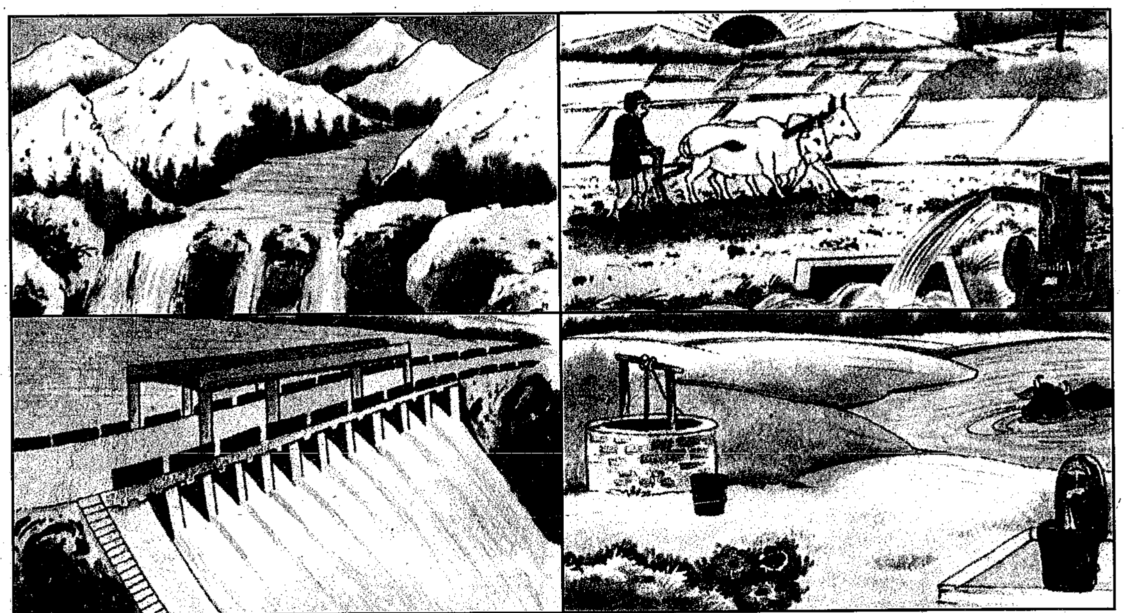
PDWR-04

Vardhaman Mahaveer Open University, Kota



Practical Approach of Water Resource Development

PDWR-04

Vardhaman Mahaveer Open University, Kota

Practical Approach of Water Resources Development

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Practical Approach of Water Resources Development

UNIT-1

KNOWING ABOUT SOILS

STRUCTURE

1.0 Objectives

Part of lack of concern for soils may be attributed to different concepts and viewpoints concerning this important product of nature. The homeowner is to have a concept of soil. It is good if the ground is mellow or loamy. The opposite viewpoint is associated with hard clay which resists being goaded into a good seedbed for a flower garden. A prime requisite for learning more about the soil is to have a general concept of what it is.

1.1 Introduction

Particle size distribution oi- soil texture undoubtedly is the most informative single property measured in an agricultural study. Soil texture is so important in directly influencing other soil properties that "soil classification" includes texture in the soil name. Simply knowing the soil texture allows one to predict many of the chemical and physical properties to be found in the field. One important example is the relationship between available water and soil texture which often used in irrigation scheduling and evaluating the irrigation methods.

1.2 Definition

Soil texture refers to the relative proportion of the various size groups of soil grains in soil mass. Specifically, it refers to the proportion of clay, silt and sand below 2 mm in diameter.

1.3 Soil Separates

A mechanical analysis reports the percentages of different size groups of particles. The two most widely used size distribution system are according to U.S. Department of Agriculture and International Society of Soil Science. The International system is commonly followed in India. International system of classifying soil separates is as below.

Sand	(2.00 - 0.02 mm)
Silt	(0.02 - 0.002 mm)
Clay	(< 0.002 mm)

1.4 Soil Textural Classes

As soils are composed of particles varying greatly in size and shape, specific terms are needed to convey some idea of their textural makeup and to give some indication of their physical properties for this soil texture class names are used, such as sand sandy, loam and silt loam. The more common textural classes are :

Texture Group	Textural Class
Fine Textured soil.	Clay, Silty clay, Sandy clay, Clay loam
Contain large amount of Clay+silt	Silty clay loam, Sandy clay loam, and Lesser amounts of sand)
Medium Textured Soils	Loam, Silt, Silt loam
(Contain moderate amount of clay and larger amounts of silt and sand)	
Coarse textured soils (Contain mostly Sand)	Sandy loam, Loamy sand, Sand

1.5 Textural Guide for Classification

The classes of soil texture are recognized on the basis of different percentages of sand, silt and clay as determined by mechanical analysis in the laboratory or approximately by surface feel technique in the field. "From these percentages, the textural class name is determined with the help of "Soil textural triangle" (Figure 2). There are 12 basic soil textural classes recognized. The use of textural triangle is simple and self - explanatory. On the basis of percentages of any two out of three fractions, one can know the textural class. For example: clay 35%, silt 30% and sand 35%.

Step 1

First go to the line where clay is expressed in %. Look for 35% clay. Follow the line as indicated by arrow.

Step 2

Now take up silt line where the silt is expressed as % silt. Follow the line as indicated by arrows. The clay line and silt line cross each other. Now, if you take up sand line as indicated by arrows, it crosses the point of intersection of clay and silt line. Soil texture is thus 'clay loam'. The area of each textural class is indicated by thick lines in the triangle. Test your knowledge with the following examples:

S.No.	% Sand	% Silt	% Clay	Texture (from Fig.2)
1.	40	45	15	?
2.	25	60	15	?
3.	20	30	50	?
4.	60	30	10	?

1.6 Coarse Fragments

In some soils, the coarse fragments-the mineral particles larger than 2 mm diameter may also exist. Significant proportions of these fragments are indicated by appropriate adjective class name. The adjectives generally used with textural class names are shown below :

Percentage of large fragments by Volume	Size of coarse fragments (dia) 0.2-7.5cm (Gravels)	7.5-25 cm (Stones)	Greater than .25 cm (Boulders)
2-15	Slightly Gravelly	Slightly Stony	Slightly Boulder
15-50	Gravelly	Stony	Boulder
50-90	Very Gravelly	Very stony	Very Boulder
90-100	Gravel	Stones	Boulders

For example, if the textural class name is "Sandy Loam", but it also contains 15-50% gravel by volume, "he modified-textural class name will be it gravelly sandy loam". However, if it contains 90% or more gravel, it will be called "gravel" and the class name is dropped.

1.7 Role of Soil Texture

It has a large influence on

(a) Wafer holding capacity.

(b) Ability to supply water to plants.

(c) Nutrient holding capacity.

(d) Ability to supply nutrient to Plants.

(e) Permeability to air, water and roots.

(f) Drainage Character.

(g) Tillage character.

(h) Run off.

(i) Erodabiliy.

1.8 Applications of Soil Texture in Water and Land Management

Soil water relation or and management parameter	Broad Soil textural group Coarse textured soils	Medium textured soils	Find textured soils
1	2	3	4
1. Workability by Implements	Light	Medium	Heavy
2. Infiltration of Water	Rapid	Moderate	Slow
3. Internal drainage	Excessive	Moderate	Slow to Impermeable
4. Run off	Slight	Medium	High
5. Surface soil crusting	Slight	Moderate	Thick
6. Soil moisture retention	Low	Medium	High
7. Available soil moisture storage capacity for crops	Low (60-85 mm/m soil depth)	High (220-240mm/m soil depth)	Medium (200 mm/m soil depth)
8. Swelling and Shrinkage and Cohesion	Low	Medium	High
9. Nutrient retention capacity	Low	Medium	High
10. Ground water rise, or capillary rise, cm, upward from G. W.	10-50	60-80	80-120
11. Sodicity hazards	Low	Medium	High
12. Deep percolation of water	High	Medium	Low

1.9 Soil Texture Determinations

Soil texture by feel analysis is a simplified and quickly approach designed to supplement laboratory testing methods for particle size analysis. In the laboratory hydrometer method may be used for determining the texture of soils.

Field method of determining soil texture :

Determination of soil texture in the field is made mainly by feeling the soil with fingers and noting the feel as grittiness, stickiness, slipperiness, plasticity, etc. This requires skill and experience. For high accuracy, the texture determined in field by surface feel should be checked against laboratory analysis. The basis of field determination of soil texture by surface feel is explained below:

(i) When felt between fingers, the sand particles in soil feel gritty or in case of very sandy samples, these can be seen by naked eye.

(ii) The feel of the silt is soft and floury when dry and is slippery or soapy when moist; but does not stick to the fingers.

(iii) The clay when felt between thumb and fingers, is sticky if moist, plastic enough to form a flexible ribbon when pressed.

