relative importance and discharge capacity

The direct irrigation scheme using a weir or a barrage as well as the storage irrigation scheme using a dam or reservoir requires a network of irrigation canal of different size and capacities. The entire network of canal is called canal system. The canal system consists of

a. Main canal

b. Branch canal

c. Major Distributaries

d. Minor Distributaries

e. Water course

a. Main canal

It is a canal taking off directly from the headwork. No direct irrigation is usually carried out from the main canal. Main canal acts as a carrier for the other canals. They usually carry water above 25 cumecs.

b. Branch canal

When a main canal reaches the area that is to irrigate, it gets divided into branches going to different part of the area. These branches are called branch canal. In general branch canal also do not carry out any direct irrigation. Branch canal are usually feeder canal for distributaries. They usually carry a discharge of over 5 cumecs.

c. Major Distributaries

These are small channels taking off from the branch canals and sometimes from the main canals. They distribute their supply through outlet into minor distributaries or watercourse for direct irrigation. Discharge in this canal varies from 0.5-5 cumecs.

d. Minor Distributaries

They take water from the major distributaries or from branch canals and supply water to the watercourses through outlets provided along them. Their main function is to reduce the length of field ditch. The discharge capacity is below 0.25 cumecs.

e. Water course (field ditch or field channel)

It is a small connecting outlet to the fields. Farmers normally construct it to take water from the outlet constructed by government. They are small channels which are excavated and maintained by cultivators at their own cost, to take water from government owned outlet points, provided in the major distributaries or minor distributaries.

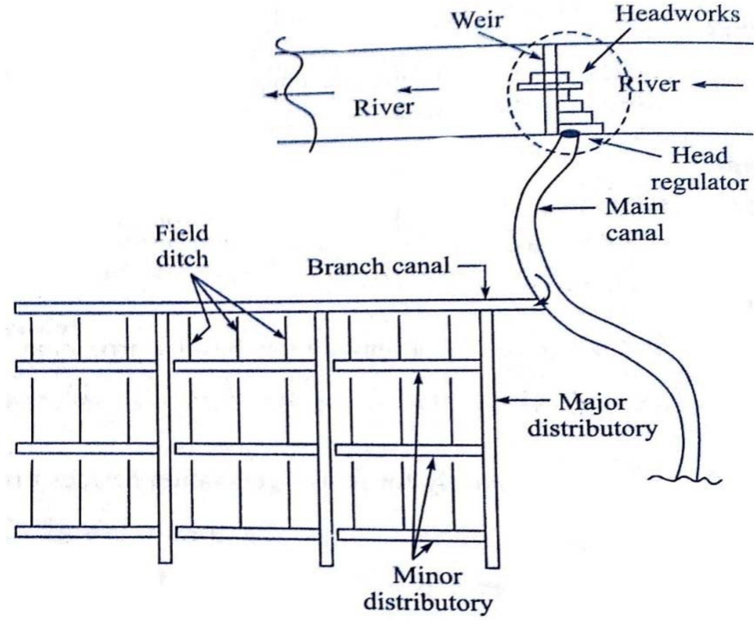


Fig: Layout of irrigation canal system

Canal alignment

A canal has to be aligned in such a way that it covers the entire area purposed to be irrigated with shortest possible length and at the same time, its cost including the cost of cross drainage is minimum.

The alignment of canal should be done based on following approach.

1. The alignment should be done such that
    - i. Minimum number of cross drainage works
    - ii. Most economical way of distributing the water to the land.
    - iii. As high, command area as possible.
2. The alignment of canal on watershed is preferred since it is most economical.
3. The length of main canal should be minimum between two points.
4. The alignment should avoid villages, roads, cremation places, place of worship, and other valuable properties.

5. The alignment should pass balanced depth of cutting.
6. The number of vines and acute curves should be minimum.
7. The alignment should not be made in rocky brackish or cracked

Based on alignment, canal may be in following types

1. Watershed or ridge canal

Watershed or ridgeline is the highest line between two drainage areas. The canal, which is aligned along a watershed or runs for most of its length on a watershed, is called watershed or ridge canal.

- This canal can supply water on both sides and thus lager area may be taken under cultivation.
- As it flows along highest line, it does not require crossing any natural drainage on its way. Therefore, costly cross drainage work (CDWs) are not at all necessary.
- It is the best irrigation canal and most economical.

2. Contour canal

A canal, which is aligned, nearly parallel to contour except for the necessary longitudinal slope is called a contour canal. Such type of canal is constructed in hilly areas.

- The contour canal can irrigate only on one side.
- As one of its banks on the higher side, so only a bank is required to construct on the lower side.
- It involves crossing the natural drainage and therefore, costly cross drainage works are required to construct.
- Drainage enters from hilly side so it has risk of breaching and silting.
- It is sometimes called single bank canal.

3. Side slope canal

It is a canal aligned roughly at right angles to the contours. Such channel is roughly parallel to the natural drainage and hence does not intercept cross drainage and hence no cross drainage structures are required.

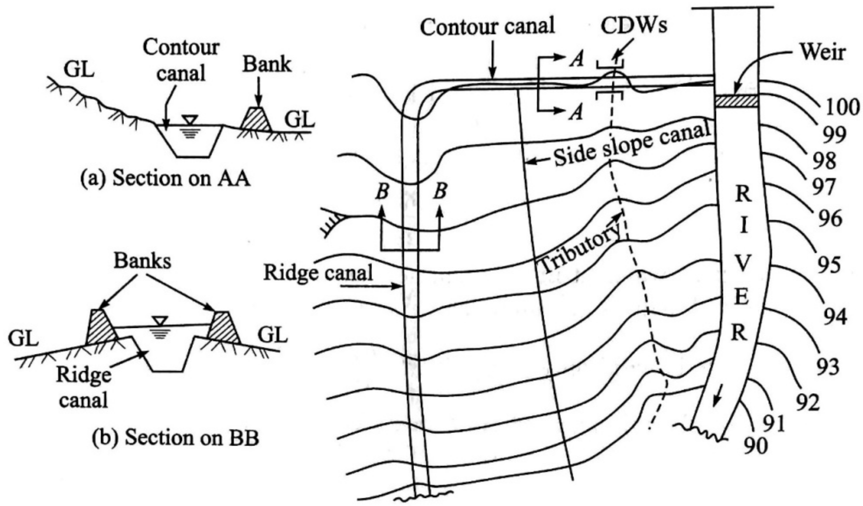


Fig. Alignment of Contour.Side slope and Ride canal

5.2. Canal losses, canal lining

Canal losses

During the passage of water from the main canal to outlet at the head of watercourse, water may be lost either by evaporation from the surface or by seepage through the peripheries of the channels. These losses are sometimes very high and may be upto 25% to 50% of water diverted into the main canal. In determining the designed channel capacity, a provision for these water losses must be made. Thus, water from the canal is lost due to following two main reasons

1. Evaporation loss from the surface
2. Seepage loss through bed and side

Evaporation Losses

- The loss due to evaporation is generally a small percentage of the total loss in unlined canal. It hardly exceeds 1% to 2% of the total water entering the canal.
- Evaporation losses are the generally of the order of 2 to 3 percent of total losses,
- In summer, the evaporation losses may be more but seldom exceed about 7% of the total water diverted into the main canal.

Evaporation losses depends on following factors

i. Temperature

ii. Wind velocity

iii. Humidity

iv. Area of water surface exposed to the atmosphere

v. Vapor pressure

Seepage loss

Seepage losses constitute major portion of loss in an unlined canal. The seepage losses are due to

1. Absorption of water in upper layer of soil below the canal bed
2. Due to percolation of water into the water table thus raising the water table

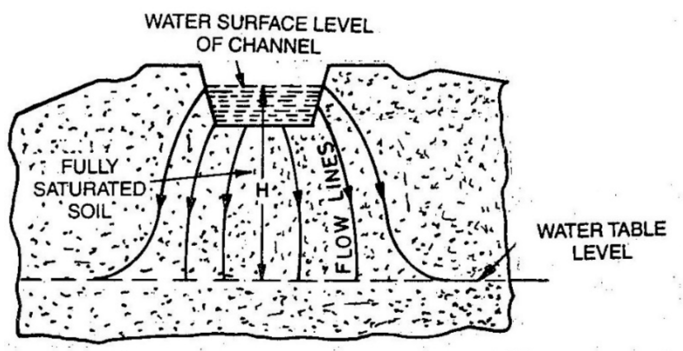


Fig. Percolation.

Seepage losses is about 25% to 50% of water diverted into the main canal and depends on

a. Under ground water table position

b. Porosity of soil

c. Turbidity of water

d. Temperature of water

e. Amount of silt carried into suspension

f. Velocity of water

g. Conditions of canal

- **The total loss, i.e., evaporation loss plus seepage loss is called transit loss**

or conveyance loss.

Prevention of canal loss

Control of canal losses can be done by following ways,

1. Canal lining
2. Avoiding canal alignment in filling
3. Selection of efficient section

Canal lining

Traditionally earthen canal is mostly used. However, loss of water through seepage is much more in such canal. Approximate amount of loss water by seepage is 25 to 50% of water diverted into the canal. This is very serious losses and reduces the irrigation potential of the same water. To avoid the seepage loss, lining of canal is must.

Definition

An impervious and stable layer provided at the beds and side of canal to control the seepage of water is called the lining of canal, which improves the life and discharge capacity of canal.

Advantage of canal lining

1. Seepage control
2. Prevention of water logging
3. Increase in canal capacity
4. High command area
5. Reduction of evaporation loss
6. Less chance of silting
7. Reduction in maintenance cost
8. Reduction in erosion
9. Reduction of weed growth

Disadvantage

1. Canal lining requires heavy initial cost investment
2. It is difficult to repair damaged lining
3. Lining being permanent, is difficult to shift the outlet if necessary

Various types of lining

Following are the important type of lining used:

1. Cement concrete lining
2. Shot Crete lining
3. Precast concrete lining
4. Cement mortar lining
5. Brick lining
6. Stone or boulder lining
7. Asphalt lining
8. Soil cement lining
9. Clay puddle lining

5.3. River training works

All those engineering works which are constructed on the river, so as guide and confine the flow to the river channel, and to control and regulate the river bed configuration, thus ensuring safe and effective disposal of floods and sediment loads.

Establishing and training the river along the certain alignment with suitable water way is the aim of the river training.

Objectives of river training works

1. To prevent river from its changing it course and to avoid outflanking of the structures like bridge, weirs, aqueducts etc.
2. To prevent flooding of surrounding countries by providing a safe passage for the floods waters without overtopping the bank.
3. To protect the river banks by deflecting the river away from the attacked banks.

4. To ensure effective disposal of sediment load.
5. To provide minimum water depth required for navigation.

Classification of river training

1. High water training or training for discharge.

   -to provide sufficient depth for navigable channel.
2. Low water training or training for depth.

   -to provide sufficient depth for navigable channel.
3. Mean water training or training for sediments.

   -for effective disposal of sediment load.

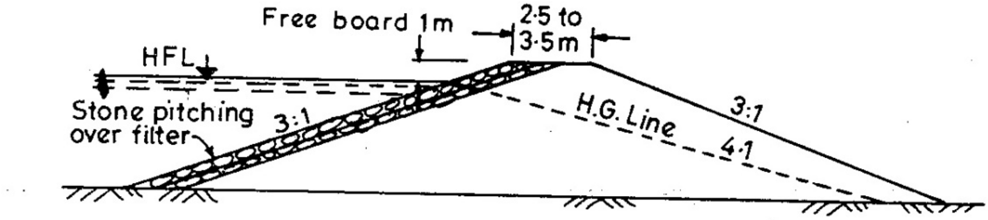
Method of river training

Following methods are used for training of river:

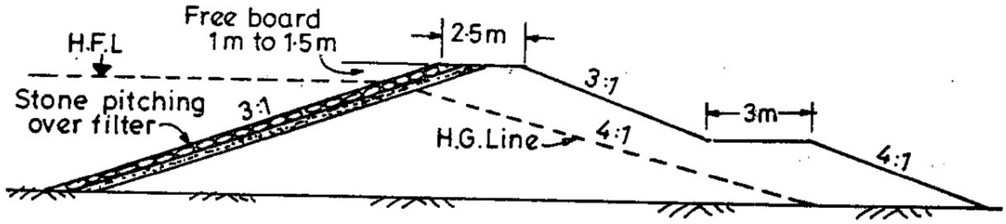
1. Marginal embankment or levees.
2. Guide banks.
3. Spurs or Groynes.
4. Artificial cut-offs.
5. Launching apron and stone pitching.
6. Pitched islands.

1. Marginal embankment or levees

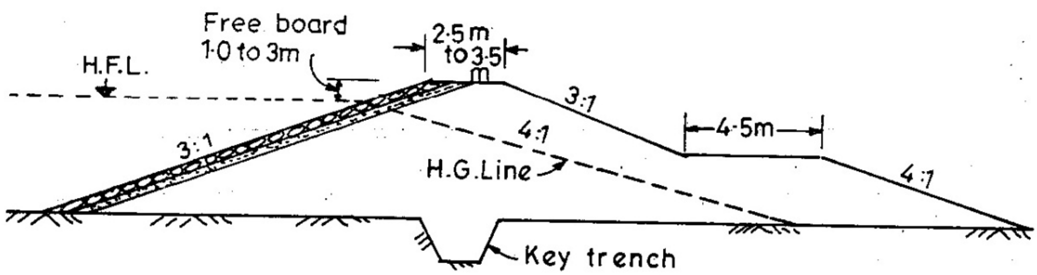
Marginal embankments are generally earthen embankments, running parallel to the river, at some suitable distance from it. They may be constructed on both sides of the river or only one side, for some suitable river length where the river is passing through towns, cities, or any other places of importance. These embankments retain the flood water and thus, preventing it from spreading into the nearby lands or towns.



(*a*) For heights below 2.5 m.



(*b*) For heights above 2.5 m and upto 3.25 m



(*c*) For heights above 3.25 m

Fig. Typical sections of levees for different heights.

2. Guide banks

These are provided to confine the flood water of alluvial rivers within a reasonable water way and provide a straight non-torturous approach towards the engineering works constructed across the river. The guide banks generally consist of two heavily constructed embankments in the shape of bell mouth

- They prevent the river from changing its course and outflanking of the works.