Thus by means of different feels among the sand, silt and clay, the soil textural group is estimated. However, errors are expected due to presence of organic matter, gypsum, calcium carbonate coarse fragments, soluble salts, etc. The individual textural class can be determined by forming the ball of moist soil and placing the ball between thumb and forefinger and 'then squeezing it to see the formation of ribbon. The flow diagram shown in Figure 1 provides step-by-step directions for determining the textural class of a soil sample, by feel method.

1.10 DETERMINATION OF SOIL STRUCTURE

Structure is very important in plant growth relationships, as it chiefly influences the amount and nature of porosity and regulates the moisture of regime in the soil. Structure is one of the soil properties which are liable to changes under different management practices such as ploughing, draining liming, fertilizing and manuring etc.

1. DEFINITION

The primary particles sand, silt and clay usually occur grouped together in the form of aggregates. The mutual arrangement of these individual soil particles and their aggregates into certain defined patterns is called structure. Natural aggregates are called peds.

Soil structure is best studied in the field natural conditions and it has three categories.

(i) Type - Shape or form and arrangement pattern of peds

(ii) Class - Size of peds

(iii) Grade -Degree of distinctness of peds.

(I) TYPE OF STRUCTURE

The four principal geometric forms of soil structure (fig. 1) are as follows:

1. Spheroidal (Granular and crumb)

In this structural type, the aggregates are more of less rounded or spherical in shape, Rounded aggregates, generally not much larger than 2 cm. in diameter often found in loose conditions in top layer of soils and readily shaken a part. Rounded aggregates are also referred as granular structure, but if especially porous, it is termed 'Crumb'. Granular and crumb structures are characteristic of many surface soils high in organic matter. These are agriculturally good structural types.

2. **Blocklike : (Angular blocky or sub-angular blocky)**

The aggregates have horizontal and vertical axes more or less equal. Cube like blocks upto 10 cm. in size are observed. These are irregularly six-faced with their dimensions more or less equal. When the faces are flattened and the edges are sharply angular, it is referred as 'agnular blocky' structure. When the edges and faces are rounded or blunt, it is termed as 'subangular blocky'.

3. **Prism like**

Columnar and prismatic sub types are characterized by vertically oriented aggregate or pillars, which vary in lengths with different soils and may reach diameter of 15 cm. or more with 6 sides. In these structural types, the vertical axes are longer than horizontal axis/artical cleavage planes are predominant. When the tops are rounded, the term 'columnar' is used. When the tops of prism are still plane or leveled, the structure is designated as 'prismatic'. These types of soil structures are found generally in sub surface layers of salt affected clayey soils, particularly the sodic soils.

4. **Plate like-platy**

In this structural type, the aggregates or groups are arranged in relat ively horizontal planes, flakes. These are horizontally layered, thin and fiat aggregates resembling potato wafers. Such structures occur in recently deposited clay soils and also inherited by parent materials, especially those by water and ice. In platy structure, horizontal axes of aggregates are longer than vertical. The horizontal cleavage planes are predominant.

5. **Single grained**

This structure has no aggregation between primary particles. It is structure less. This occurs normally only in sands and slits of low organic matter content. It is found in highly coarse textured soils, viz, sandy, etc. It is an undesirable structure.

6. **Massive**

It has also no aggregation but is coherent and free from any pore space. Examples of this are the structure of puddled soil mass in rice fields, hard clay pans in sub surface layers. Massive structure in soil can be obtained by working clayey (fine textured soil) in wet condition by implements. Massive structure becomes very hard after drying.

1.11 Classes of structure

Each primary structural type of soil is differentiated into five size classes depending upon the size of individual peds. The term commonly used for the size classes are

(a) Very fine or very thin

(b) Fine or thin

(c) Medium

(d) Coarse or thick

(e) Very coarse or very thick

The term thick and thin are used for platty types, while the terms find and coarse are used for other structural types. The size class of the soil structure can be find out by using Figure 2.

1.12 Grades of Structure

Grades indicate the' degree of distinctness of individual peds. It is determined by noting the stability of aggregates and the ease with which they separate from other peds. Grade of structure is influenced by the moisture content of the soil- Three terms commonly used to describe the grade of soil structure are :

(a) Weak	:	Indistinct formation of peds which are barely durable.
(b) Moderate	:	Moderately well developed peds which are fairly durable and distinct
(c) Strong	:	Very well formed peds which are quite durable and distinct.

For naming a soil structure the sequei,ce followed is grade, class and type; for example, strong coarse angular blocky.

1.13 Significance of soil structure in soil and water management

There is a saying that if you improve the soil structure of a sick soil, you will improve crop yield, indicating that soil structure influences number of soil properties affecting crop yields. Soils texture cannot be altered but soil structure can be amended to suit crops. Soil structure influences soil water plant relations, permeability, aeration, root growth and nutrient availability etc.

Soil structure controls the following :

1. Tilth
2. Infiltration
3. Hydraulic conductivity/permeability
4. Soil aeration
5. Seeding emergence
6. Soil moisture retention and release
7. Water logging
8. Water loss due to deep percolation
9. Nutrient availability
10. Root growth
11. Soil erosion
12. Soil compaction

Types of soil structures and their relation with water movement in soil

Soil structure (Type)	**Water relation**
Granular & crumb	Good in retention of available water and optimally permeable

Angular Block & Sub-anguiar blocky	Moderately permeable
Platy	Slowly permeable
Columnar & Prismatic	Imperfectly permeable
Massive & Single grained	Excessively permeable or ill drained.

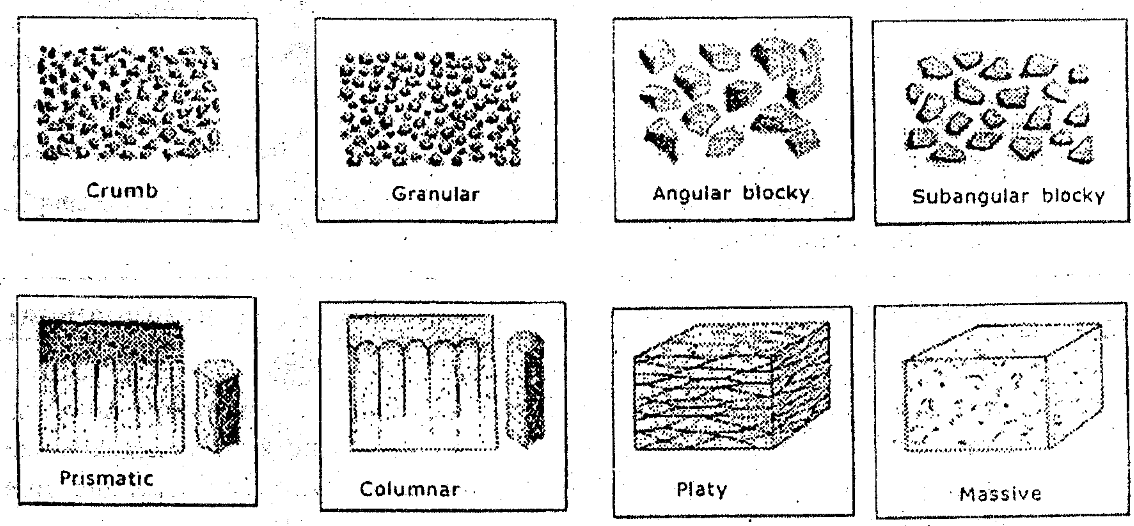

Figure 1 : Type of Soil Structures

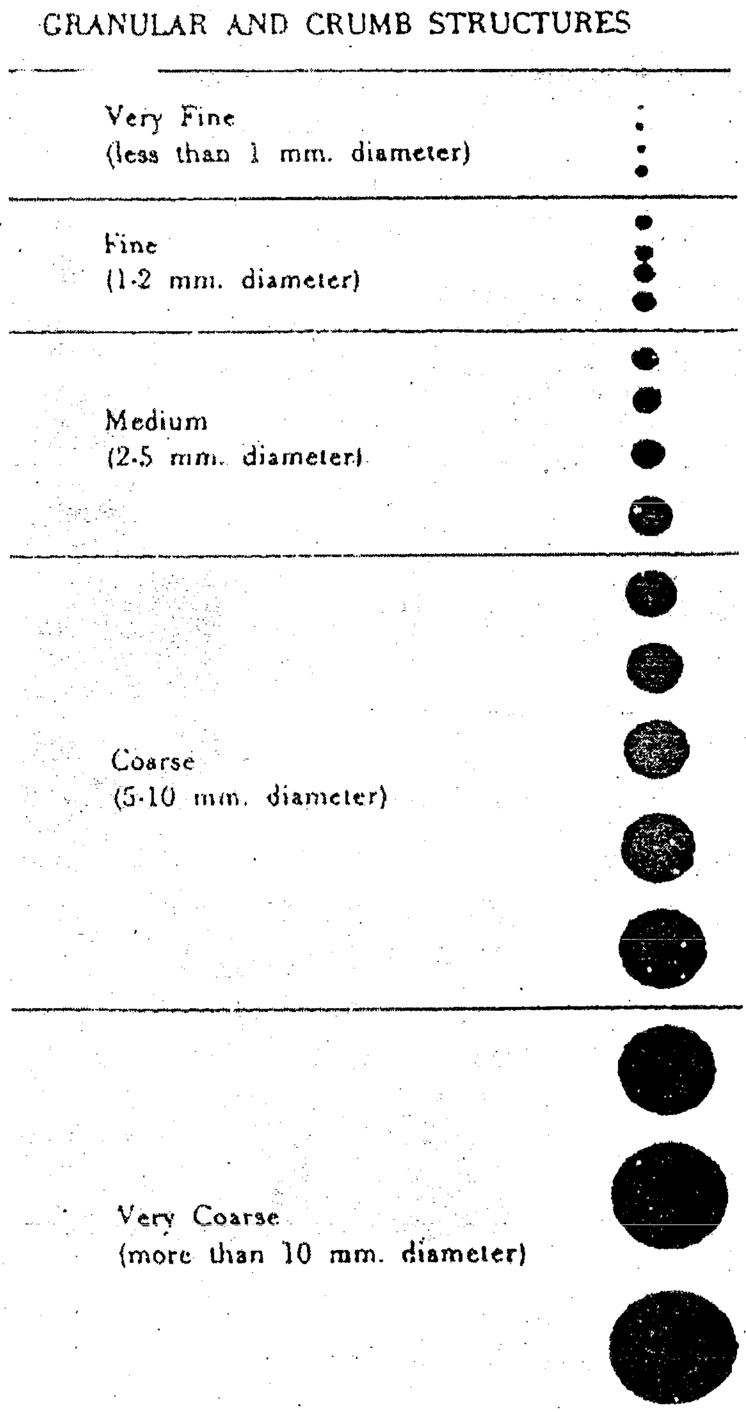

Figure : 2A, Class (Size) of Structure

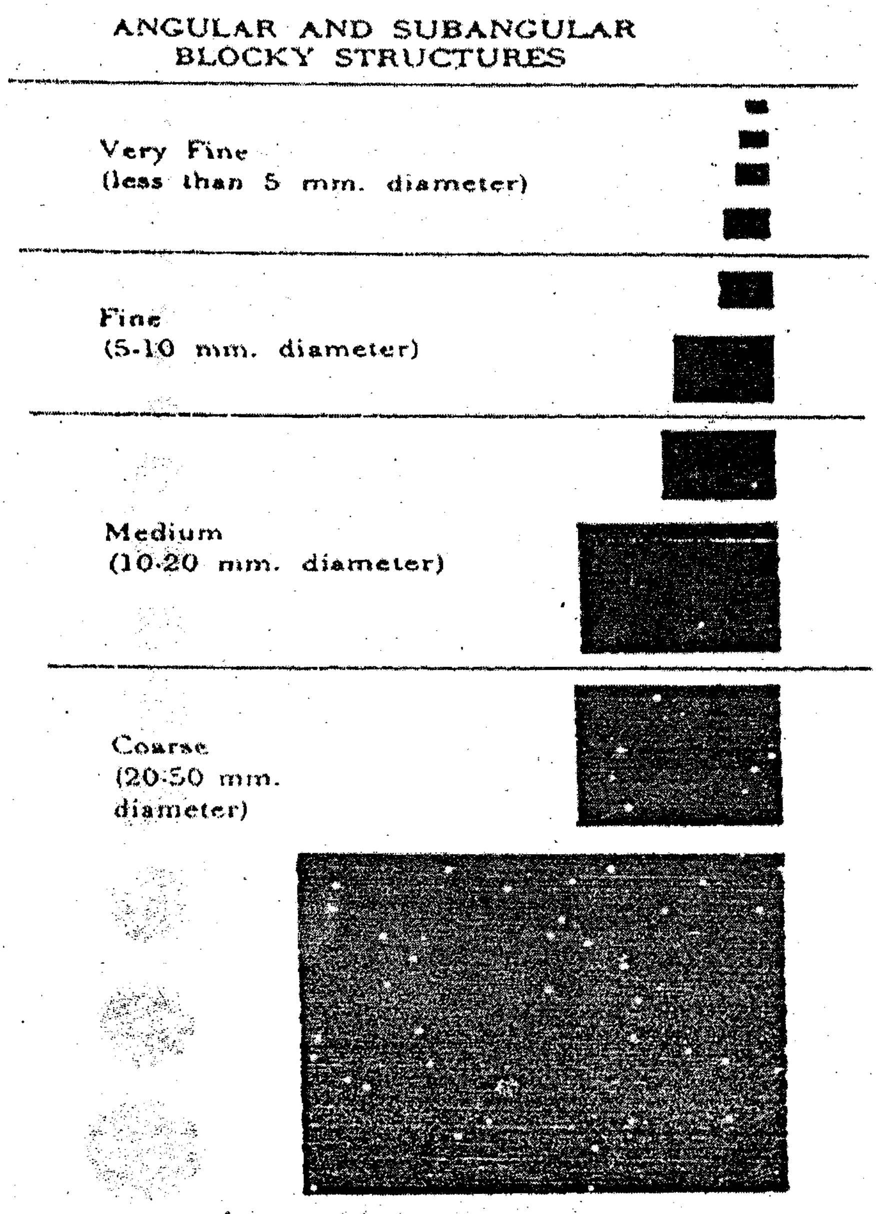

Figure : 2B, Class (Size) of Structure

1.14 Self Assessment Test

1. How you can find out the texture of the soil in the field?
2. What you understand by texture and structure of the soil?
3. Discuss the importance of texture and structure of soil in water management

1.15 Key Words

'Texture' refers to the proportion of clay, silt and sand below 2 mm in diameter.

'Structure' the primary particles sand, silt and clay usually occur grouped together in the form of aggregates

1.16 Suggested Readings

Bear, Firman E, 'Chemistry of the Soil'.

Black, C, A., 'Soil Water Plant Relationship'

Motiramani 'The chemistry and Fertility in Tropical Asia'

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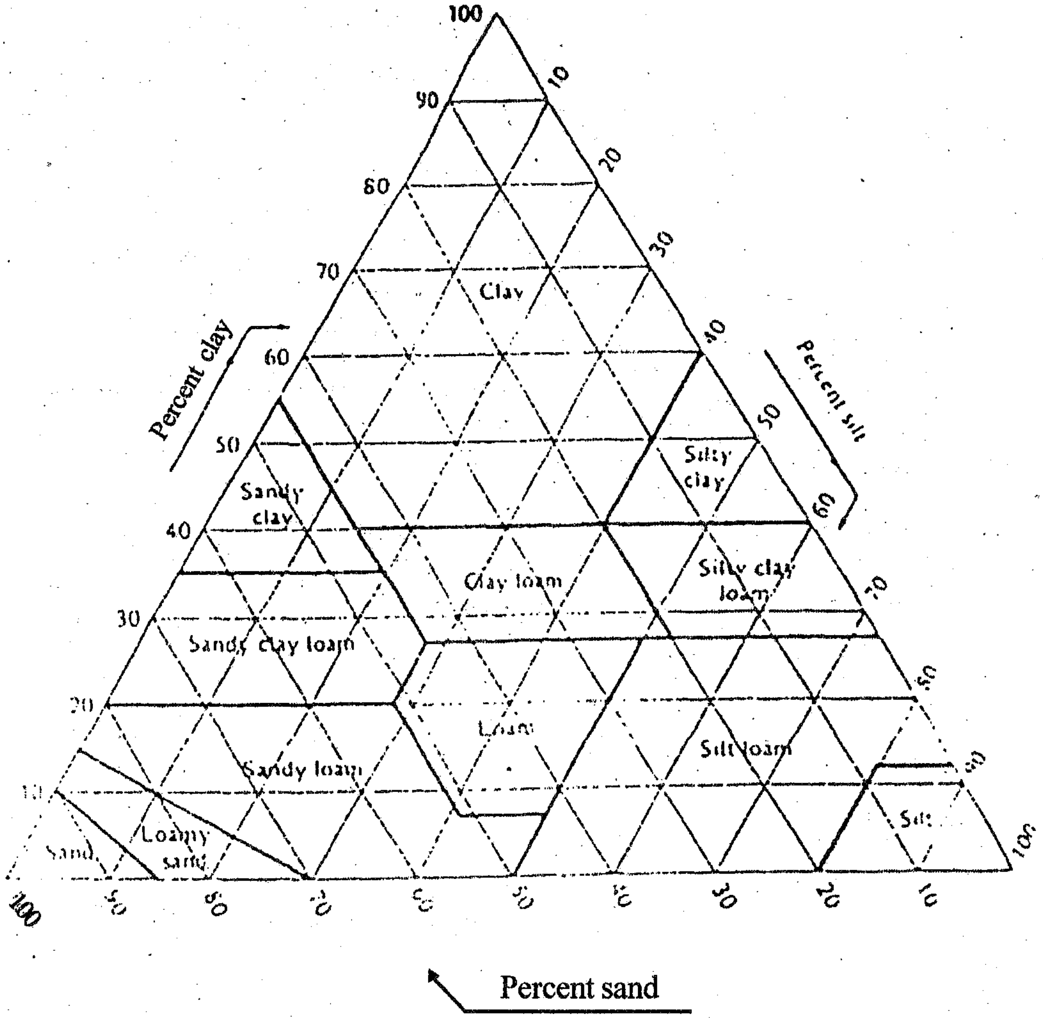

Figure 2 : Percentage of sand, silt and clay in the major soil textural desses. To use the diagram, locate the percentage of clay first and project inward as shown by the arrow. Do likewise for the percent silt (or sand). The point at which the two projections cross will identify the class name.