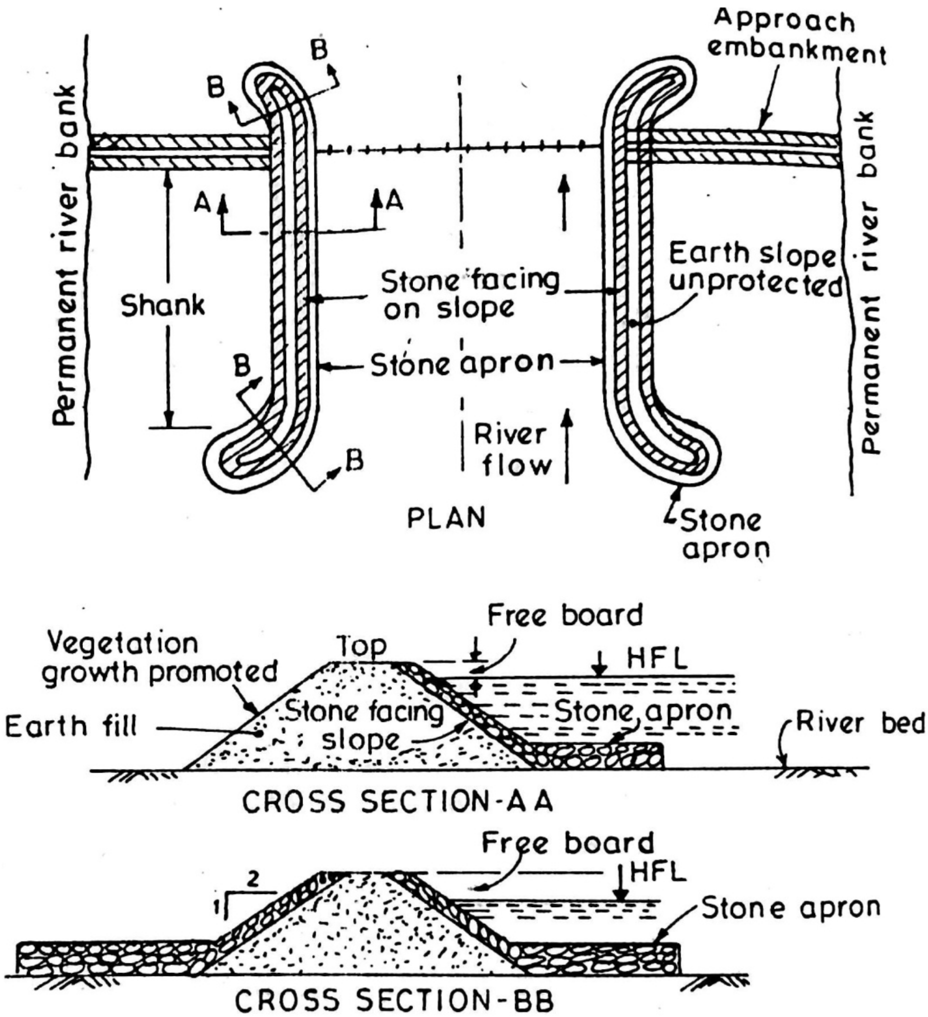


Fig. Guide Bank details.

It is also known as bell's bounds.

3. Spurs and Groynes

These are the embankment type structures, constructed transverse to the river flow, extending from the bank into the river. They are constructed in order protect the bank from which they are extended, by deflecting the current away from the bank.

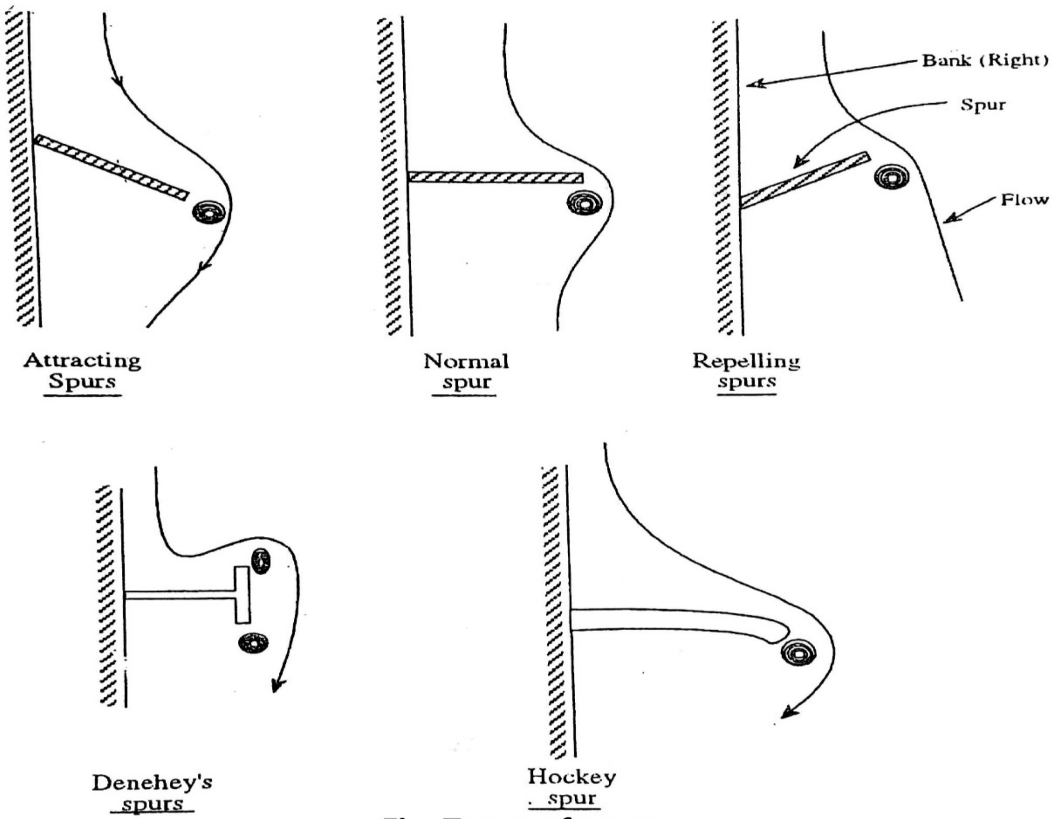
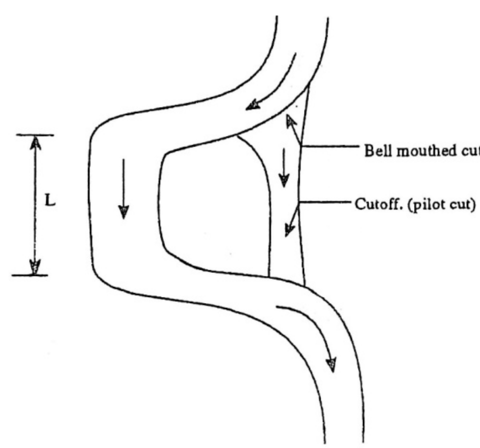


Fig. Types of spurs

4. Artificial cut-off

When meandering goes on increasing and may endanger some valuable land or properties, then the river course may be straightened by inducing an artificial cut-off.

For inducing an artificial cut-off, only a plot channel is required to be constructed. The flood water gradually enlarges the plot cut to the required cross-section.



Cut off

5. Stone pitching and Launching apron

River banks are damaged by the waves of flowing water. To protect the bank, a pitching work of stones, bricks and concrete blocks can be used. Concrete blocks and brick works are very costly; hence, stone pitching is mostly adopted.

Whenever a slope face is protected by stone pitching against scour, the pitching is extended beyond the toe on the bed, in form of packed stone as shown in the fig. The stone dumping is known as launching apron.

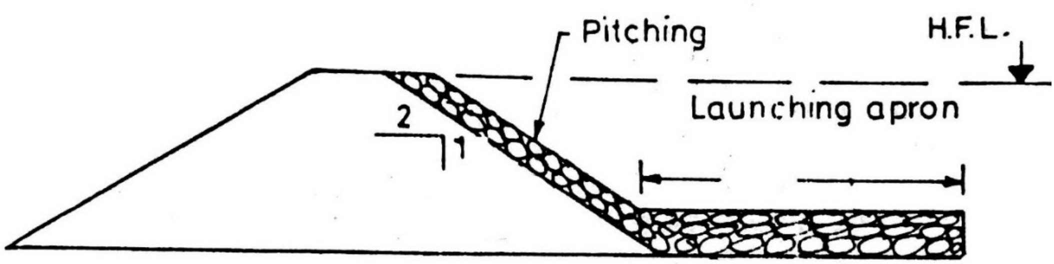


Fig. Stone pitching and launching apron

If such protection is not provided, scour will occur at toe with consequent undermining and collapse of stone pitching.

3. Learning process and support materials

Following are the learning process of this unit:

-theoretical notes
-presentation
-group work

4. Assessment

A. Very short answer question.

1. What is irrigation canal?
2. What do you mean by lining of canal?
3. Which type of canal alignment canal alignment results maximum C/D works?
4. Define water course with neat sketches.

B. Short answer question.

1. Classify canals on the basis of alignment and describe any one of them.
2. Differentiate watershed canal and counter canal.
3. Differentiate watershed canal and counter canal.
4. Write about contour canal including merits and demerits with figure.

C. Long Questions.

1. Describe the types of river training works with figures.
2. How can you classify canal. Explain.
3. Explain about the canal loss and canal lining?

Glossary

Revenue- the income returned by an investment, turnover

Famine- extreme shortage of food in a region

Breaching- an opening, tear or rupture

Outflanking- to move around the side of

Collapse- to break apart and fall down suddenly

Undermining- the act of digging underneath (something) or making a passage

Reference materials

Suggested texts and references

Irrigation Engineering and Hydraulic Structures –Santosh Kumar Garg

Irrigation and Water Power Engineering- Dr. B.C. Punmia, Dr. Pande B.B. Lal, Ashok Kumar Jain and Arun Kumar Jain

Irrigation and Water Power Engineering- Madan Mohan Das and Mimi Das Saikia

Irrigation Engineering(Including Hydrology)-R.K. Sharma and T.K. Sharma

Irrigation Engineering and Hydraulic Structures-Dr. V.C. Agarwal

Engineering hydrology-K. Subramanya

Engineering hydrology-Dr. K.N. Dulal and Er. Sanjeeb Baral

Unit 6
Water logging and Drainage

1. Objective

- To define water logging
- To list out the causes and effects of water logging
- To identify the remedial measures for water logging
- To compare surface and sub surface drainage
- To familiar with hill irrigation practice in Nepal

2. Contents

2.1. Definition of water logging

An agricultural land is said to be "water-logged" when its productivity or fertility gets affected by the high water table .This happens, when the water table rises into the root zone of plants , making the root zone ill aerated and suspending the bacterial activity there.

6.2. Causes and effects of water logging

Causes of water logging

1. Over irrigation of land, without giving any rest to it, results in heavy percolation and subsequent rise of water table.
2. Cultivation of wet crops in every season and applying more water than required by crops also increase the chances of water logging.
3. Seepage of water from high adjoining land to the sub soil of land (which becomes water-logged).
4. Seepage of water through bed and sides of adjoining canals, reservoirs, which are at higher level than the water logged land, resulting in the rise of water table.
5. Inadequate surface drainage on land, resulting in the percolation and the subsequent rise of water table.
6. Impervious obstruction in the path of laterally moving subsoil water causes

the rise of water table on upstream side of obstruction.

7. Excessive rains in the locality, causes heavy percolation, leading to rise of water table.

8. Frequent submergence of land due to floods in adjacent river; increase the chances of water logging.

9. Soil having poor drainage qualities such as clay. Such soil cannot drain percolated water which leads to rise of water table.

10. Excessive rains in the locality, causes heavy percolation, leading to rise of water table.

Effects of water logging

1. Ill aeration, and reduction of crop yield:

   When water table rises to root zone of the crops, circulation of air near the root zone is reduced. In absence of oxygen, the bacteria which produce necessary nitrates for the plants growth die soon and growth of plant is affected adversely. This condition is also called ill aeration.

2. The normal cultivation operation such as tilling and ploughing etc. becomes difficult. In extreme cases the free water may rise over the surface of land making cultivation operations impossible.

3. Certain water loving plants like grasses weeds etc. grow excessively in water-logged land thus affecting growth of main crops.

4. Water logging causes salinity:

   Salinity is the process of accumulation of some harmful salts like sodium sulphate, sodium chloride, sodium carbonate etc. on soil surface and at some depth below the upper surface due to rise of water table.

   (If water table has risen up or plants roots happen to come within the capillary fringe, water is continuously evaporated by capillarity. Thus a continuous upward flow of water from the water table to the land surface gets established. With this upward flow, the salts which are present in water also rise towards surface, resulting in deposition of salts in root zone of crops. The alkali salts present in the root zone of the crops has corroding effect on the roots, which reduces the osmotic activity of plants and checks the plant growth. Such soils are called saline soils and the condition is called salinity. Whenever there is water- logging salinity is must.)

5. Temperature of soil is lowered and hence bacterial activities are retarded causing less food available for the plant.
6. Water logging result in colder and damper climate, resulting in marshy lands and breeding of mosquitoes, causing outbreak of disease like malaria and dengue.
7. Delay in cultivation operation.

Preventive /Remedial Measure of Water

1. **Reducing the intensity of irrigation**

   In the areas where there is chance of water logging intensity of irrigation should be reduced. Land rotation should be adopted.

2. **Adopting crop rotation**

   Sowing of wet crops (requiring more water) in every season should be discouraged. A wet crop should be followed by a dry crop. i.e. crop rotation should be adopted.

3. **Optimum use of water**

   Farmers should be educated and trained in using the just required quantity of water, which will give optimum yield.

4. **By providing intercepting drain**

   Intercepting drains along the channels should be constructed whenever necessary. These drains can intercept and prevent the seeping canal water from reaching the area likely to be water-logged.

5. **Improving the natural drainage of area**

   To reduce the percolation water shouldn't be allowed to stand in the land for a longer period. The water falling on land and excess irrigation water should be effectively and quickly drained out. This can be achieved by improving the natural drainage of area by measures like clearing the obstructions in the path of flow.

6. Lining of canals and water course

To control the seepage through bed and sides of canals passing through porous soils, canals should be lined with impervious materials.

7. By provision of artificial drainage system

An efficient drainage system should be provided in order to drain away the storm water and excess irrigation water. A good drainage system consists of surface drain as well as sub surface drain.

8. Introduction of lift irrigation

Lift irrigation should be introduced in the place of canal irrigation, in places where there is a possibility of water logging. Lift irrigation utilizes underground water and maintain the water table at lower level.

2.3. Remedial measures of water logging:

1. Controlling the loss of water by seepage from canal.
2. Providing adequate surface drainage
3. Providing efficient under drainage
4. Charging irrigation tax on volumetric basis

Land drainage

Only optimum quantity of irrigation water to irrigation field gives good /maximum production. Excess than the optimum quantity is not absorbed by plants which may percolates and help in raising the water table and creates problem of water logging. The excess irrigation water must be removed as early as possible. The removal of excess irrigation water from agricultural land is called the land drainage. To remove excess of irrigation water, two types of drainage system can be provided

1. Surface drainage
2. Sub-surface drainage (Tile-drainage or under-ground drainage)

Surface drainage

Surface drainage is the removal of excess rain water falling on the fields or the excess irrigation water applied to the fields by constructing open ditches, field drains and other related structure. The land is generally sloped towards these drains. Surface drainage consists of two types of drains they are;

1. **Shallow surface drains**

   They are trapezoidal in cross-section. They are mainly used to remove the surface run-off and a part of excess irrigation water. It reduces the percolation of storm water. These are useful if there are local accumulations of storm water in some depression as shown in figure 8.10

2. **Deep drains**

   Deep surface drain or outlet drains carry the storm water discharge from the shallow surface drains and the seepage water coming from the underground tile drains.

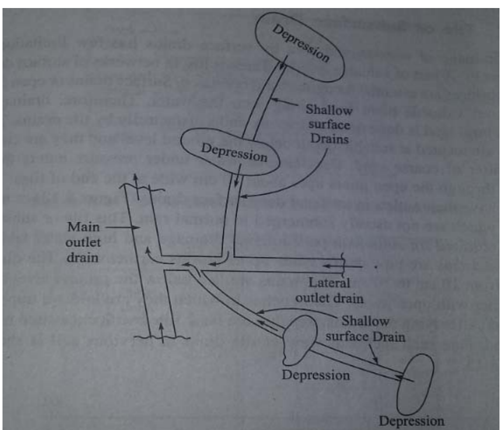


Figure 8.10 Networks of shallow surface drains with outlets.

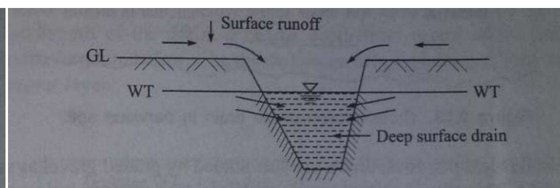


Figure 8.11 Deep surface drain to remove water logging.