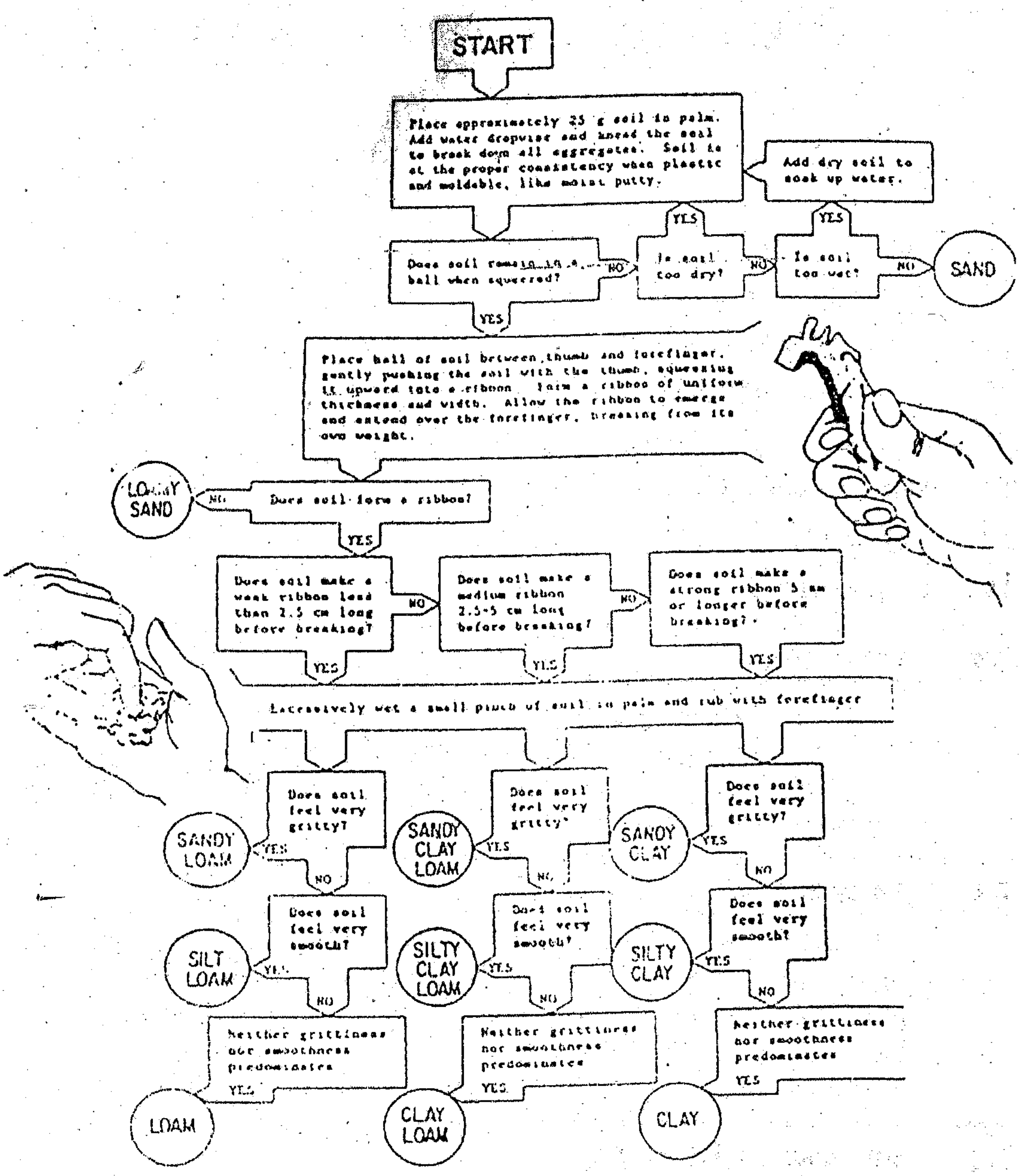

Figure : 1 Determination of Soil Texture by Feel Method

UNIT-2

TO CALCULATE INFILTRATION RATE

STRUCTURE

2.0 Objectives

Measurement of infiltration rate is essential in studies concerning hydrology, runoff and erosion, irrigation and water conservation. Planning of water management and conservation activities require accurate information on the rate at which water enters the soil under different conditions.

2.1 Introduction

It is the downward entry of water into the soil. The hydraulic characteristics of water application in irrigation are influenced by the infiltration phenomenon. The soil infiltration rate will affect advance and recession times, deep percolation and tail water runoff in furrow and border systems; advance and ponded times in level borders (basin) and maximum available application rate for sprinkler or irrigation systems.

2.2 Infiltration Rate (IR)

The actual rate at which the water enters the soil under specified conditions is called infiltration rate. It has the dimensions of velocity (say cm / hr.)

2.3 Factors affecting infiltration rate

The dominant factors affecting infiltration rate are as follows:

(i) Soil moisture content - The infiltration rate decreases as the soil moisture content rises.

(ii) Hydraulic conductivity of the soil profile.

(iii) Bulk Density, Texture, and Structural Porosity of Soil.

(iv) Cultivation - Cultivation increases the porosity and breaks the surface soil.

(v) Vegetal cover.

(vi) Presence of organic matter.

(vii) Presence of salts in the soil.

Infiltration rates are generally lower in soils of heavy texture than in soils of light texture (Figure - 1). The influence of water depth over soil on infiltration rate was investigated by many workers. It has been established that in surface irrigation, increased head (water-depth) increases initial infiltration slightly, but the head has negligible effect after prolonged irrigation.

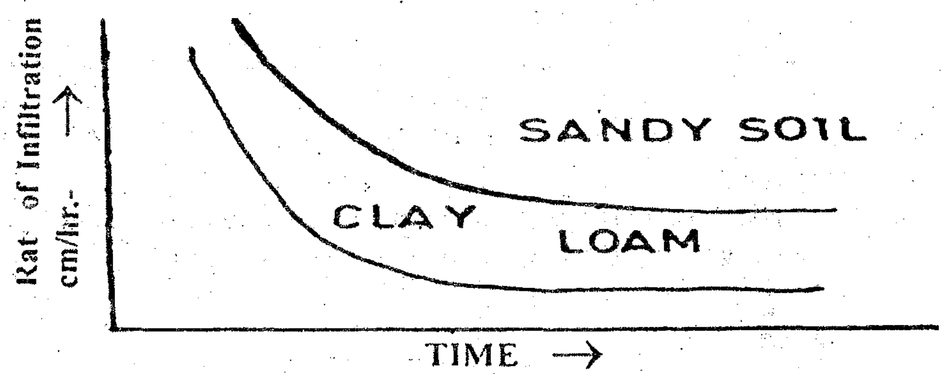

Figure 1 : Effect of type of soil on Infiltration

During irrigation the infiltration rate goes on decreasing. The rate of decrease is rapid initially, but subsequently the infiltration rate tends to approach a constant value which is called Basic Infiltration Rate (Ib) (Figure - 2)

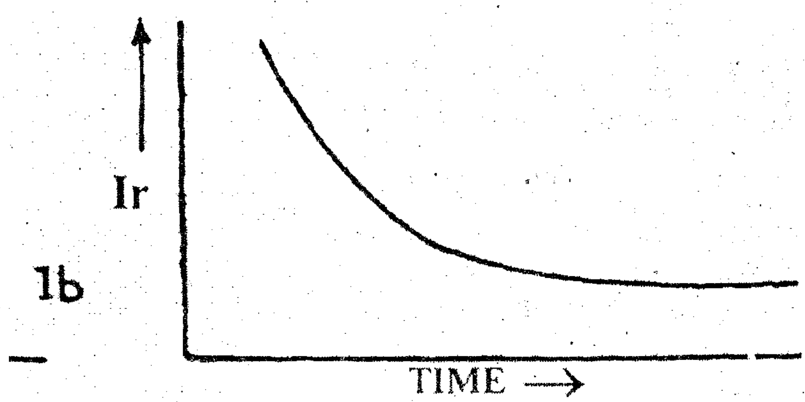

Figure 2 : EFFECT OF TIME ON INFILTRATION RATE

The Basic Infiltration Rate can be defined as the rate at which water will enter the soil after a period of several hours the change in the infiltration rate becomes very slow.

2.4 Cumulative Infiltration (Y)

It is the total quantity of water that enters the soil in a given time (Figure - 3)

Infiltration rate (IR) and cumulative infiltration (Y) are the two parameters commonly used in evaluating the infiltration characteristics of soil.

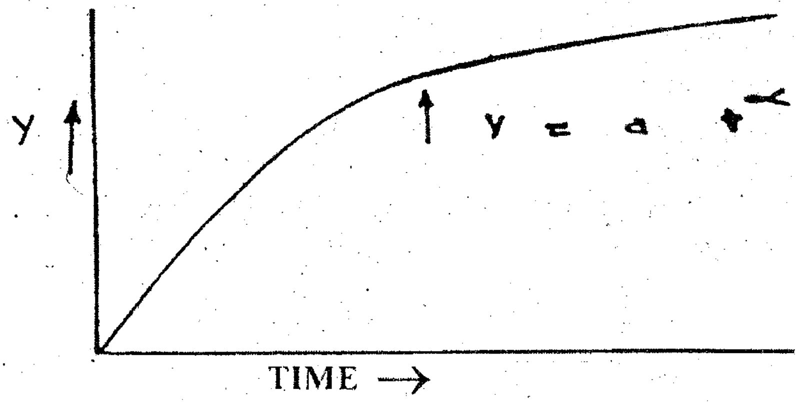

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Figure 3 : ACCUMULATED INFILTRATION (Cumulative

For design purposes, the relationship between cumulative infiltration and elapsed time are usually expressed by the following empirical equation.

Where $Y = at^{\propto}$

Y = cumulative infiltration in time 't'

t = elapsed time or infiltration opportunity time and

a and $\propto$ are characteristic constants.

The value of a and $\propto$ are to be determined from the observed data of infiltration test.

The infiltration rate at any time 't' is obtained by differentiating euqation (1) as follows:

$$Y = at^{\propto}$$

2.5 Measurement of Infiltration

For estimating infiltration characteristics of soil following methods are used:-

i. Concentric Cylinder Infiltrometer

ii. Basin Ponding Test

(i) Concentric Cylinder Infiltrometer (See Figure)

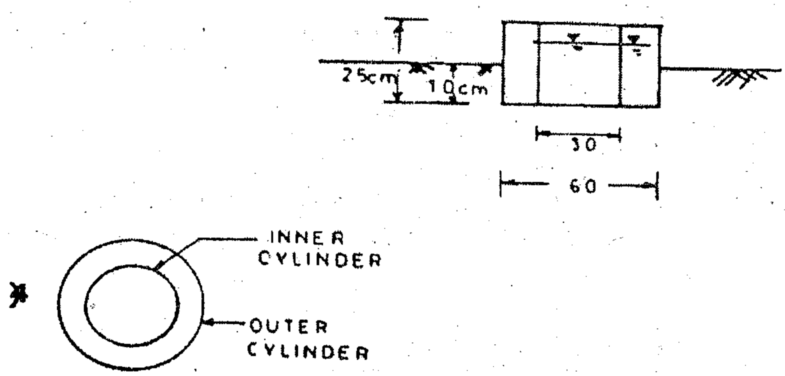


Figure - 4

The equipments consist of two concentric cylinders as shown in Fig. 4. The cylinders are usually 25 cm deep. The inner cylinder, from which the infiltration measurements are taken, is usually 30 cm in diameter. The outer cylinder, which is used to form the buffer pond to minimize lateral spreading of water, is about 60 cm. in diameter. The cylinders are installed about 10 cm deep in the soil.

The water is added in inner and outer cylinder upto desired level, say 10 cm above the ground. After the initial reading, point gauge measurements are taken at frequent intervals, say 5 min. to determine the amount of water that has infiltered during the time interval. Water is added quickly after each measurement so that a constant average infiltration head could be maintained. The average depth of water maintained in the cylinder is 7 to 12 cm which is approximately equal to the expected water level in the border or basin during irrigation. The buffer pond is filled with water immediately after filling the inner cylinder to maintain the same depth in both the cylinders. The data are tabulated in the form as given in Table.1

It is necessary to conduct at least 4 tests at suitable locations in the field having uniform soil. The average values of cumulative infiltration (Y) and average infiltration rates are plotted as a function of elapsed time (t) as shown in (Figure - 5)

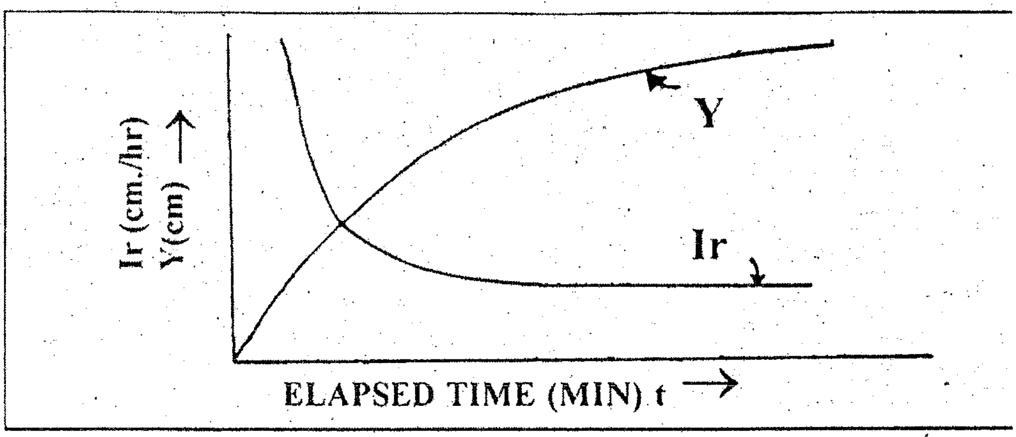


Figure - 5

$$Y = at^{\propto}$$

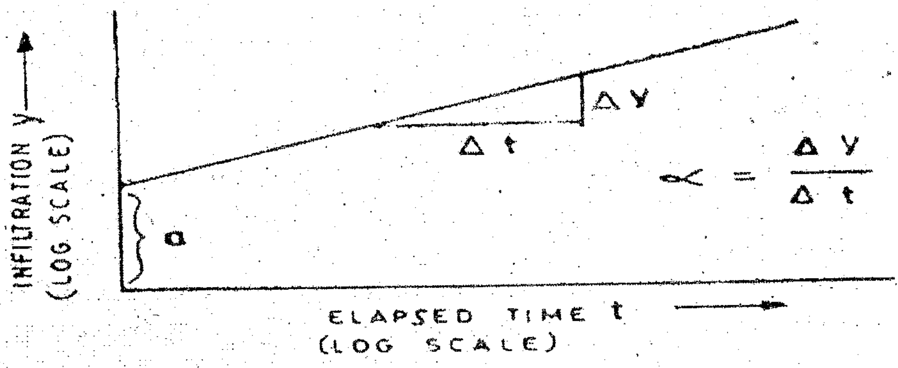
This function plotted on ordinary co-ordinate paper gives a parabolic curve. When the data are plotted on log-log paper, a linear relationship is indicated as shown below.

$$Y = at^{\propto}$$

taking log of both sides,

$$\log Y = \log a + \propto \log t$$

This is the equation of a straight line and the values of a and $\propto$ can be found out by plotting the values of Y and t on log-log paper or by fitting the straight line by the method of least squares (Figure 6)



(Figure - 6)

Knowing the values of a and α we can use the equation $Y = at^{\alpha}$ for finding out cumulative infiltration or infiltration rate at any time 't'.

(ii) Basin Ponding Test: Generally, this is conducted in clay soils, because of their swelling properly. Ring basins (inner and outer) can be constructed by building bunds. Point gauge is fixed outside of the inner basin. Further test is conducted in the similar manner as cylinder infiltrometer test.

Approximate -Infiltration Rates of Soils :

(Adopted from IARI Mon-graph No.1)

Types of Soil	**Basic Infiltration Rate (mm/hr)**
Coarse Sand	19.0 - 25.5
Fine Sand	12.5 - 19.0
Fine Sandy	10.0 - 12.5
Loam Silty loam	7.5 - 10.0
Clay loam	4.0 - 7.5
Clay	< 4.0

2.6 Precautions during the test

(i) The moisture content of the soil may be nearly equal to that of the soil when irrigation is likely to be applied.

(ii) The depth of water in the cylinder should be between 7 and 12 cm as this is the expected irrigation depth.

(iii) The water depth in outer and inner cylinders should be approximately equal.

(iv) Three to five tests for each soil type may be carried out to arrive at the average results.