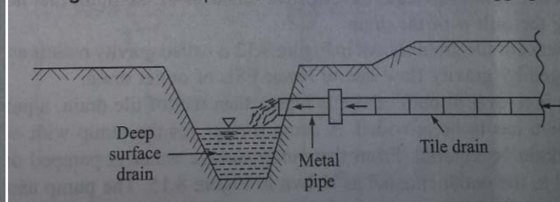


Figure 8.12 Deep surface drain as outlet of tile drain.

Tile or sub-surface drainage

The removal of excess sub-soil water from agricultural field is known as sub surface drainage.

The drainage of water logged areas by surface drains is not very satisfactory for the following reasons.

1. Valuable agricultural land is wasted in the construction of surface drains.

2. Valuable plants foods are washed down in the open drains.

Thus the drainage of agricultural land is done more satisfactorily by covered tile drains.

Tile drains are laid at suitable depth below the ground level to drain off the sub-soil water. These are required in case of soil with poor drainage quality such as clay. The drain usually consists of earthenware pipes of 10 to 30 cm diameter. These drains are laid below the ground level butting each other with open joints. The pipes are placed in trenches and the trenches are filled back with sand and excavated earth as shown in fig 8.14 below. The sub soil water enters the drain through the open joints .the drains have their outlets in natural or artificial channels.

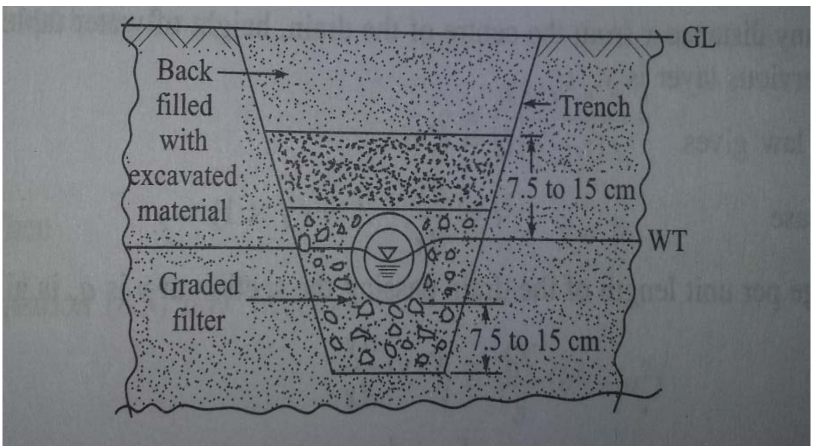


Figure 8.14 Cross-section of tile drain in less pervious soil.

2.4. Causes of canal damage, maintenance tasks

When irrigation canal system is put into operation after construction, it is essential for its maintenance for proper and efficient functioning. Canals are required to maintain regularly due to the following causes:

i. Silting in canal

In unlined channel, silt creates a regular problem as the velocity of water is not enough to carry the silt along with water to the crop field. In the canal headwork, silt excluder and little downstream of head work silt ejector are provided to arrest the silt from entering the canal. Yet a part of silt enters the channel, removal of which is necessary.

The methods adopted for silt removal are:

By iron rakes: These rakes dragged in canal to dislodge the silt.

Flushing: Canal is flushed with clear water and deposited silt is lifted up and then drained off the silt laden water.

Silt scouring fleet: With the help of barges operated by cable, silt is agitated by maneuvering the barges up and down.

Bundle of thorny bushes: They are tied together and pressed down by weight of stones and are pulled inside the canal by animals. Muddy silts are dislodged quite satisfactorily.

Loaded boats: Reduction of area of flow by loaded boat to increase the velocity of flow.

Water jets: Silt is stirred by water jet with the help of pumps to dislodge the silt.

Dredger: Dredger is used seldom to clean the silt.

Manual labour: With the help of manual labour also, silt is removed.

ii. Weed growth

Weeds are unwanted plants that grow profusely in water under some favorable conditions. Weeds decrease the area of flow, offer resistance to flow. The deposition of silt and light encourages the growth of weed. If velocity of flow is increased, fine silt is held in suspension, water becomes turbid, light cannot penetrate to help the growth of weed.

Another method is rush rotation. It is the process of running the channel with full supply depth to obstruct light. Then the canal is left dry for some time. In the dry period weed cannot resist the scorching sun rays. Long duration of closure has killing effect on the weed growth.

Weed control may be done by manual labour and burning them when dry.

i. Overflowing of canal banks

   If canal overflows during heavy rains, bank height is required to increase.

ii. Breaching of canal banks

To reduce the failure of bank, it has to be strengthened. Banks can be strengthened by formation of internal and external berms by silting and extra earthworks. When berms are formed, canal banks cannot breach due to seepage or piping. To reduce silting to form berms, submersible spurs are constructed.

2.7. Hill irrigation practice in Nepal

The technique practiced for artificial application of water in the agricultural field in hilly areas is known as hill irrigation. Hill irrigation schemes in Nepal are usually small scale in nature.

Nepalese farmers have recognized the importance of water resources for centuries and have been constructing irrigation system at their own initiative to intensify their agricultural production. Irrigation development in the country remained in the hands of people for many years. This tradition has given birth to the FMIS (Farmer Managed Irrigation Scheme) scattered all over Nepal. These systems have developed their own rules, norms and procedures of management.

In FMIS, farmers are responsible for all the management activities encompassing water acquisition from the source to delivery to the point in the field and management of the system including the resource mobilization and management of resource for operation and management.

In Nepal, FMIS occupies special status in the national economy and food security system. It is estimated that 40% of the food production is produced out of 1500 FMIS in hill areas and 1700 systems in the Terai of Nepal.

3. Learning process and support materials

Following are the learning process of this unit:

- theoretical notes
- presentation
- group work

4. Assessment

A. Very short answer questions.

1. What is water logging?

B. Short answer question.

1. List the causes of water logging?
2. What are the maintenance tasks for canal damages.
3. What are the remedial measures for water logging?

C. Long Questions.

1. Explain the hill irrigation practice in Nepal.

Glossary

Submergence= the act of immersing below the surface of a liquid

Turbid= (of a liquid) opaque or thick with suspended matter

Reference materials

Suggested texts and references

Irrigation Engineering and Hydraulic Structures –Santosh Kumar Garg

Irrigation and Water Power Engineering- Dr. B.C. Punmia, Dr. Pande B.B. Lal, Ashok Kumar Jain and Arun Kumar Jain

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Unit 7
Hydrology and flood estimation

1. Objective

- To define hydrology
- To describe the hydrologic cycle
- To familiar factors affecting runoff
- To arrange estimation of flood and peak flood
- To list out and describe the methods of stream/river discharge determination
- To describe ground water hydrology

2. Contents

2.1. Definition of hydrology

Hydrology means the science of water. It is defined as the science that deals with the occurrence, circulation and distribution of water of the earth and earth's atmosphere. As branch of earth science, it is concerned with the water in streams, and lakes, rainfall and snow fall, snow and ice on land and water occurring below the earth's surface.

Hydrology can be basically classified as

1. Scientific Hydrology-the study which is chiefly concerned with academic aspects.
2. Engineering Hydrology or Applied hydrology- a study which is concerned with engineering application.

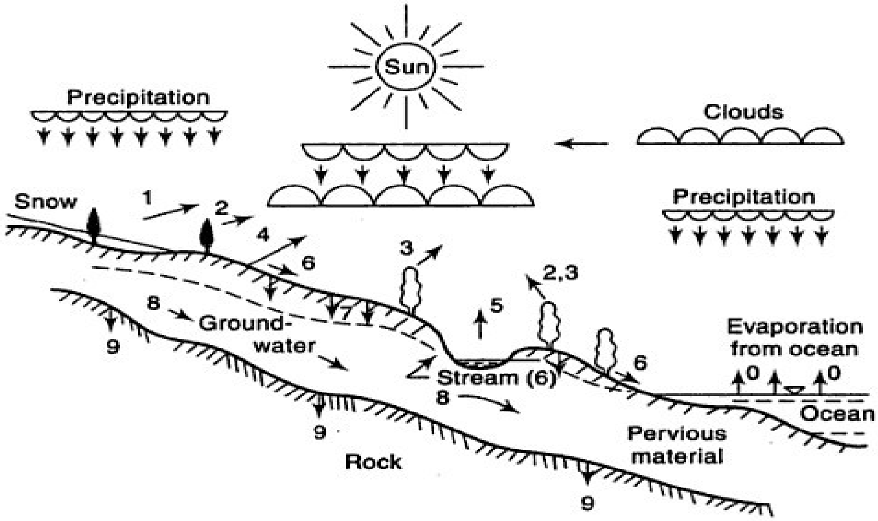
In a general sense engineering hydrology deals with

i. Estimation of water resources.

ii. The study of processes such as precipitation, runoff, evapotranspiration, and their interaction and

iii. The study of problems such as floods and droughts, and strategies to combat them.

2.2. The hydrologic cycle



0 = Evaporation from ocean
1 = Raindrop evaporation
2 = Interception
3 = Transpiration
4 = Evaporation from land
5 = Evaporation from water bodies
6 = Surface runoff
7 = Infiltration
8 = Groundwater
9 = Deep percolation

Fig. 1.1 The Hydrologic Cycle

The hydrologic cycle is the descriptive term applied to the general circulation of water from the ocean to the atmosphere, to the ground and back to the ocean again. Fig 1.1 above shows the various phase of hydrologic cycle. The cycle may be considered to begin with the water of ocean.

The water in oceans evaporates due to heat energy provided by solar radiation. The water vapour moves upwards and forms clouds. While much of cloud condense, it fall back to the oceans as rain, a part of the cloud is driven to the land areas by winds. There they condense and precipitate as rain, hail, sleet, etc. A part of the precipitation may evaporate back to the atmosphere during falling. A portion of precipitation that falling on land is retained temporarily in the soil, in surface depression and on vegetation and other objects until it is returned to the atmosphere by evaporation and transpiration. Vegetation also sends a portion of water from the ground surface back to atmosphere through the process called **transpiration.**

Another portion runs off from the ground surface into the streams and is returned to the ocean.

Still another portion percolates into the ground and joins the ground water which also finds its way slowly to streams as ground water flow. However, some portion of the ground water which percolates to the great depths appears after long intervals as springs and reaches to streams and rivers. Further the entire quantity of water that reaches the stream doesn't flow directly to the ocean, because throughout its travel a portion of it returns to atmosphere by evaporation and transpiration and some portion seeps into the ground.

Components of hydrological cycle

The important components involves in hydrological cycle are:-

a. Evaporation
b. Transpiration
c. Precipitation
d. Interception
e. Infiltration
f. Run-off
g. Evapotranspiration

Evaporation

Evaporation is the process in which a liquid changes to the gaseous state at the free surface, below the boiling point through the transfer of heat energy.

Loss of water as vapour from the open surfaces of oceans, rivers, lakes and reservoir and wet soil under the influence of heat is known as evaporation. It is the process by which water moves from earth to atmosphere.

Transpiration

Transpiration is the process by which the moisture absorbed by the roots of the plants and circulated through the plant body, returns back to the atmosphere by stomata of the leaves of the plants.

Loss of water as vapour from the leaves of plants is known as transpiration.

Precipitation

The precipitation denotes all forms of moisture that reaches the earth's surface in liquid or solid form due to condensation of the atmospheric vapour. The usual forms of precipitation are rain, snow, sleet, hail, mist, dew, and frost.

Infiltration

Infiltration is the process by which water enters from the surface of soil and moves downwards to join the ground water.

Run-off

The portion of precipitation which flow over the ground after meeting various losses like evaporation, interception, infiltration, depression storage etc. is called run-off or overland flow or excess rain fall. Run-off ultimately join ocean through streams and rivers.

Evapotranspiration

Evapotranspiration is sum of water used by plants in transpiration and water evaporated from adjacent soil in specified times. In other words it is the sum of plant evaporation and land evaporation. It is also called the consumptive use.

Preciptation

The precipitation denotes all forms of moisture that reaches the earth's surface in liquid or solid form due to condensation of the atmospheric vapour.

The important forms of precipitations are as follows,

1. **Rainfall:** Precipitation in the form of water drops of sizes larger than 0.5mm.
2. **Drizzle:** A fine sprinkle of numerous water droplets of size less than 0.5mm and intensity less than 1mm/h is known as drizzle.
3. **Glaze:** When rain drizzle comes in contact with cold ground at around 0° C, the water drops freezes to form an ice coating called glaze.
4. **Hail:** Precipitation in the form of large lumps of ice of an irregular shape called hail. Size of the particle is around 5 to 10 mm or more.
5. **Snow:** Snow is another important form of precipitation. Snow consists of ice crystals which usually combine to form flakes.

6. **Sleet:** When rain drops are falling through atmosphere, sometimes these freeze into small spherical ice-grains. This is called sleet. Size of particle is around 1 to 5mm.

2.3. Measurement of Rainfall by Rain Gauges

Precipitations (Rainfall) are expressed in terms of the depth to which rainfall water would stand on an area if all the rain were collected on it. Thus 1 cm of rainfall over a catchment area of 1 km^2 represents a volume of water equal to $10^4\ m^3$ ($\frac{1}{100}\times1000\times1000 = 10^4 m^3$).

The rainfall is collected and measured in rain gauge.

A rain gauge consists of a cylindrical vessel assembly kept in an open to collect rain. Following considerations are important for setting of rain gauge station.

- The ground must be level and in the open and the instrument must present a horizontal catch surface.
- The gauge must be set as near the ground as possible to reduce the wind effects but it must be sufficiently high to prevent splashing, flooding, etc.
- No object should be nearer to the instrument than 30 m or twice the height of the obstruction. The instrument must be surrounded by an open fenced area of at least 5.5m$\times$ $5.5m$.

Rain gauges are of two types they are,

1. Non recording rain gauge: Ex:-Symon's rain gauge, I.S.I standard rain gauges
2. Recording or Automatic rain gauge:- Weighing bucket type, Tipping bucket type, Float type, Radio reporting type

Non –recording rain gauge

Non recording rain gauges gives only the total depth of rainfall. As the name indicates these rain gauge do not record the rainfall directly but only collect the rain water which when measured gives the total amount of rainfall at the rain gauge station during the measuring interval. Example of non-recording rain gauge is Symon's gauge

Symon's gauge

Symon's gauge consists of a cylindrical metal case of internal diameter 127 mm with its base enlarged to 203.2mm diameter. At the top of the case a funnel is fixed which is provided with a brass rim measuring exactly 127mm inside diameter. The funnel sank is inserted in a glass bottle placed inside the case. The rain gauge is fixed in masonry or concrete foundation such that the funnel rim is exactly 305 mm above the ground level. The rain water enters the bottle through the funnel and gets collected in the bottle. The rain water collected in the bottle is measured with the help of a standard measuring glass supplied with each rain gauge which indicates the millimetres of rain that has fallen at the rain gauge station. At each station the observations for the rainfall are taken at 8:30 a.m. If rainfall is likely to exceed the capacity of bottle, then few intermediate observation are also taken. The sum of observations taken will represent total rainfall of the past 24 hours of the day.