2.7 Self Assessment Test

1. What is the objective and purpose of infiltration rate determination?

2. Discuss the factors, which affect the infiltration rate.

3. What are the precautions to be observed during measurement of infiltration rate?

2.8 Key Words

'Infiltration' means downward entry or movement of water into the soil surface.

'Cumulative Infiltration rate' refers the total quantity of water that enters the soil in a given time.

2.9 Suggested Readings

Bear, Firman E, 'Chemistry of the Soil'.

Black, C. A., 'Soil Water Plant Relationship'

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Determination of Infiltration Rate

Location .... Soil Type...

Date of observation..........................

Local time hrs.	Time inter val.	Cumulative time min.	Volume of water in-filtered ml.	Depth of water intake cm.	Cumulative depth of water	Infiltration rate cm/hr.

infiltration equation = ayt ....

Basic Infiltration Rate = ... cm/hr

UNIT-3

MEASUREMENT OF HYDRAULIC CONDUCTIVITY

STRUCTURE

3.0 OBJECTIVES

The main aim of drainage investigation is to obtain sufficient information on the agro-climate, topography, soil characteristics, water table and other factors of the area, which influence the design of any drainage system. Investigations of site conditions to determine feasibility of a drainage system and its design are essential for a successful drainage project. Hydraulic conductivity is an important parameter for the designing of subsurface drainage system. This chapter explains various methods of measurement of hydraulic conductivity.

3.1 INTRODUCTION

In agricultural productivity drainage plays an elemental and important role. Drainage should be judiciously exercised to strengthen the society, encourage economy and maintain fauna and flora. The objective of drainage is to protect existing agricultural lands for steady growth of agriculture. In some areas, natural drainage may be adequate to permit the sustainable cropping intensity and desired productivity. However, the natural drainage often needs to be supplemented with artificial drainage to dispose of excess water from agricultural lands. Source of excess water include precipitation, snow melt, over irrigation, canal seepage, reservoir leakage, artesian flow from aquifers, underground seepage from adjacent areas and extra water applied to leach salts from crop root zone.

In planning and developing of drainage projects, sound drainage investments must be considered and drainage measures balanced with proper irrigation and agro-economic benefits.

In semi-arid and arid regions, subsurface drainage is required to control high water table as well as to reclaim saline lands. Identifying specific areas for drainage is of critical importance to ensure only the areas which require drainage are actually drained. Investigations are necessary to accurately determine all such areas where high water table and/or salinity conditions occur. A number of key parameters must be thoroughly investigated and clearly understood prior to conclude proper subsurface drainage design criteria for any affected area.

3.2 MEASUREMENT OF HYDRAULIC CONDUCTIVITY

Saturated hydraulic conductivity (Ksat) is an essential design parameter in drain spacing determination. Ksat describes the transmitting properties in the soil profile. The larger the Ksat value the greater the ability of the soil to transmit water.

Saturated K values are generally correlated with soil texture and structure. Cracks in the soil, root channels and other small conduits left by biological processes in the soil greatly influence the hydraulic conductivity. In layered soil, K values generally differ between layers.

Following hydraulic conductivity values for different soil texture are found in literature (Table 1).

Number of hydraulic conductivity tests

The number of hydraulic conductivity tests required for a drainage survey is related to the soil variability in the project area. When soil survey data is available, the sites for hydraulic conductivity tests are selected on the basis of soil type. Otherwise, the tests should be made on a regular grid. The size of the grid is governed by soil variability and the time and budget considerations.

Table 1. Soil texture-hydraulic conductivity relationship.

Soil texture	Hydraulic conductivity (m/day)
Clay	<0.01
Silty clay	0.010-0.015
Silty clay loam	0.015-0.024
Clay loam	0.024-0.012
Sandy clay loam	0.012-0.091
Silty loam	0.091-0.231
Loam	0.231-0.427
Very fine sandy loam	0.427-0.732
Fine sandy loam	0.732-1.036
Sandy loam	1.036-1.524
Loamy fine sand	1.524-2.134
Loamy sand	2.134-2.743
Fine sand	2.743-3.658
Sand	3.658-4.877
Coarse sand	4.877-7.315

At each site, a minimum of two tests should be conducted in two holes a few meters apart. If the results of two tests are significantly different, then a third test should be conducted. The required density of test sites is related to soil variability and the expected drain spacing (Table 2).

Table 2. Maximum number of hectares represented by one test site.

Soil Conditions	Probable Drain Spacing		
	< 30 m	= 50 m	> 75 m
Heterogeneous	< 5	5-10	10-15
Less heterogeneous	5-10	10-25	20-40
Homogeneous	10-25	25-50	40-75

The depth below the drain level, for which the information on hydraulic conductivity is generally needed is limited to 1/8 of the expected drain spacing (i.e. S/8) in homogeneous soils and 1/20 of the drain spacing (i.e. S/20) in stratified soils. Thus with an anticipated drain spacing of 60 m, the hydraulic conductivity could be measured over a depth of 7.5 m below the drain level in homogeneous soils and 3 m in stratified soils. In all cases, however, the depth should not exceed 15 m from the soil surface. Within these limits the following test depths are recommended (Kamra & Rao, 1992):

Homogeneous soils

- at all test sites	1 m below expected drain depth
- at 1 out of 5 sites	3 m below expected drain depth or to a barrier if shallower.

Stratified soils

- at all test sites	Conduct hydraulic conductivity tests on major soil strata upto to 3 m below drain depth or to a barrier if shallower.

Measurement of hydraulic conductivity are best taken during the monsoon season since the water table depth is likely highest, which provides good Ksat measurement above the drain depth.

Number of methods have been developed for in-situ measurement of hydraulic conductivity of soil. There are laboratory method as well as field methods.

Laboratory Methods : In determination of Ksat in laboratory, the samples are collected in the field. The quality of the result depends very much upon the quality of the sample owing to soil variability; a large number of locations may have to be sampled. The principle of all measurement method is that water is arranged to lower through the sample while the rate of flow and the corresponding head losses are recorded. During the measurement the head may be kept constant (constant head method) resulting in steady flow through the sample, or the head may decrease (falling head method), resulting in decreasing rates of flow during the measurement. The Ksat may than be determined from the flow and head recorded using Darcy's law.

Field Methods : The main drawback of laboratory measurement is that the K-value only relates to a small part of the soil. In general determination of the K-value in the field is preferable over laboratory estimation. The important field methods for measurement of Ksat are auger hole method; inverse auger hole method; piezometer test and drain outflow method.

3.2.1 AUGER HOLE METHOD

Ksat can be determined by using auger hole method following approaches given by Hooghoudt (1936), Ernst (1950) and Kirkham (1948). The rate of rise of water level in the auger hole is measured for calculation of insitu data. The detailed description can be found in Luthin (1978).

R	=	Radius of hole,
X	=	Depth of impermeable layer below the bottom of hole,
W	=	Depth of water table in the hole from ground surface,
D	=	Depth of hole below reference level,
H	=	Depth of hole below water table (static water table),
Z	=	Distance of ground surface below the reference level,
Zo	=	Depth of the water level in the hole at the time of first reading,
Zn	=	Depth of the water level at the end of measurement,
WT	=	Depth of the water table below the measurement unit,
Yo	=	Distance between the static water level and water level in the hole at the time of first reading,
Yn	=	Distance between the static water level and water level in the hole at the end of measurement,
Y	=	Depth of water level from static level at any time t after the first reading,
ΔY	=	The rise of water level in the hole over a period of measurement dt.

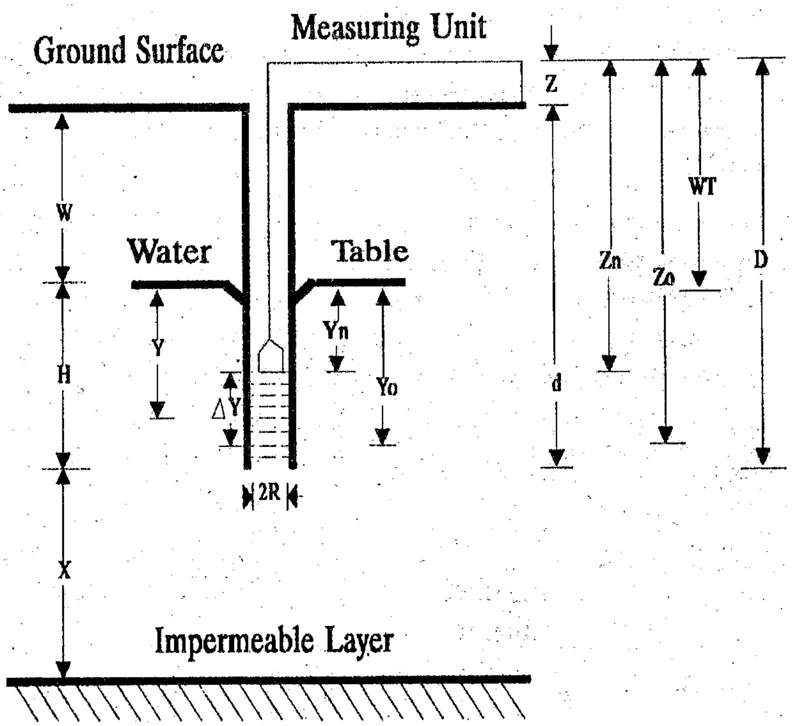

Figure 1 Measurement of Saturated Hydraulic Conductivity by Auger Hole Method.

The following procedure may be followed to calculate the hydraulic conductivity by the auger hole method :

- Make 3 auger holes by a 10 cm diameter auger, a minimum of 1 m apart at mid spacing and at 3 depths at 1.0, 1.5 and 2.0 m. to get the hydraulic conductivity of different soil layer. Deeper hole must be drilled first and various soil layers are examined & described. The actual depth of the shallow hole is determined on the basis of the profile investigations. Care should be taken so that disturbance of the soil is minimum.
- Leave the auger holes for 24 hours to allow the static water table to stabilize.
- Measure the depth of hole, and depth of static water table with respect to a reference point.
- Bail out the water from the auger hole by removing 20 to 40 cm of water depending upon depth of water table in the hole. Measure the depth of water in the hole after bailing. Normally 20 cm of water should be left in the hole.
- Record the rise of water in the hole using a float allowing maximum time interval of one minute. The best interval to use is a function of the permeability of the soil. Highly permeable soils may require 5 to 10 seconds.

Removal of water from the hole

This can start when equilibrium with the surrounding groundwater is attained and the depth of the water table has been recorded. Usually it will take 10-30 minutes to refill the hole in a moderately permeable soil (k = 1 m/day), some hours in a slowly permeable soil (k = 0.10 m/day).

The seeping of the groundwater into the hole will also re-open soil pores in the wall of the hole that may have been closed by the auger. If an open blade type of auger is used, it is unnecessary to remove the water from the hole 2 or 3 times for this purpose. The most effective way of removing the water is with a bailer viz.: a thin-walled pipe of about 50 to 60 cm in length, with a diameter of about 2 cm less than the diameter of the auger-hole and with a valve at the bottom. This bailer can also be used in combination with a perforated tube for making a hole in the unstable sandy soils.

The water level in the hole should be reduced 20 to 40 cm ($y0$ = 20 - 40 cm, see Figure 1). One or two bailings are required - depending on the length and diameter of the bailer used. If the soil has a very low hydraulic conductivity, it will be better to bail at least 40 cm of water from the hole in order to increase the rate of rise; this will reduce the time required for taking a reliable measurement. For measuring high hydraulic conductivity values, a $y0$ of 20 cm is better (Beers W.F.J., 1983).

Measurement of the rate of rise

The measurement properly consists in determining the rate at which the water rises in the hole. The observations are made either with a constant time interval (Δt) or with the fixed intervals for the rise of the water (Δyt), depending on the equipment available. In order to increase the accuracy of the results and reduce the effect of irregularities some 5 readings are usually taken as the water level rises.

If an electric device is used a fixed Δy is chosen. If a float with a measuring tape is used either Δy or Δt can be measured at regular intervals. However several stop-watches are necessary for measuring with a fixed Δy, whereas if measuring is done at regular intervals of time it is sufficient to use one watch with a good second hand.

The time interval (Δt) chosen depends on the permeability of the soil and is usually 5-10-15 or 30 seconds. A Δt is usually observed to be corresponding to a Δy of about one cm. For soils with a very low permeability (k=0.01, r=4, $\Delta y/\Delta t = \pm 0.01$ to 0.02 mm per second), a Δy of about 5 mm and a Δt of some minutes is a good combination. If the soil has a very high permeability (k = 10, $\Delta y/\Delta t$ = about 10 mm per second) an interval of 5 seconds is observed. It will be clear that for soils with a high permeability Δy greatly exceeds 1 cm and only one or two reliable readings can be taken. Two men are needed for an interval of 5 seconds, whereas 10 second intervals can easily be read and recorded by one man.

Due consideration should be given to the fact that it is not permissible to continue the measurements for too long since the funnel-shaped draw down of the water table which develops about the top of the hole as the hole fills would become too large. This would result in a decrease of the actual H-value and consequently in a decrease of the rate of rise and if the k-factor were computed from the original H-value this would give too low a value for k.

Care should be taken to ensure that not more than about 25 percent of the volume of water removed from the hole has flowed back at the end of the measurements. In other words the measurements should be completed before $y_n < \frac{3}{4} y_o$ or , which is easier to calculate, before $\Delta y > \frac{1}{4} y_o$. For instance: if 40 cm of water have been removed (y_o = 40) we may measure over a range of ¼ y_o = 10 cm or up to y_t = 30 cm, assuming that the time interval between the removal of the water and the beginning of the actual measurements is very short and only a matter of a few seconds.

If the drainable pore space is more than 10 percent and the diameter of the hole is rather small (r = 4 cm) it is possible to obtain reliable measurements over a larger range, for instance upto 1/3 yo.

2.2 times more water is needed to fill a hole with a 6 cm radius than one with a 4 cm radius, so that - if the holes used have a large diameter (r = 6) the range for reliable measurements is often smaller than ¼ .

The order of magnitude of the rate of rise in a hole with a radius of 4 cm will usually be 1-2 mm per second for a moderately permeable soil (k = 1m/day), 0.01-0.02 mm for a very slowly permeable soil (k=0.01) and some centimeters per second for a highly permeable soil (k = 10). It will be clear that in the case of a highly permeable and moderately permeable soil we should start the measurements as soon as possible after bailing where in the case of a slowly permeable soil there is no reason to hurry.

Performa for In Situ Hydraulic Conductivity Measurement	
Location:	Radius of hole= 5 cm
Date:	Z (distance of ground surface below the reference level)=
Well water temperature=	WT (Depth of water table below the measurement unit)=
Depth of hole=	D (Depth of hole below the measurement unit)=
	Bund Height=
	Zo (Depth of water level in the hole at the time of first reading)=

Reading Number	Time (t) in sec (cummulative)	Δt	Height of water (Zn) cm	Δz

After finding all the parameters the value of K can be calculated using following equation (Van Beers, 1976).

For $X \geq H/2$ where $H = D - WT$

$$K = \frac{4000R^2 \quad \Delta Y}{(H+20R)\left(2-\frac{Y}{H}\right)(Y\Delta t)}$$

Where X, H, WT, D, d, R, ΔY, Y in cm, T in second and K in m/day

For $X = 0$

$$K = \frac{3600R^2 \quad \Delta Y}{(H+10R)\left(2-\frac{Y}{H}\right)(Y\Delta t)}$$

For $0 < X < H/2$

$$K = \frac{\dfrac{4000R^2\Delta Y}{(H+20R)\left(2-\frac{Y}{H}\right)(Y\Delta t)} + \dfrac{3600R^2\Delta Y}{(H+10R)\left(2-\frac{Y}{H}\right)(Y\Delta t)}}{2}$$

K-values on actual temperature from above equations are converted to 20°C by the following equation using viscosity at a particular temperature.

$$K20^o = \frac{Kx^o \mu x^o}{\mu 20^o}$$

Different values for viscosity can be taken from literature (Appendix I).

3.2.2 INVERSE AUGER HOLE

In this technique an auger hole is filled with water to a certain level and its subsequent rate of fall is recorded as the water flows from the hole into the surrounding soil (Figure 2). This method gives Ksat value above the water table. Ksat value obtained by this method may be high due to cracks etc. Procedures and formulae for inverse auger hole method are described below.