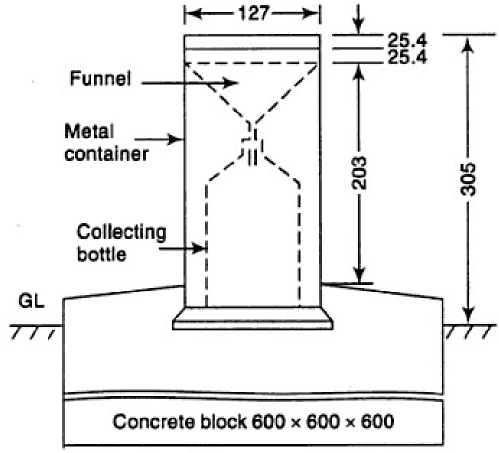


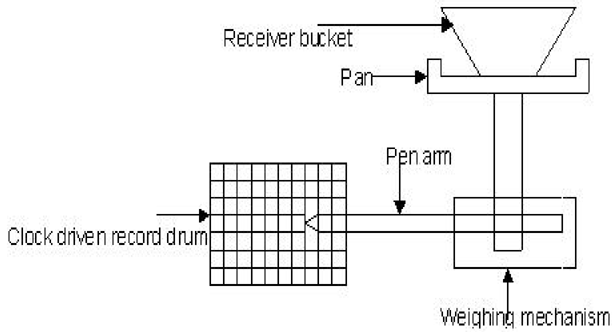
Fig. 2.5 Nonrecording Raingauge (Symons' Gauge)

Limitation of non-recording rain gauge

- It gives the total depth of rainfall but not the history of rain.
- Daily attendant is required
- Chances of human errors

Self-recording or Automatic rain gauge

These are also called integrating rain gauge or continuous gauge. These rain gauge automatically record the rainfall on a graph paper. We obtain a graph in which on y-axis total rainfall value and on x-axis time are shown. From this record it is possible to know when rainfall is started, when it is ended and intensity of rainfall in a given time interval. Following are some of commonly used recording rain gauge.



Tipping bucket type

It consist of 300 mm diameter funnel which collects rain water and conducts it to a pair of small buckets provided just below the funnel as shown in figure, which is adopted for use by US Weather Bureau. The buckets are so balanced that when 0.25mm of rainfall collects in one bucket, it tips and empties its water into storage can below and at same time other bucket is brought under the funnel. The tipping actuates an electrically driven pen to trace a record on clockwork –driven chart. It may be noted that the record from the tipping bucket gives data on intensity of rainfall. The water collected in the storage can is measured at regular intervals to provide the total rainfall and also serve as a check.

Weighing bucket type

The Weighing bucket type of rain gauge consists of a receiver bucket supported by a weighing mechanism. When rainfall occurs, it is collected in the bucket and the weight of water collected causes movement of weighing mechanism. The movement is transmitted to a recording pen through a system of links and levers. The pen traces a record of rainfall on graph paper mounted on rotating drum. That drum is driven mechanically by a spring clock.

Advantage of Automatic of self-recording rain gauge

- Rainfall is recorded automatically therefore no attendant is required to go every day.
- Thy not only gives the depth of rainfall but also gives the history of rainfall.
- Human errors in measuring the rainfall are eliminated.

- The rain gauge can be placed in far off places and hilly areas.
- These gauge works for longer periods without attention.

Limitations

- They are costly as compared to non-recording gauges.
- Mechanical and electrical deficit are developed which affect the recording of rainfall.

Estimation of rainfall

Point rainfall also known as station rainfall refers to the rainfall data of station. For most of the hydrologic problems, it is necessary to determine the mean or average depth of rainfall over a particular area. The following three method are used for computing the mean depth of rainfall over an area

1. Arithmetic Mean Method
2. Theissen Polygon Method
3. Isohyetial Method

Arithmetic Mean Method:

In this method the average depth of rainfall over an area is obtained by dividing the sum of depth of rainfall recorded at all the rain gauge stations located in the area by the number of stations. Thus if $P_1, P_2, P_3 \dots\dots\dots P_n$ are the depths of rainfall recorded at the n rain gauge stations distributed over an area then the average depth of rainfall P is given as

$$P = \frac{P_1 + P_2 + P_3 + \cdots + P_n}{n}$$

Advantage

- This method is simple and quick
- Computer processing is possible

Limitation

- The method gives good result if rain gauge is uniformly distributed all over the catchments.
- The rainfall value recorded at different stations should be close to each other.

Thiessen's method

1. A map of catchment area is plotted to some suitable scale.
2. Various rain gauge stations in the catchments area are marked on the map
3. Straight lines are drawn joining the adjacent rain gauge station to form triangles.

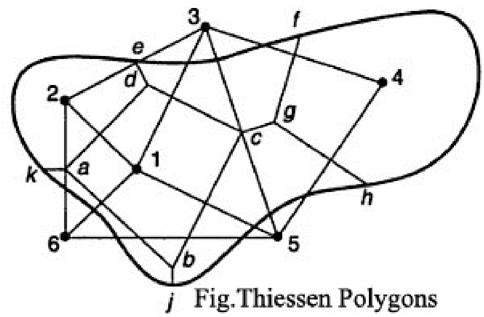


Fig.Thiessen Polygons

4. Perpendicular bisectors are drawn on each straight lines.
5. The area enclosed between the perpendicular bisectors and the boundary of catchment is the area of influence of the rain gauge station. This area is called Thiessen's polygon
6. The area of polygons around each rain gauge station is measured by planimeter.
7. If $P_1, P_2 \ldots\ldots\ldots, P_6$ are the the rainfall magnitudes recorded by the stations 1, 2,…….n respectively and A_1, A_2 ………., A_6 are respective areas of the Thiessen polygons, then the average rainfall over the catchment "P" is given by

   $$P = \frac{P_1A_1 + P_1A_1 + \ldots + P_6A_6}{A_1 + A_1 + \ldots + A_6}$$

Isohyet method

This is the most accurate method of finding the mean rainfall over catchments.

An isohyet is a line joining points of equal rainfall magnitude

1. A map of catchments area is plotted to a suitable scale.
2. Various rain gauge stations in the catchments areas are marked in the above map. The rainfall values recorded are also indicated.
3. Isohyets are then drawn by linear interpolation.
4. The areas enclosed between isohyets are measured with the help of Planimeter.

5. If $P_1, P_2, P_3 \ldots \ldots, P_n$ are the values of isohyets and if $a_1, a_2, a_3 \ldots \ldots, a_{n-1}$ are the inter isohyets areas respectively, then the mean precipitation over the catchment of area A is given by,

$$\bar{P} = \frac{a_1\left(\frac{P_1+P_2}{2}\right)+a_2\left(\frac{P_2+P_3}{2}\right)+\ldots+a_{n-1}\left(\frac{P_{n-1}+P_n}{2}\right)}{A}$$

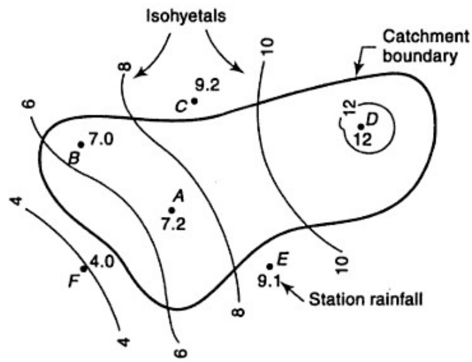


Fig. 2.14 Isohyetals of a Storm

2.4. Rainfall Runoff Process

For a given precipitation, the evaporation, infiltration, evapotranspiration and depression storage requirements will have to be first satisfied. When these requirements are satisfied excess rain water moves over the land surface to reach the smaller channels.

Run-off

Run off is that portion of precipitation, which finally joins streams and rivers in the catchments area after meeting various losses like evaporation, interception, transpiration, depression storage etc. In other words if various losses are subtracted from rainfall the remaining amount of water is called runoff.

Runoff = Rainfall – Losses

Losses consists of (i) interception (ii) evaporation (iii) Transpiration (iv) Infiltration (v) Depression storage

Runoff is expressed as depth of water in cm or mm.

In general sense runoff includes, (i) Surface runoff (ii) Sub surface runoff

(iii) Ground water flow

Surface runoff

The portion of rainfall which flows over the ground surface to reach the nearer stream or river after meeting various losses like evaporation, interception, transpiration, depression storage etc. is called surface runoff. It is also called the surface runoff or overland flow or excess rainfall. This part of runoff reaches stream within very short time after the start of rain.

Sub-surface runoff

It is that portion of runoff which moves laterally through the upper crust of soil and reaches the stream without joining G.W.T. it is also known as inter flow, through flow, storm seepage or quick return flow. Sub surface runoff moves very slowly as compared to the surface runoff. Hence it takes longer time to reach stream and river.

Ground water runoff

A part of infiltrated water percolates towards the ground water table. After spending considerably a long time, this part of ground water reaches the streams or rivers. This part of rainfall is called ground water runoff or base flow. It takes very long times to reach streams and rivers.

2.5. Infiltration

Infiltration is the process by which water enters the surface strata of soil and moves downwards to join the ground water. This first replenishes the soil moisture deficiency and the excess water moves downwards to become a part of ground water.

"The rate at which the water actually infiltrates through a soil at given time is known as the infiltration rate."

"The maximum rate at which a soil in any given condition is capable of absorbing water is called its infiltration capacity. Unit of infiltration capacity is mm/hr. Different soil will have different infiltration capacity."

Initially when the soil is dry and the rainfall occurs some rain water is consumed in wetting the soil particles and the infiltration rate is high. But as rain continues, capacity of the soil to absorb the water progressively decreases.

According to Horton

Horton expressed the decay of infiltration capacity with time as,

$$f_p = f_c + (f_o - f_c)\, e^{-K_h t}$$

Where,

f_p= infiltration capacity at any time t from the start of rainfall.

f_o = initial infiltration capacity at t=o

f_c = Final steady state infiltration capacity occurring at t= t_c

K_h= Horton's decay coefficient which depends upon soil characteristic and vegetation cover.

Factor affecting infiltration rate:

1. Porosity
2. Soil moisture
3. Vegetation
4. Compaction due to rain
5. Compaction due to man and animal
6. Entrapped air
7. Temperature
8. Washing of fine particle
9. Land slope

Infiltration capacity of soil is found by two methods:

1. Infiltrometers (Ring type and Tube type)
2. By analysis of rainfall and runoff data

2.6. Evaporation and transpiration

Evaporation

Evaporation is the process in which a liquid changes to the gaseous state at the free surface, below the boiling point through the transfer of heat energy.

Loss of water as vapour from the open surfaces of oceans, rivers, lakes and reservoir and wet soil under the influence of heat is known as evaporation. It is the process by which water moves from earth to atmosphere.

Transpiration

Transpiration is the process, by which the moisture absorbed by the roots of the plants and circulated through the plant body, returns back to the atmosphere by stomata of the leaves of the plants.

Loss of water as vapour from the leaves of plants is known as transpiration.

2.7. Factors affecting runoff from catchments:

Various factors affecting the runoff can be divided into two groups,

- Storm factor
- Catchments factors

Storms factors

a. Types of precipitation

Precipitation may be in the form of rainfall or snow fall. Precipitation in the form of rainfall produces runoff immediately whereas in the form of snowfall produces runoff only after melting of snow.

b. Depth of precipitation

Greater the depth of precipitation more will be the runoff.

c. Intensity of rainfall

Runoff increases with the intensity of rainfall. High intensity rainfall produce more run-off science infiltration losses are lesser.

d. Frequency of rainfall

Rains occurring more frequently will produce more runoff because the soil in wet condition having lesser absorbing tendency.

e. Climatic condition during rain

Climatic condition such as temperature, wind velocity, humidity etc. influences the rainfall losses. Hence they will affect the runoff.

Catchments Factors

a. **Size of catchments:** Greater the catchments area more will be the runoff.

b. **Shape of catchments:**

Catchments are classified into two types I) fan shaped ii) fern shaped
Fan shaped catchments gives greater runoff than fern shaped because in fan shaped catchments tributary are shorter in length and uniform.

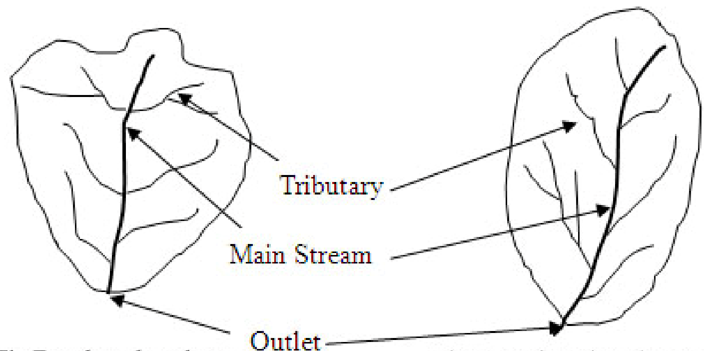


Fig:Fan-shaped catchment   Fig: Fern-shaped catchment

a. Slope of catchment area

Catchments with steeper slope produce more runoff than with flat catchments. Because in case of steep catchments runoff moves more quickly reducing the losses.

b. Soil condition

The infiltration loss depends on the permeability of soil. Runoff in case of impermeable soil will be more as compare to permeable soil.

c. Vegetation

If catchments area is covered with thick vegetation the flow is detained for long time and absorbed. Hence runoff in such areas will be lesser compare to barren or empty land.

d. Elevation

Elevation of the catchments influences the various climatic factors and rainfall losses. Therefore it affects the runoff.

Estimation of flood

An overflow of large amount of water beyond its normal limits, especially over normally dry land is called flood.

Or,

It is defined as an overflowing of water source due to rise in level of water above normal level due to factors such as excess rain melting of ice etc.

2.8. Estimation of flood by rational method:

This is widely used method of peak flood estimation in engineering hydrology for small catchments,

In this method peak flood discharge is worked with using equation,

$$Q_P = \frac{CIA}{360}$$

Where,

Q_P = Peak flood in cumec

C = Coefficient of runoff

A = Area of catchment in hectare.

I = intensity of rainfall in mm/hr.

Limitations

- It is suitable for small catchments upto 50 Km^2 area.
- Evaluation of runoff coefficient (C) and rainfall intensity (I) needs detail hydrological study.

2.9. Estimation of peak flow by Empirical Methods:

Following empirical formula can be used for calculation of peak flood,

1. Dickens formula

$$Q_P = C_D \times A^{\frac{3}{4}}$$

Where, Q_P = Peak flood discharge in m^3/s

C_D = Dickens constant with value varies from 6 to 30

A = are of catchments in Km^2

2. Ryves formula

$$Q_P = C_R \times A^{\frac{2}{3}}$$

Where,

Q_P = Peak flood discharge in m^3/s

C_R = Ryeves coefficient

C_R = 6.8 for area within 80 km from the east-cost.

C_R = 8.5 for areas which are 80 – 160 km from east –coast.

C_R = 10.2 for limited areas near hill

3. Inglis formula

This formula is based on flood data of catchment in western Maharashtra.

$$Q_P(m^3/\text{s}) = \frac{124A}{\sqrt{A+10.4}}$$

Where

A=Area of catchments in km^2

4. Fanning's formula

For American catchments

$$Q = C \times A^{\frac{5}{6}}$$

Where average value of C may be taken equal to 2.54

2.10. Stream/River discharge determination (float method, velocity rod method, current meter, velocity area method):

1. Float method
2. Velocity rod method
3. Current meter
4. Velocity area method

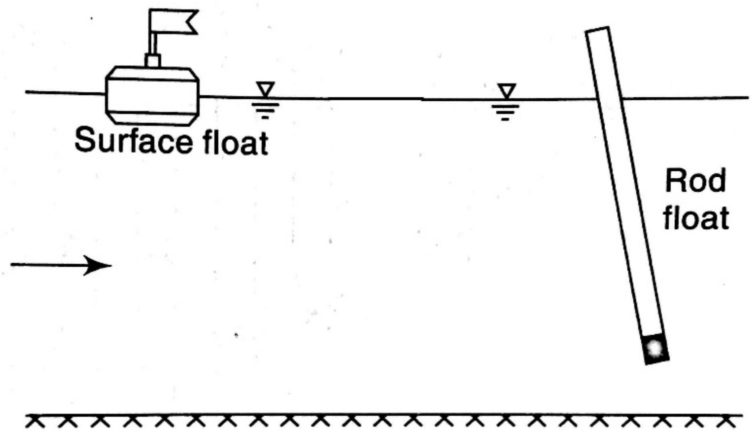
1. Float Method

If flow meter is not available or rough estimate is enough, we can measure the discharge of stream by float method.

Surface float consists of object that can float on water surface such as partially filled bottles, wooden float, coconuts, oranges etc. In this method the float is allowed to travel on the water surface for a known distance and time taken to travel the distance is noted. The distance is divided by time which gives surface velocity of flow. The mean velocity of flow can be calculated by multiplying surface velocity by 0.85

i.e., Mean velocity = 0.85 × Surface Velocity

The width of stream and mean depth stream can be measured by tape, levelling staff an etc. product of which gives the cross-sectional area of stream.



Surface float and velocity rod

Now discharge of stream is given by,

Q = Mean velocity × Cross-sectional area

Here in figure,

Mean velocity of flow (V_m) = $\frac{l}{t}$

Where, l= distance travelled by surface float

t= time taken to travel

Cross sectional area (A) = W×d

Where, W= width of stream at selected section

d= mean depth of stream

Discharge through stream (Q) = V_m × A

2. Velocity rod method

These are wooden rod of 25 to 50mm dia. The certain weight is attached at the bottom to keep them nearly vertical in water. The weight in bottom is adjusted such that bottom of rod reaches to level of 0.94d from surface. (Where d is depth of water in stream)

In stream, the rod is allowed to travel in a known distance and time taken to travel is noted. Distance travel divided by time taken gives the velocity of flow,

Advantage of velocity rod over surface float is that, they directly give the mean velocity of flow,

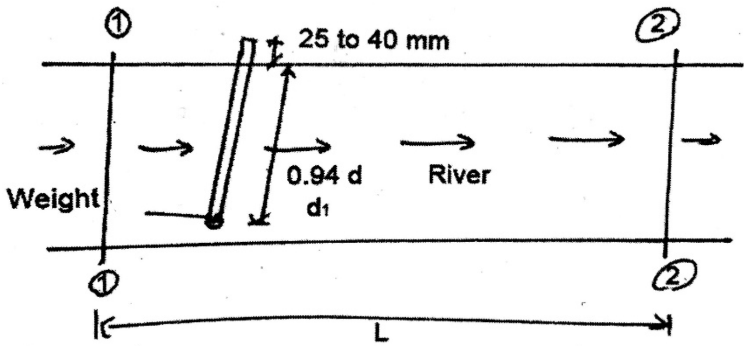


Fig. Velocity rod method

Now discharge of stream is given by,

Q = Mean velocity × Cross- sectional area of Stream

Here in figure,

Mean velocity of flow (V_m) = $\frac{l}{t}$

Where, l= distance travelled by velocity rod

t= time taken to travel

Cross sectional area (A) = W×d

Where, W= width of stream at selected section

d = mean depth of stream

Now,

Discharge through stream (Q) = $V_m \times A$

3. Current meter

Current meter is the instrument used for velocity measurement. It is simple in construction, rugged and most reliable. Broadly current meters are of two types, depending upon the orientation of their revolving axle as under:

a) Vertical-axis current meter

A Gurley or price current meter essentially consists of the head, tail, hanger, recording or indicating device and suspending device. The head is just a yoke carrying a wheel of 12.7 cm diameter with six conical cups attached to a horizontal frame. This wheel revolves in an anti-clockwise direction on a shaft which passes into the cummutator box having arrangements to electrically show the revolutions by either single or ponta strokes. The tail consists of a stem with two vanes, one adjustable and one rigidly fixed. One of the vanes has an adjustable weight. The tail balances the head and retains the meter parallel to the current of flow. Each rotation of the rotar operates a contact mechanism which energizes a headphone as well as electric flash counter. The recording device consists of a telephone and battery equipment. The latest current meters employ electro-magnetic counters with digital or analogue displays. The accuracy of the instrument is about 1.5% at threshold value and improve to about 0.3% at speeds in excess of 1.0 m/s. In deep waters meter can be used by cable suspension and in shallow waters by wadding rod. The limitation of the instrument is that it cannot be used where there are appreciable vertical components of velocities.

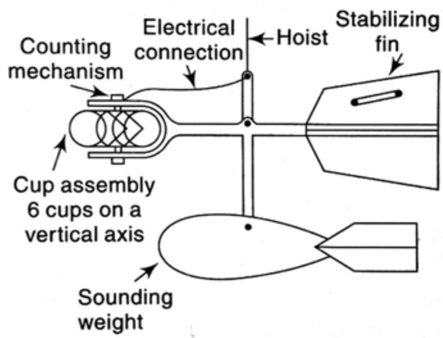


Fig. Vertical-axis current meter

b) Horizontal-axis current meter

It consists of a propeller mounted at the end of an horizontal shaft which lends it the name of propeller current meter. The rotation about horizontal axis is accomplished by means of screws or propeller shaped blades. It is rugged instrument unaffected by oblique flows of 15°. Its accuracy is about 1% at threshold value and about 0.25% at a velocity of 0.3 m/s and above.

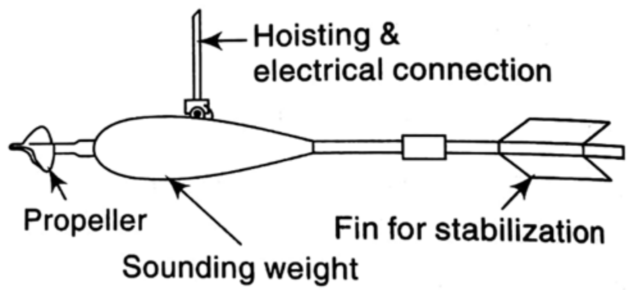


Fig. Horizontal-axis current meter

Rating of current meter

The current meter is precisely rated in still water. It is mounted on a carriage which moves on rails along a straight channel or rotates about a central pivot in a circular basin. The rating is done by moving the carriage through still water tank. The speed of the carriage is computed from the time required to travel a known distance. From several such observations of the runs at various speeds a curve is plotted showing the relation between meter contacts per unit time and water speed. The relation between the revolutions per second of current meter cups and velocity of water is given by the equation:

$$V = aN + b$$

Where, V = velocity of flow (m/s), a and b = constants; value 0.65 and 0.03 respectively and N = number of revolutions of meter per second

4. Velocity area method:

In velocity area method entire river cross section is divided into number of compartments. The mean depth of flow and mean velocity of flow for each compartment is measured. The velocity of flow of each compartment is measured by current meter. The sum of discharge through each compartment gives the total discharge through stream.

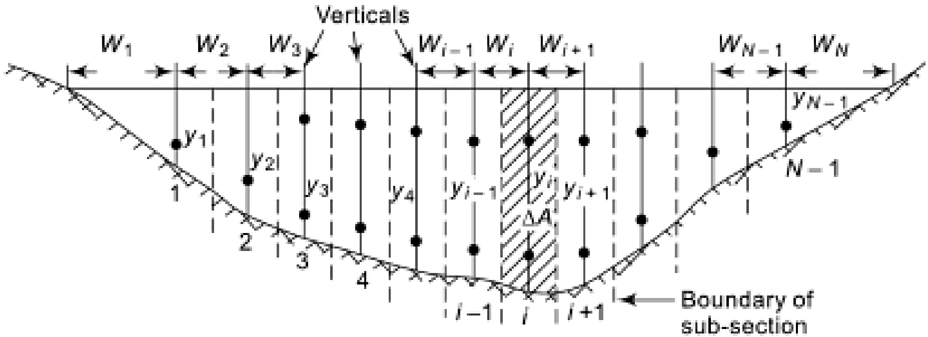


Fig. 4.14 Stream Section for Area-velocity Method

It is obvious that accuracy of discharge measurement increase with number of compartments used. Following point should be considered while deciding the number of compartment.

- Each segment with shouldn't be greater than 1/15 to 1/20 of width of stream.
- Discharge in each segment should be less than 10 % of total discharge.

Figure 4.14 above shows a cross section of river which is divided into N compartments by N-1 verticals. The average velocity over each section is measured. The discharge is calculated by the method of mid-section.

$Q = \sum_1^N \Delta Q_i$

Q_i =Discharge in ith segment

=Depth at ith segment × (½ with to right + ½ width to left) × average velocity at ith segment

$\Delta Q_i = y_i \times (\frac{w_i}{2} + \frac{w_{i+1}}{2}) \times v_i$ for I = 2 to N-2

For the first and last section, the segments are taken to have triangular areas and area is calculated as,

$$\Delta A_1 = \overline{w_1} \cdot y_1$$

Where, $$\overline{w_1} = \frac{\left(W_1 + \frac{W_2}{2}\right)^2}{2W_1}$$

$$\Delta A_N = \overline{w_{N-1}} \cdot y_{N-1}$$

Where, $\overline{W_{N-1}} = \frac{\left(W_N + \frac{W_{N-1}}{2}\right)^2}{2W_N}$

To get discharge,

$$\Delta Q_1 = \Delta A_1 \times v_1 \text{ And } \Delta Q_N = \Delta A_N \times v_{N-1}$$

2.11. Ground water hydrology

Ground water

Water that occurs below the surface of earth is known as ground water or sub soil water. The main source of ground water is the infiltration during the rainfall. The infiltrated water first satisfies the soil moisture deficiency, thereafter percolates to reach the ground water table.

Water exists in two zone under the ground they are,

1. Saturated zone
2. Unsaturated zone

Saturated Zone

The zone below the ground water table is known as saturated zone. In this zone all of the soil pores are completely filled with water. Water exist in this zone are called ground water. It is also called phreatic zone.

Unsaturated zone

The zone between the ground surface and ground water table (G.W.T.) is known as unsaturated zone. Water and also air present in this zone. It is also called zone of aeration.

This zone can be divided into three categories,

Soil zone: This zone exists just below the ground surface. This zone is also called root zone since root of plants penetrate up to the bottom of this zone. Infiltrated water first fills up the void spaces in this zone.

Intermediate zone: Region between capillary zone and soil zone is called intermediate zone. In some areas where the ground water table is nearer to ground surface this zone may not exists.

Capillary zone: This zone exists just above ground water table .In this zone water is held by capillary force.

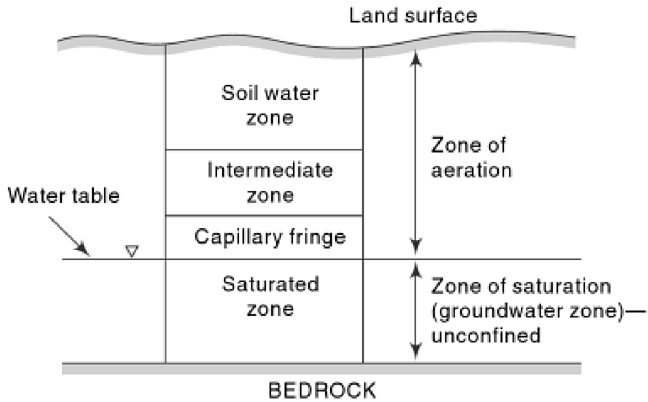


Fig. 9.1 *Classification of Subsurface Water*

Ground water aquifer

Aquifer is a water bearing stratum of previous material which permits free flow of water through it. The amount of water present in an aquifer depends on the porosity of the aquifer. The flow of water through the aquifer depends on the permeability of the aquifer.

2.12. Types of aquifer

a. Unconfined aquifer

b. Confined aquifer

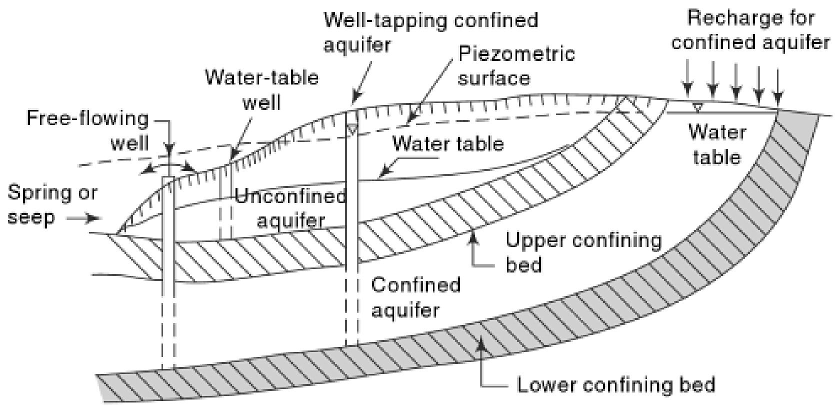
c. Perched aquifer

a. Unconfined aquifer

The topmost water bearing stratum having no impervious strata laying over it is called unconfined aquifer. Unconfined aquifer is also called as free aquifer or non-artesian aquifer.

b. Confined aquifer

When aquifer is sandwiched between two impervious strata, it is called confined aquifer. The pressure in confined aquifer may be more than the atmospheric pressure. This is also called pressure aquifer or artesian aquifer.



c. Perched aquifer

A special case of unconfined aquifer which occurs whenever an impervious layer of limited areal extent is located between normal water table and the ground surface is called perched aquifer. Usually the perched water table is of limited extent and the yield from such situation is very small.

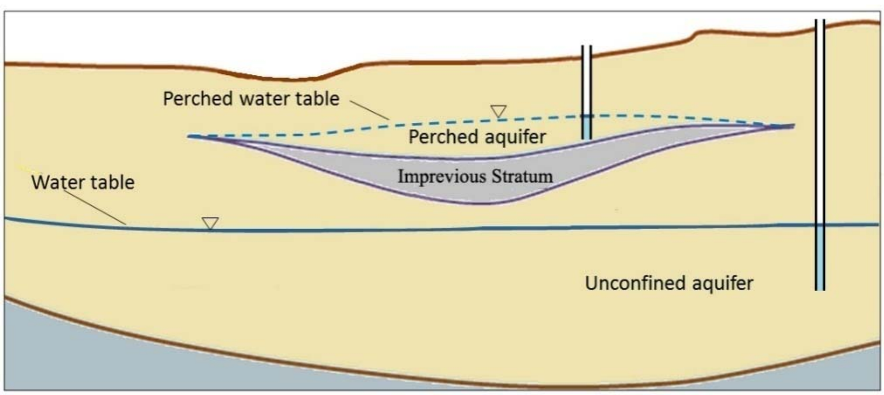


Fig. Perched Aquifer

Aquiclude

Aquiclude is a stratum of soil, which holds large amount of water in its voids but will not allow the free flow of water. Fine grained soil such as clayey soils are good example of aquicludes. (Soil with more porosity but less permeability acts as aquiclude.)

Aquitard

Aquitard is stratum of soil which holds appreciable amount of water but allow the water to move very slowly through it. Soil with more porosity and low permeability acts as aquitard. Example silty clay, sandy clay etc.

Aquifuge

Aquifuge is the stratum of soil which neither contains water nor allows the movement of water through it. Example rock.

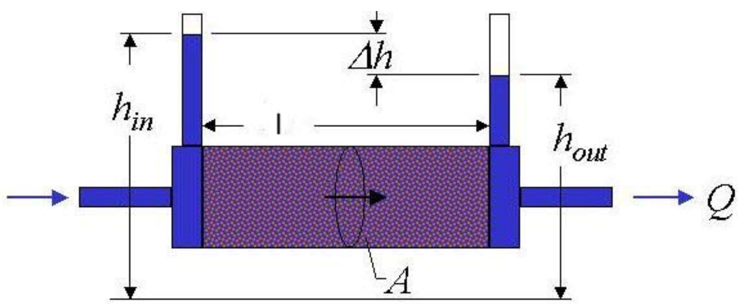
2.13. Ground water movements Darcy's law

In 1856 Henry Darcy, A French hydraulic engineer, on his experimental evidence purposed a law relating the velocity of flow in porous medium (i.e. in soil). This law is known as Darcy's law.

According to Darcy the velocity of flow in porous medium is directly proportional to the hydraulic gradients,

$$v \propto i$$

$$v = ki$$



Where

v = Velocity of water in soil mass

i = Head loss per unit length called "hydraulic gradient" given by, $i = \frac{h_{in} - h_{out}}{l}$

h_{in} - h_{out} = Δh = Loss of head

l = length of soil mass

K = Coefficient of permeability having the units of velocity.

Thus, discharge Q through soil mass can be expressed as

Q = A X V

Q = **KI**A

Where A = cross sectional area of soil mass.

3. Learning process and support materials

- Following are the learning process of this unit:
- theoretical notes
- presentation
- group work
- prepare field trip for the stream/river discharge determination

4. Assessment

A. Very short answer question.

1. Define hydrology.
2. What is evaporation?
3. State Darcy's law.
4. Define ground water hydrology.
5. What are the types of aquifer?

B. Long Questions.

1. Describe the stream/river discharge determination by velocity area method.
2. Describe any one of the methods of rainfall measurement by Rain Gauges.
3. Describe hydrological cycle.
4. Describe Symons gauge with net sketch.

Glossary

Droughts- a period of unusually low rainfall

Strategies- a plan of action intended to accomplish a specific goal

Combat- to fight with

Catchment- any structure or land feature which catches and holds water

Impervious- impenetrable, impermeable, particularly of water

Reference materials

Suggested texts and references

Irrigation Engineering and Hydraulic Structures –Santosh Kumar Garg

Irrigation and Water Power Engineering- Dr. B.C. Punmia, Dr. Pande B.B. Lal, Ashok Kumar Jain and Arun Kumar Jain

Irrigation and Water Power Engineering- Madan Mohan Das and Mimi Das Saikia

Irrigation Engineering(Including Hydrology)-R.K. Sharma and T.K. Sharma

Irrigation Engineering and Hydraulic Structures-Dr. V.C. Agarwal

Engineering hydrology-K. Subramanya

Engineering hydrology-Dr. K.N. Dulal and Er. Sanjeeb Baral

Unit 8
Waterpower engineering

1. Objective

- To familiar hydropower development in Nepal
- To describe flow duration curve
- To arrange general layout plan of hydropower project
- To describe Run off River(ROR) and Picking type of hydropower plant
- To describe the types of hydraulic turbine

2. Contents

2.1. Introduction

Flowing water in rivers, canals, ocean, waves, and tides etc. has tremendous kinetic energy. Again when water is stored in reservoir by constructing dam at higher altitude, it has plenty of potential energy. These two types of kinetic and potential energies are used to produce electricity with the help of hydraulic turbine and electric generator.

The process involved to convert this tremendous water power or energy into electrical energy is called water power engineering. The energy of water is used to run the turbine, to convert water energy to mechanical energy. When shaft of the electrical generator is rotated by this mechanical energy, electrical power is produced. The power so produced is called hydroelectric power. This scheme is known as hydel scheme or water power plant or hydropower plant.

Source of energy

With the technology developed so far electricity can be generated by one of the following three conventional sources.

- Hydro power
- Thermal power
- Nuclear power
- Besides these, there are some other unconventional source which are,

- Tidal power
- Solar power
- Geothermal power
- Wind power

Hydropower

Hydropower uses the power of water to produce energy. Flowing water has three types of energy heads namely - Potential head, Pressure head and Kinetic head. The running water with one or combination of more than one type of energy heads causes spinning of turbine that runs generator, which produces electricity.

Advantage of hydropower

Following are the main advantage of hydropower plants-

- Environment friendly and non-polluting source of energy.
- Very cheap and renewable source of energy.
- Once hydropower plants are constructed lasts for long.
- The conversion of electrical energy in other forms of energy is easy.
- Possible to build power plant of high capacity.
- Provides employment opportunities.
- Cost of hydropower generation is less than other source of energy.
- Reservoir constructed for power generation can be used for multi-purposes.
- Very efficient for peaking load, i.e. opening and closing can be done in short time as desired.

Disadvantages

- Long gestation period (takes long time for construction).
- Large initial cost.
- Firm power may not be very high.
- There could be submergence of large area, so the ecological balances could be upset.
- Need long transmission lines to transmit generated energy to other places.

2.2. Hydropower development in Nepal

The development of hydropower in Nepal started from with construction of Pharping hydropower plant (500kw) in 1911 in a financial help of British government. After 30 years, Sundrijal plant came in operation with 900kw capacity followed by Panauti hydropower plant that was commissioned in 1965. Only in 1889, total installed capacity reached to 250MW, contributed by Kulekhani, Marsyangdi, Trisuli, Sunkoshi etc.

The "Hydropower development policy 2001" of Nepal provides guidelines for the hydropower development in Nepal. The government of Nepal has adopted liberal policy to attract private investment for the development of small hydropower projects. NEA has announced its policy to purchase the power produced by private developers of small hydropower projects upto 25MW capacities at flat or declared rate. Also, in order to assist capital investment for hydropower construction, domestic commercial banks are showing great interest to invest in hydropower project. This trend has encouraged the private sector to put up Small hydropower projects and meet the growing demand of power in the country.

Electricity act, 2049 has facilitated wide business opportunities to local and foreign investor for developing hydropower project. In this regard, government has already granted permission to few independent power producers. Khimti(60MW), Bhotekoshi(36MW), Indrawati(7.5MW), Chilime(20MW), Piluwa khola(3MW), Chaku khola(1.5MW), Sunkoshi small(2.6MW) and khudi(4MW) have already started generating electricity and Some other projects are in final stage of construction and some are in the processes. The independent producers contribute about 25% of total installed capacity of Nepal's power system. Till now, ours total installed capacity is about 700MW and NEA has contributes 75% of it.

Note:

- Electricity demand of Nepal is about 1200MW
- Electricity production is 750MW
- Demand of electricity is growing at rate of 7% per year
- The largest hydropower plant in Nepal is Kaligandaki A-144MW

- In 1966, i.e. 44 years ago, Dr. Hari Man Shrestha assessed the total hydropower potential in Nepal as 83,500 MW.
- Nepal has approximately 40,000 MW of economically feasible hydropower potential.

Hydropower plants in Nepal

Existing Major hydropower stations

S.N.	Hydropower stations	Power output
1.	Middle Marsyangdi	70,000 kw
2.	Kaligandaki 'A'	144,000 kw
3.	Marsyangdi	69,000 kw
4.	Kulekhani 1	60,000 kw
5.	Kulekhani 2	32,000 kw
6.	Trisuli	24,000 kw
7.	Gandaki	15,000 kw
8.	Modi khola	14,800 kw
9.	Devighat	14,100 kw
10.	Sunkoshi	10,050 kw
11.	Puwakhola	6,200 kw
	Total	**459,159 kw**

Small hydropower stations

S.N.	Hydropower stations	Power output
1.	Chatara	3,200 kw
2.	Panauti	2,400 kw
3.	Tatopani/myagdi (1&2)	2,000 kw

4.	Seti(pokhara)	1,500 kw
5.	Phewa(pokhara)	1,000 kw
6.	Tinau (butwal)	1,024 kw
7.	Sundarijal	640 kw
8.	Pharping***	500 kw
9.	Jomsom**	240 kw
10.	Baglung	200 kw
11.	Khandbari**	250 kw
12.	Phidim**	240 kw
13.	Surnaiyagadh(baitadi)	200 kw
14.	Doti	200 kw
15.	Ramechhap	150 kw
16.	Terathum**	100 kw

Under construction

S.N.	**Power projects**	**Power output**
1.	Upper tamakoshi	456,000 kw
2.	Chamelia	30,000 kw
3.	Kulekhani III (storage)	14,000 kw
4.	Gamgadh	400 kw

Classification of hydropower project

1. Classification based on head

a. Low head plant < 15m

b. Medium head plant: 15m to 50m

c. High head plant >50m

2. But in Nepal classification based on head is as

a. Very high head: >350m

b. High head: 150m to 350m

c. Medium head: 60m to 150m

d. Low head: 15m to 60m

e. Very low head: < 15m

3. Classification based on installed capacity

a. Micro hydropower project (up to 100KW)

b. Mini hydropower project (100KW to 1MW)

c. Small hydropower project (1MW to 25MW)

d. Medium hydropower project (25MW to 100MW)

e. Large hydropower project (greater then 100MW)

4. Classification based on storage capacity

a. Run-Off river hydropower plant (ROR)

b. Peaking runoff river hydropower plant (PROR)

c. Storage or reservoir hydropower plant

d. Pumped storage hydropower plant

5. Based on functional basis

a. Base load power plant

b. Peak load power plant

c. Isolated plant

d. Interconnected Plant

Gross Head and Net head

Gross Head (H_g)

The gross head is the difference between the water level in head race and the water level in the tailrace.

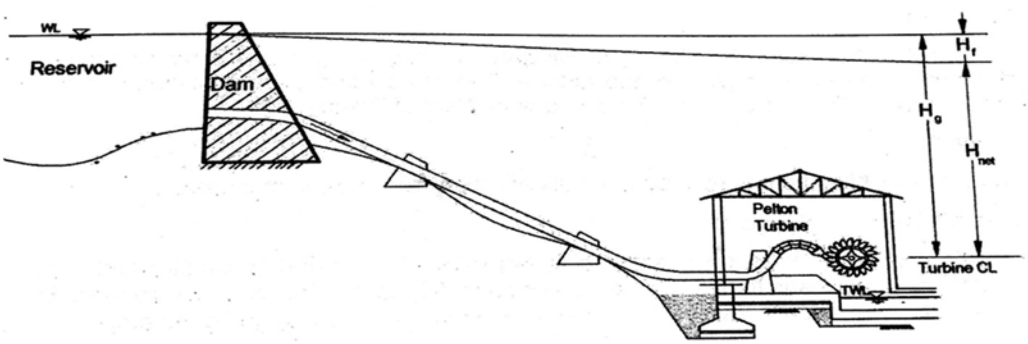
- For storage plant, gross head $\mathbf{H_g}$ is the difference between water level in reservoir and water level in tailrace as shown in figure.
- For runoff plant, gross head $\mathbf{H_g}$ is the difference in water level in the point of diversion of water and water level at the point where the water is returned back to the river.
- For hydro power project with Pelton turbine, gross head $\mathbf{H_g}$ = water level at intake - turbine axis level as shown in figure below.
- For hydropower plant with Francis turbine, gross head $\mathbf{H_g}$ = water level at intake –tail water level as shown in figure.

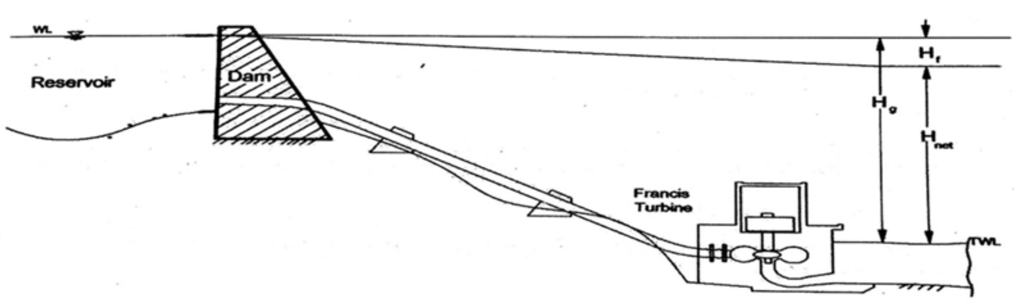
Net head ($\mathbf{H_{net}}$)

It is the head available for the turbine after deducting the head losses with the system. The neat head is equal to,

Net Head (H_{net}) = Gross head (H_g) - Head loss (H_l)

Operating head:-Operating head is the simultaneous difference of water surface elevation in the forebay and tail race.





Power generated from hydropower plant

The power generated from hydro plant is function of head and discharge. For a particular project, the head is constant and different power can be generated using discharge of different amount.

$$P = \eta \times \gamma \times Q \times H \text{ KW}$$

Where,

η = overall efficiency of a system.

γ = Specific weight of water whose valve is 9.81 KN/m^3

H = head of water in m

Q = Discharge in m^3/s

Overall efficiency of plant

The overall efficiency of plant is the product of hydraulic efficiency, turbine efficiency and generator efficiency.

$$\eta = \eta_h \times \eta_t \times \eta_g$$

Where,

η_h = Hydraulic efficiency

η_t = Turbine efficiency

η_g = Generator efficiency.

8.3. Flow duration curve

The flow duration curve is a plot that shows the percentage of time that the flow in a stream is likely to equal or exceed some specified value of interest. For example, it can be used to show the discharge of the stream that occurs or is exceeded some percent of the time (e.g., 80% of the time).

Flow duration curve is obtained by plotting the increasing valves of stream flow (i.e. Q) as ordinates and percentage of time for which the flow equated or exceeded is plotted as abscissa. A flow duration curve of river is shown in figure below.

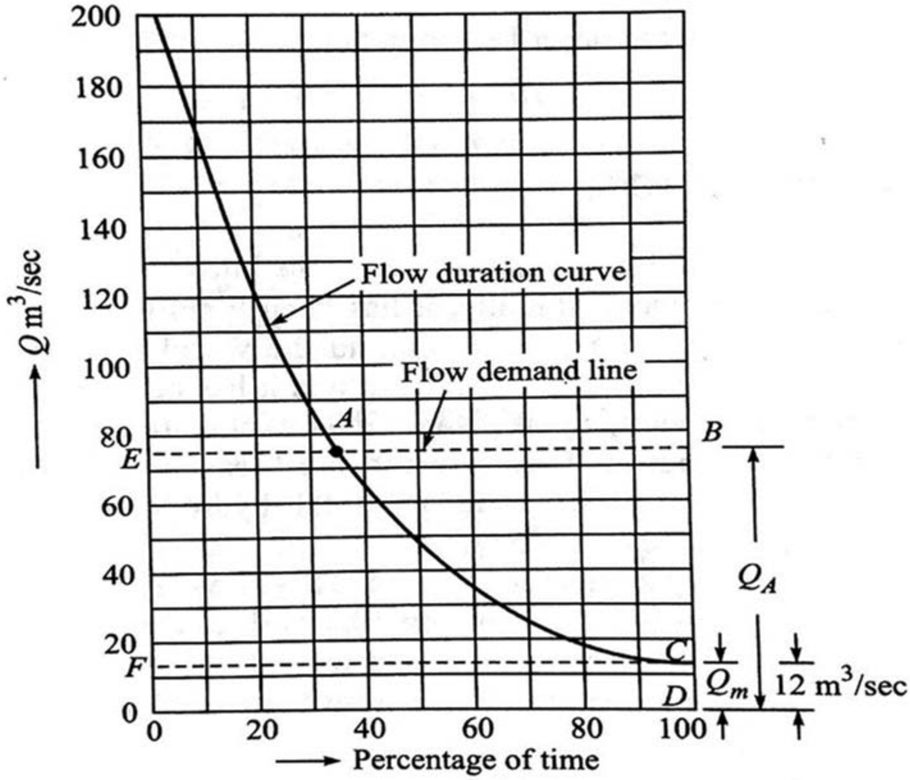


Fig:-Flow Duration curve

In above figure, if you look at the flow value at 60%, you will see that it is 35 m^3/s. This does not mean that the flow rate is 35 m^3/s for 60% of the time, but that the flow (35 m^3/s) is equaled or exceeded for 60% of the time.

- Flow duration curve helps to evaluate firm energy, secondary energy and total energy.
- In above figure Q_m=12m^3 /sec is the minimum flow available in river for power production for 100% time of the year. The power corresponds to this Q_m is the firm or primary power.
- Flow duration curve is highly useful in planning and design of water resource project.

Steps for computation of flow duration curve

a. Calculate total number of flow data N

b. Rank 1, 2……… N represented by n

c. Compute frequency as f=N/n

d. Compute probability of exceedance as P= 1/f

e. Place discharge in descending order

f. Draw probability of exceedance Vs discharge curve to get the flow duration curve.

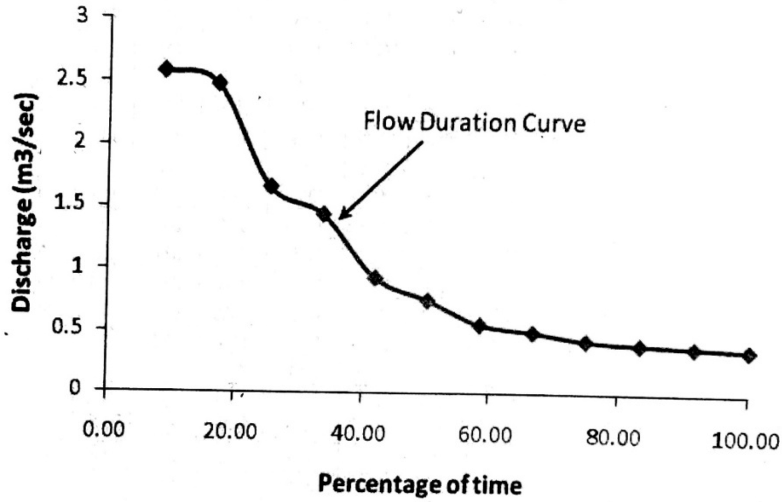
Problem: The long term monthly flow of a small stream is shown in table below

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Q(m^3/sec)	0.36	0.38	0.40	0.50	0.76	1.67	2.59	2.49	1.45	0.94	0.56	0.43

Solution

Month	Discharge (m^3/sec)	Rank (n)	Frequency(F) N/n	Probability of exceedance (P) (1/f)	Discharge (m^3/sec)
January	0.36	1	12.0	8.33	2.59
February	0.38	2	6.00	16.67	2.49
March	0.4	3	4.00	25.00	1.67
April	0.5	4	3.00	33.33	1.49
May	0.76	5	2.40	41.67	0.94
June	1.67	6	2.00	50.00	0.76
July	2.59	7	1.71	58.33	0.56
August	2.49	8	1.50	66.67	0.5
September	1.45	9	1.33	75.00	0.43
October	0.94	10	1.20	83.33	0.4
November	0.56	11	1.09	91.67	0.38
December	0.43	12	1.00	100.00	0.36

The value of probability of exceedance Vs discharge is plotted to get flow duration curve as shown in figure below



Use of flow duration curve

- Flow duration curve helps to evaluate firm energy, secondary energy and total energy.
- Flow duration curve is highly useful in planning and design of water resource project.
- FDC helps to evaluate the low level flows.
- Planning and design of hydropower project
- Total amount of sediment transmitted by river can be found out if FDC along with sediment rating curve is available
- FDC provides runoff variability of river: If curve has steep slope throughout it indicates stream has highly variable discharge

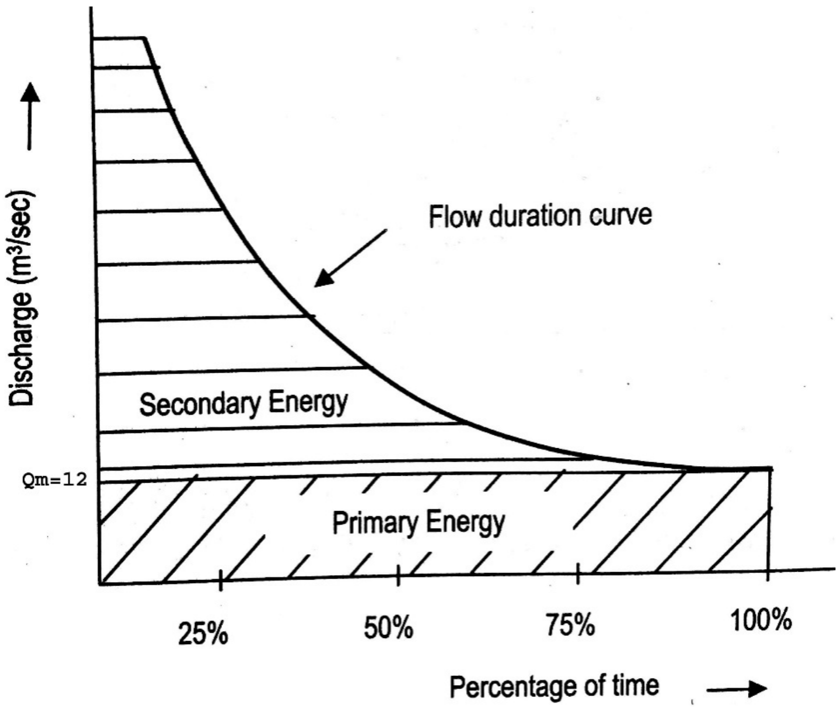
2.4. Firm (or primary) power and secondary (or surplus) power

Firm (or primary) power

The power, which is ensured to a consumer at any time of the day, is known as firm power. This is also known as primary power. Firm power is available for 100% of time for a year. Firm power corresponds to the minimum stream flow and is available for all times. The firm power of hydropower plant can be increased by the use of poundage, so that greater minimum flow is available for 100% of time.

Secondary (or surplus) power

The secondary power is the amount of power, which is in excess of the firm power. It is also called surplus or non-firm power. The plant can deliver the secondary power only for a part of a year so it is the seasonal power. It is comparatively less valuable. It is useful in interconnected system.



"Firm power and secondary power can be better understood with the help of flow duration curve as shown below."

In above figure Q_m=12m^3 /sec is the minimum flow available in river for power production for 100% time of the year. The power corresponds to this Q_m is the firm or primary power.

2.5. Power system and load

Power system

System of transmission of high voltage is called power system or power grid. Modern power system is served by several power plants, which are interconnected to form power grid. Thus a power grid is a system in which series of hydropower station are functioning at a time with satisfying the demand on electricity to the people without disturbance in their works, if any station needs to be stopped.

The electricity generated from the generator is distributed to the consumer using different power system. This system is;

1. Isolated system
2. Interconnected system

Isolated system

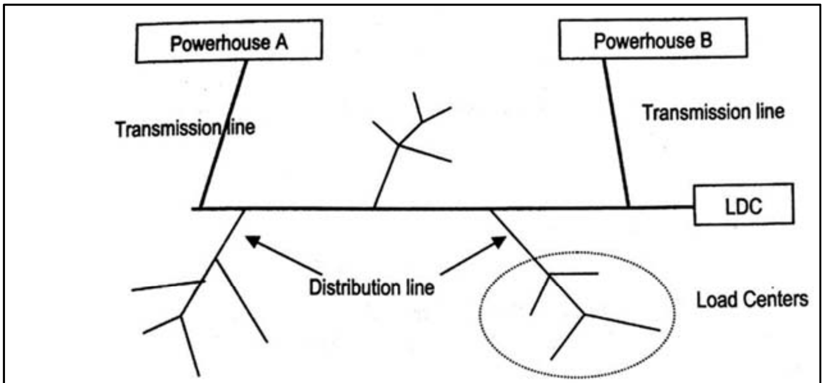
In this system the power generated from power station is not connected to other power system or national grid. All the power generated is distributed in the surrounding village and development center near by the power station. This type of power system is easy to operate as compared to inter connected power system.

- The disadvantage of such power system is that, load centers of the system can't receive the power from other power station during failure of Power plant.
- The excess power generated can't be transmitted to other load station.

Interconnected system

In this system the power generated from the various power stations is connected to each other by transmission lines and transmitter. Operation of plant under such system is relatively complex with compared to the isolated system. The advantages of this system are

- During the failure of plant, power for the load center near by the failure plant can be obtained from the other plant.



Components of power grid system are

- Generation stations (Powerhouse) (generators, transformers, switchgear)
- Transmission lines
- Load dispatch center
- Substations
- Distribution lines
- Distribution transformers
- Households / consumers

- The excess power generated by a power plant can be transmitted to the other load center through the transmission line.

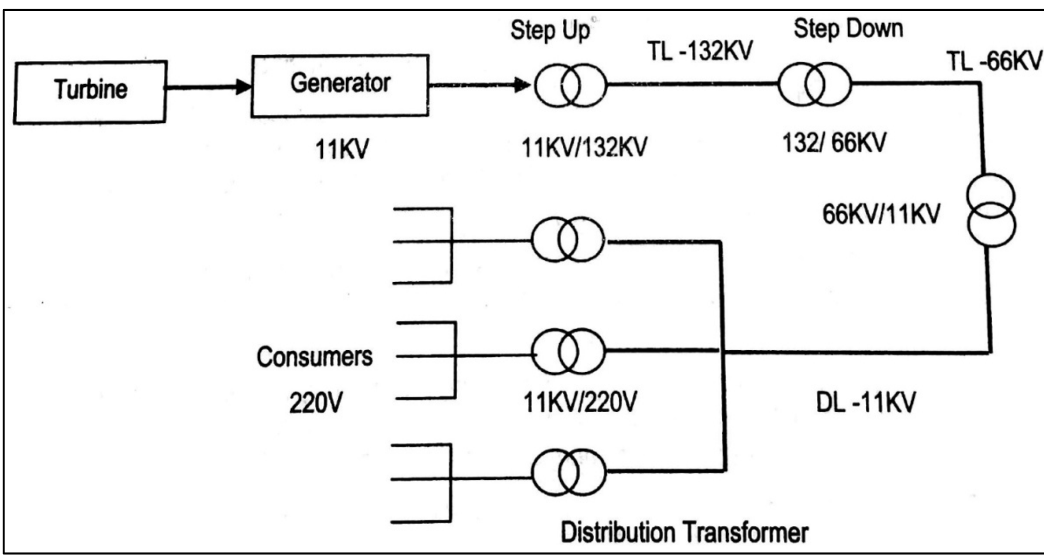


Fig: Transmission system

Load curve

Load curve is the graph of load consumption with respect to any time. So this curve gives indication of power used at any time. The unit of electrical consumption is kilowatt-hour. One kilowatt hour is called unit in common language.

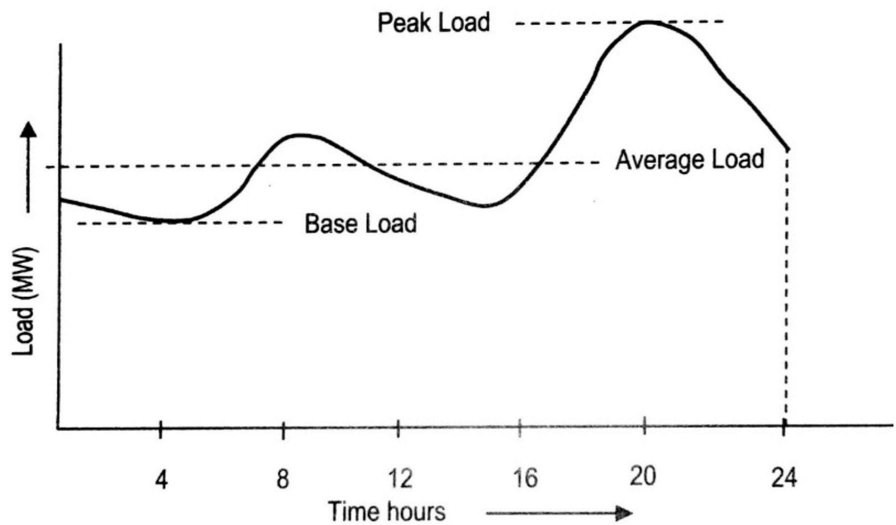


Fig:- Load curve of the day(Daily load curve)

Generally, load curve is the daily load curve, weekly load curve, monthly load curve and yearly load curve.

Peak load: The highest demand in a day is called peak load.

Average load: The average load is defined as the average consumption over the definite period of time.

Base load: Minimum load within a day is called base load.

8.6. Load factor, Utilization factor and Capacity factor

Load factor

It is the ratio of average load during the certain period to peak load during the same period. Load factor may be daily load factor, weekly load factor, monthly load factor or yearly load factor, depending upon the time consideration.

Therefore, load factor = Average load in certain time period / Peak load in same time period

For example, a power plant generates 8500000 KWh in a certain week and the maximum peak load during the week is 120000KW.

Load factor during this week = 8500000 / (7×24×120000)

= 42.16%

Utilization factor

It is the peak load developed during the certain period to the installed capacity of the plant.

In other words, utilization factor is the ratio of utilized power to the maximum power available. It may vary from 0.4 to 0.9 for hydropower plant

Utilization factor = peak load / installed capacity

Capacity factor or plant factor

It is the ratio of the energy that the plant actually produced during any period to the energy that is might have produced if operated at full capacity throughout the period. For hydropower plant, capacity factor varies from 0.25 to 0.70 or more.

For example, if the plant has the installed capacity of 100MW and in 100 hours, it produces 5500000KWh,

Then capacity factor = 5500000 / (100×1000×100)

= 0.55

Installed capacity

The plant capacity which is economically viable is known as installed capacity. It is also defined as the maximum power, which can be developed by all generators of the plant at normal head and full designed flow.

$$P = \eta\gamma Q_d H \text{ KW}$$

Where,

η = overall efficiency of a system.

γ = Specific weight of water whose valve is 9.81 KN/m^3 $10KN/m^3$.

H = head of water in m

Q_d = Designed discharge m^3/s

2.7. General Layout plan of hydropower plant

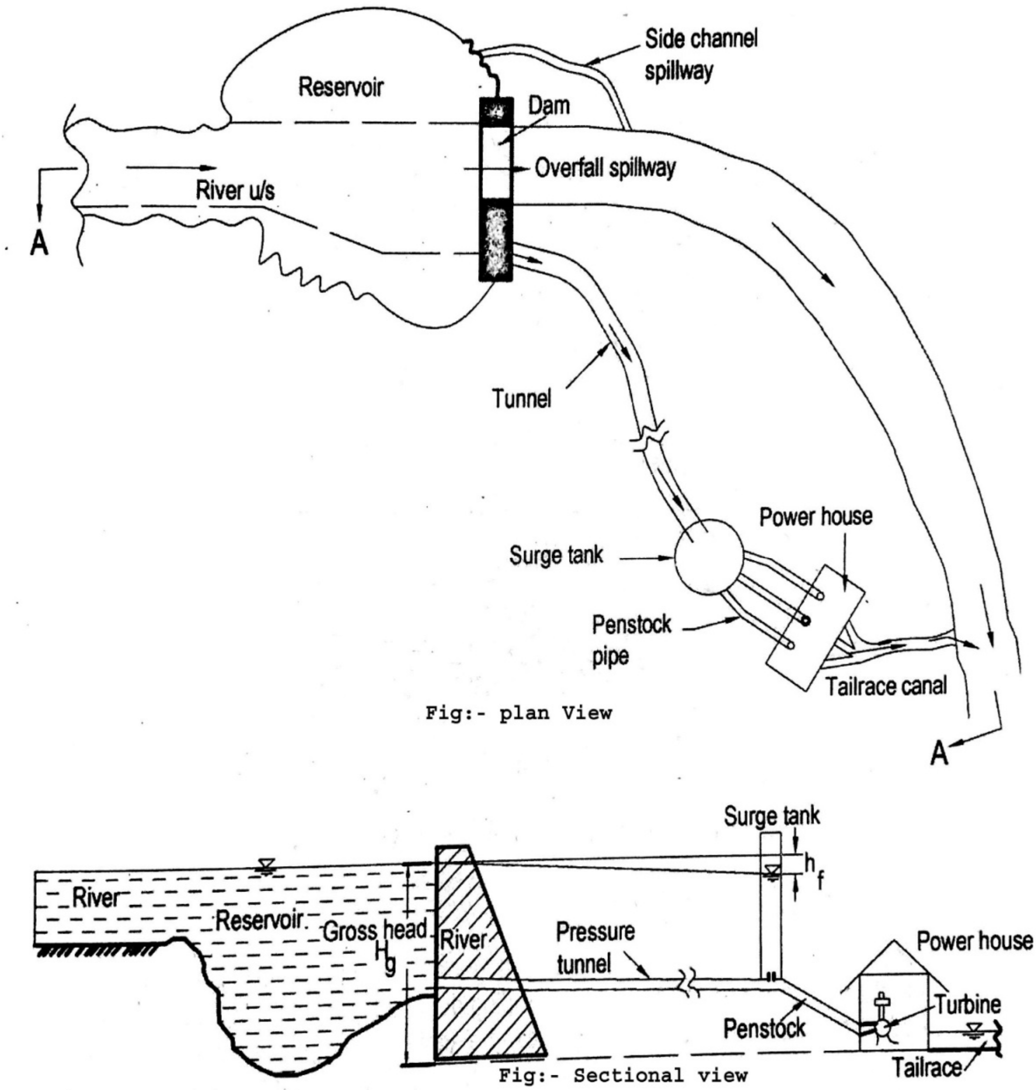


Fig:- plan View

Fig:- Sectional view

Fig: Plan and sectional view of storage hydro power plant

Components of Hydropower

Following are the main components of Hydropower

1. An impounding structure such as dam to store water for creating head (for Storage type) or a diversion head works for diverting the water to water conductor system in case of ROR type

i. An intake system containing thrash rack and gate to control and regulate the flow into the conductor system.

ii. A water conductor system either open channel or pressure tunnels

iii. Headrace canal/pipe/tunnel, etc.

iv. Forebay /surge tank

v. Penstock pipe

vi. Anchorage block

vii. Power house

viii. Turbine

ix. Generator

x. Tailrace canal

xi. Transmission lines

2.8. Run off river (ROR) and Picking type of hydropower plant

Run-Off River (ROR) hydropower plant:

Run off river plants are those which utilize the flow as it comes, without any storage being provided.

These plants are essentially a low head plant and are constructed in Perennial River. In this types of hydropower plant, water retaining structure such as dams are constructed at river for the diversion of water into the canal only, not for the storage purpose. The water diverted into the power canals transfers its energy to turbine to produce electricity and this water is disposed downstream of river through tailrace canal.

The power generated is function of discharge of river and, maximum during excess flow period and decreases during the dry period.

Because of no needs of heavy water retaining structures, ROR plants can be constructed in low cost in relatively short period of time. But the energy production of this type of plant is not large.

Peaking runoff river hydropower plant

Peaking runoff river hydropower plants are similar to the ROR hydropower plant, the difference is that, PROR plants are provided with small poundage to meet the peak demand of the day. The storage capacity of the reservoir provided is not very large. In this plant the poundage allows storage of water during lean periods of the day and use of this water during peak period. Based on the size of the storage structure provided it may be possible to cope with hour to hour fluctuation.

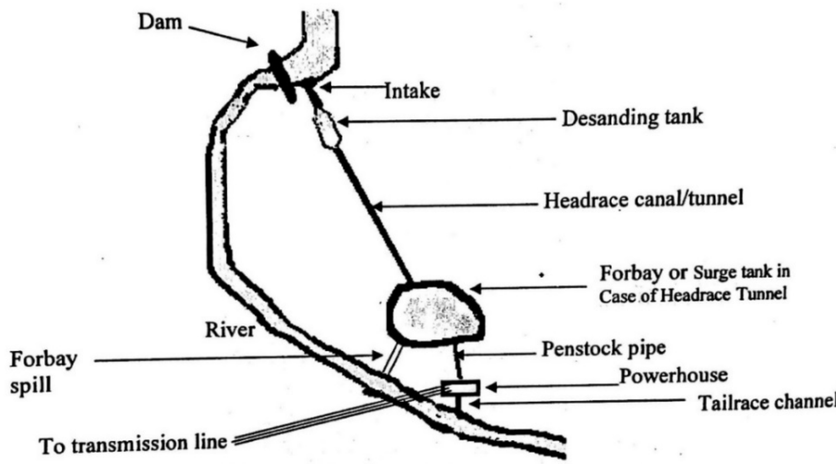


fig.: Runoff river hydropower plant

Storage or Reservoir hydropower plant

In these types of hydropower plants a dam is constructed across a river to create reservoir at upstream as shown in figure. Extra water coming in during the rainy season is stored so that schemes (plants) may run throughout the year. Powerhouse is constructed at the toe of dam or below the dam at suitable location. Water from the reservoir to powerhouse is carried through a tunnel. If tunnel is long enough and water head is very high, surge tank is provided upstream of powerhouse.

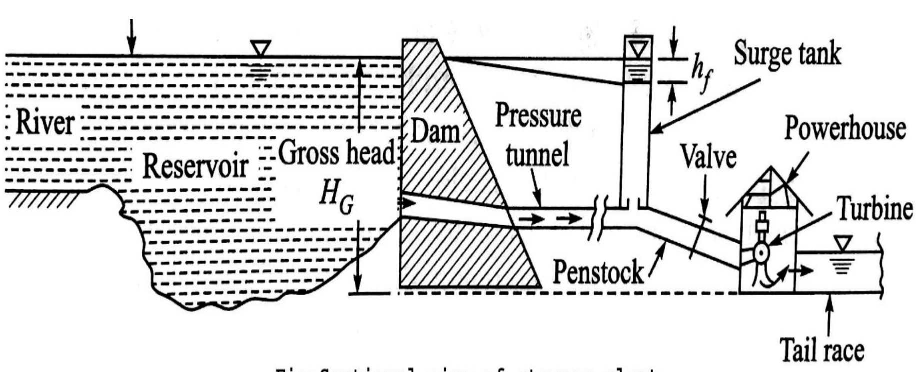


Fig:Sectional view of storage plant

Pumped storage hydropower plant

This type of hydropower plant consists of small upper reservoir, powerhouse, turbine, pump and tailrace water reservoir. During peak hours it generates electricity by using water available in upper reservoir. During the off-peak hours, water from the tailrace reservoir is pumped back by a pump to the upper reservoir

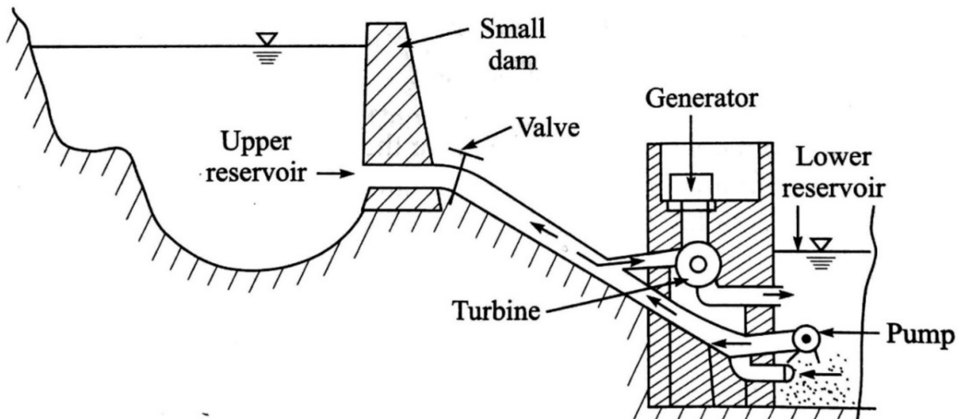


Fig:Sectional view of pumped storage plant

2.9 Introduction and types of hydraulic turbine

The hydraulic machines which convert hydraulic energy into mechanical energy are called turbines. The mechanical energy is used in running the electric generator which is directly coupled to the shaft of turbine.

The water through the penstock pipe strikes to the runner of turbine and make it rotate i.e., the hydraulic energy is converted to mechanical energy. The shaft of the turbine runner is directly coupled with shaft of the generator, thus providing the necessary mechanical energy to generator which converts mechanical energy into electrical energy.

A hydraulic turbine consists of

i. A wheel called runners provided with number of curved vans on its periphery.

ii. A guiding apparatus to direct the flow of water at inlet in specified direction.

Generally, there are two types of turbines, they are

i. Impulse turbine.

ii. Reaction or pressure turbine.

Impulse turbine

A turbine, in which water entering the runner possess kinetic energy only known as impulse turbine. The kinetic energy of water is converted into mechanical energy in this type of turbine. The example of impulse turbine is Pelton turbine and Turgo turbine.

As the name indicates, it is the turbine, which runs by the impulse force of the water. Water is introduced through the nozzle of the penstock pipe to the runner of the turbine which impinges on the buckets fixed on the runner and the shaft. The mechanical energy obtained on the shaft of the runner could be used for some other useful purpose.

Reaction or pressure turbine

The reaction turbine is the turbine in which water entering the runner possesses pressure as well as kinetic energy. As water flows through the runner, water is under pressure and pressure energy goes to changing into kinetic energy. Obviously this type of turbine is always enclosed by airtight casing and the runners and casing is completely full of water. For example, Francis, Kaplan and Thomson turbine are reaction turbine.

Pelton turbine (An example of impulse Turbine)

Pelton turbine is tangential flow impulse turbine which consists of following component as shown in figure.

a. **Nozzle:** Circular pipes with reduced diameter than that of penstock with valve to control rate of flow.

b. **Runners and Bucket:** The runner consists of circular disc, on the periphery of which a number of buckets evenly spaced are fixed.

c. **Casing:** The main purpose of the casing is to provide barrier to the turbine. It prevents splashing of the water and discharge water to tailrace.

d. **Breaking jet:** A small jet of water directed on the back of vanes to stop the runner in short time after spear water valve being closed.

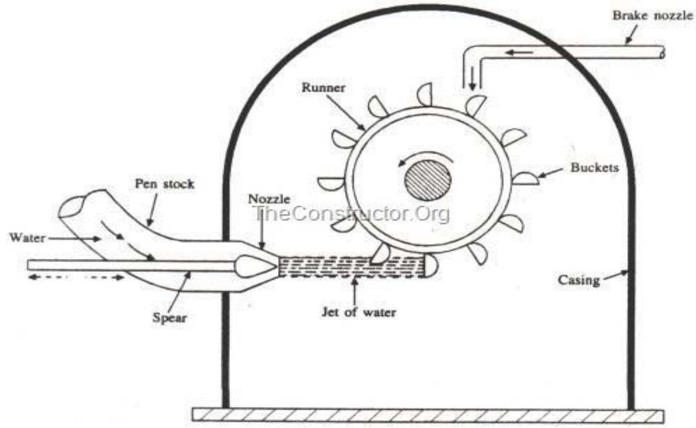
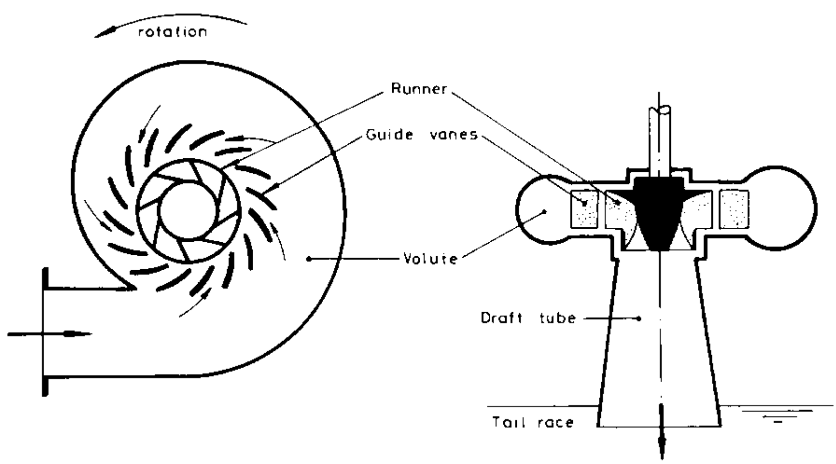


Fig. Pelton turbine

Francis turbine (An example of reaction turbine)

Francis turbine is an inward mixed flow reaction turbine. In this turbine water under pressure enters the runner from the guide vanes towards the center in radial direction and discharge out of runner axially. It operates under medium head and medium discharge.



Main component of Francis turbine

a. Casing

Also known as scroll casing which completely surrounds the runner. Water from penstock pipe enters to it. The cross-sectional area of this casing decreases uniformly along the circumference to keep the fluid velocity constant in magnitude along its path.

b. Guide mechanism

These are provided to regulate the quantity of flowing water and to make the entrance of water smoothly without shock**.**

c. Runner

Runner is circular wheel on which series of curve vanes are fixed.

d. Draft tube

A tube or pipe of gradually increasing area to discharge water from exit of turbine to the tail race.

The main types of turbines used in hydroelectric engineering practice are;

i. Francis turbine

ii. Pelton turbine

iii. Kaplan turbine

iv. Propeller turbine

Factors to be considered while selecting turbine

a. Available head

- Very high head > 350: Pelton turbine only
- High head: (150-350): Pelton or Francis
- Medium head :(60-150m): Francis turbine is usually used.
- Low head (30m to 60m): Between 30m to 60m both Kaplan and Francis can be used.
- Very low head (Below 15m): Propeller turbines are commonly used for head upto 15m

b. Efficiency

The turbine selected should be such that it gives highest overall efficiency for various operating condition.

a. Water quality: (i.e. sand content chemical or other impurities) Quality of water is more crucial for the reactive turbine then reaction turbines.

b. Specific speed:

c. Rotational speed:

3. Learning process and support materials

- Following are the learning process of this unit:
- theoretical notes
- presentation
- group work
- prepare field trip for the observation of hydropower project

4. Assessment

A. Very Short Questions.

1. What is ROR type hydropower?
2. Define firm power.
3. Define load factor.
4. Define flow duration curve.

B. Short Questions.

1. List the types of hydraulic turbine and describe about Pelton turbine.
2. Define the terms: a) Utilization factor b) Capacity factor

C. Long Questions.

1. Draw the general layout of hydropower plant and describe the components also.
2. What is flow duration curve? What are uses of it? Differentiate between firm power and secondary power.

Glossary

Gestation- the process of development of a plan or idea

Assist- to help

Impinges- to collide, to crash

Casing- that which encloses or encases

Crucial- being essential or decisive for determining the outcome or future of something extremely important

Reference materials

Suggested texts and references

Irrigation Engineering and Hydraulic Structures –Santosh Kumar Garg

Irrigation and Water Power Engineering- Dr. B.C. Punmia, Dr. Pande B.B. Lal, Ashok Kumar Jain and Arun Kumar Jain

Irrigation and Water Power Engineering- Madan Mohan Das and Mimi Das Saikia

Irrigation Engineering(Including Hydrology)-R.K. Sharma and T.K. Sharma

Irrigation Engineering and Hydraulic Structures-Dr. V.C. Agarwal

Engineering hydrology-K. Subramanya

Engineering hydrology-Dr. K.N. Dulal and Er. Sanjeeb Baral