The Ksat value is computed from the following equation :

$$K = \frac{1.15 * r * \log(ho + \frac{r}{2}) - \log(ht + \frac{r}{2})}{t - to}$$

where

K	=	Hydraulic conductivity of soil, cm/hr
r	=	Radius of hole, cm
ho	=	Initial water level, cm
ht	=	Water level at any time t, cm
t, t0	=	Time, sec

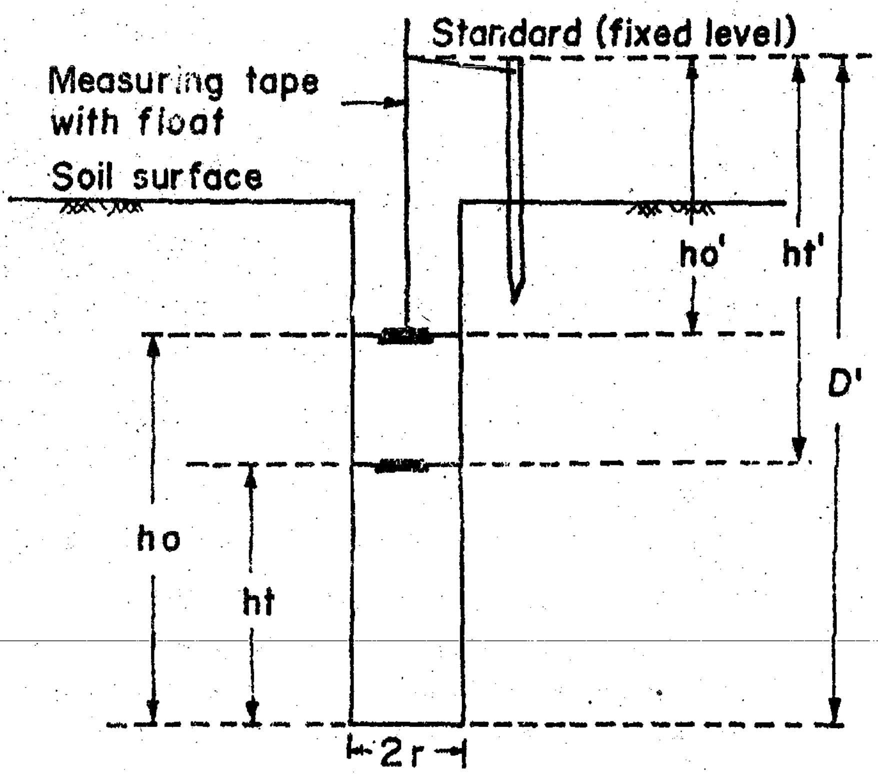

Figure 2: Geometry of Inverse Auger Hole method

3.2.3 PIEZOMETER METHOD

In piezometer method, a smaller volume of soil than that for the auger hole method comes into play and the variations between results from replicate holes tend to be higher. The advantage is that the hydraulic conductivity value of a particular layer in a stratified soil can be measured. A hole of 10 cm diameter or more is augered to the desired depth below the watertable and a tightly fitting rigid tube is pushed into the hole to prevent the seepage of water from the sides; while ensuring the entry of water into the tube from its base only.

3.2.4 DRAIN OUTFLOW METHOD

This method determines the Ksat at a site by simultaneously measuring drain discharge and the change in water table height at mid spacing. The two conditions, steady state and non steady state, can be used for estimating the saturated hydraulic conductivity.

Steady state condition: Hooghoudt (1940) gave a steady state drain spacing formula (known as ellipse equation) for pipe drainage. He judiciously combined the solution for radial flow and horizontal flow to drains to develop an equivalent depth de. H_e adapted the ellipse equation for use to any reasonable depth to an impervious layer.

$$q = \frac{4Kh(2d_e + h)}{L^2}$$

Where,

q	=	Drainage rate in volume per unit area drained per unit time, m/day.
K	=	Hydraulic conductivity of the soil, m/day.
L	=	Spacing between the drain, m.
h	=	Height of water table above the drain axis, m.
d_e	=	Equivalent depth of impervious layer below drains, m.

If the hydraulic conductivity of the layer of the soil below drain depth is different than the hydraulic conductivity of the soil above drain depth, above equation can be written in the following form :

$$q = \frac{8K_b d_e h}{L^2} + \frac{4K_a h^2}{L^2}$$

Where,

K_a	=	Hydraulic conductivity of the soil above the drain
K_b	=	Hydraulic conductivity of the soil below the drain

The term $4k_a h^2/q$ is taken by Luthin (1966) to represent the flow to the drains primarily through the saturated soil above the drains and the term 8Kbdeh/q to represent the flow through the saturated soil below drain depth.

Above equation may be written as :

$$q = A\,h + B\,h^2$$

Or this equation can also be written as :

$$\frac{q}{h} = A + B\,h$$

where

$$A = \frac{8\,K_b\,d_e}{L^2}$$

and

$$B = \frac{4\,K_a}{L^2}$$

Above equations show that q-h relation will approach a straight line when the value of Bh^2 is small, compared to the value of Ah. Such a straight line indicates a better transmissivity below the drain level than above the drain level. When flow above the drain level is not low, the q-h line will be curved and its shape will depend on the relative contribution made by each of the two layers. The stronger the curvature, the larger the contribution made by the layer above the drains. A plot of q/h versus h helps one to interpret the measured q-h relationship. The q/h versus h relation is presented by a straight line making an angle with the horizontal axis, if the value of B ($\tan\alpha = 4K^a/L^2$) is relatively small, the q/h line will be horizontal.

Non-steady state conditions : Steady state drainage condition may not apply in all cases. The limitation applies to a climate in which the rainfall is generally non-steady in nature. Also the steady state is such that the water table depth and drain outflow respond directly and quickly to recharge. In all these cases the non steady state drainage formulae give more accurate results. When these conditions prevail, the falling water table equation such as Glover-Dumm may be used to calculate the hydraulic conductivity (Smedema and Rycroft, 1983).

According to Glover-Dumm the mid spacing water table head ht at $t=t_t$ related to the head h_0 at t=0 as:

$$\frac{ht}{h0} = 1.16\, e^{-\alpha t}$$

Where

$$\alpha = \frac{\pi^2\,K\,d_e}{\mu\,L^2}$$

t = The time period during which the water table falls from h_0 to h_t (days)

h_0 = Initial water table head at mid spacing at $t=t_0$ (m)

h_t = Water table head at t=t (m)

$\propto$ = Reaction factor (day^{-1})

μ = Drainable pore space (m^3, m^{-3})

L = Drain spacing (m)

d_e = Equivalent depth to the impermeable stratum (m)

K = Hydraulic conductivity (m/day)

The reaction factor is a direct index of the intensity with which the drain discharge rate responds to changes in the recharge.

Similarly this equation may be written for discharge as:

$$q = \frac{8 K d_e h_0}{L^2} e^{-\alpha t}$$

So, during the recession, the hydraulic head and discharge may be written as

$$h_t = 1.16 h_0 e^{-\alpha t}$$

and

$$q_t = 1.16 q_0 e^{-\alpha t}$$

Where

q_0 = The discharge rate at t = 0

q_t = The discharge rate at t = t

According to the above equation the reaction factor may be estimated as under.

$$\alpha = 2.3 \frac{(\log h_0 - \log h_t)}{t}$$

$$\alpha = 2.3 \frac{(\log q_0 - \log q_t)}{t}$$

For design of large scale subsurface drainage system the hydraulic conductivity and drainable porosity may be computed using drain flow water table data. In computation of drainable porosity, the contribution of evapotranspiration in lowering of water table may also be considered. These values are the representative design parameters compared with the point measurement and give cost effective design.

3.3 SUMMARY

In planning and developing of drainage projects, sound drainage investments must be considered and drainage measures balanced with proper irrigation and agro-economic benefits. Drainage systems are often necessary component of sustained agricultural development and long-term management of irrigation projects. There are numerous types of land drainage problems and an early diagnosis of the nature, cause and extent of these is essential to establish a comprehensive program of investigations.

In drainage investigation, project objectives, remedial measures to be considered and time schedule for study and implementation also have to be taken into account.

3.4 SELF ASSESSMENT TEST

- How many hydraulic conductivity tests should be conducted and on what factors it depends?
- Describe auger hole method for measurement of saturated hydraulic conductivity.
- Explain inverse auger hole method for measuring hydraulic conductivity.

3.5 KEY WORDS

- **Saturated hydraulic conductivity:** Measurement of hydraulic conductivity in saturated soil conditions.
- **Auger hole method:** In this technique water is removed from an auger hole ana the rate of rise of water level in the auger hole is measured.
- **Inverse auger hole method:** In this technique an auger hole is filled with water to a certain level and its subsequent rate of fall is recorded as the water flows from the hole into the surrounding soil.

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Appendix I

Viscosity of Water at different Temperature

TEMPERATURE (0_c)	Viscosity ($ml^{-1}t^{-1}$)
1	1.7374
5	1.5190
10	1.3080
11	1.2746
12	1.2412
13	1.2078
14	1.1744
15	1.1410
16	1.1138
17	1.0866
18	1.0594
19	1.0322
20	1.0050
21	0.9828
22	0.9606
23	0.9384
24	0.9162
25	0.8940
26	0.8754
27	0.8568
28	0.8382
29	0.8196
30	0.8010
31	0.7854
32	0.7698
33	0.7542
34	0.7386
35	0.7230
36	0.7096

TEMPERATURE (0_C)	Viscosity ($ml^{-1}t^{-1}$)
37	0.6962
38	0.6828
39	0.6694
40	0.6560
41	0.6446
42	0.6332
43	0.6218
44	0.6104
45	0.5990
46	0.5890
47	0.5790
48	0.5690
49	0.5590
50	0.5490

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UNIT-4

KNOWING THE IRRIGATION SYSTEM & PREPARATION OF OPERATION PLAN

STRUCTURE

4.0 Objectives

The aim of this unit is to acquaint the students/user to know the different components of an irrigation system, its basic function and basic principles of preparation of an operation plan of irrigation system.

This module describes the broad layout of an irrigation system and the hydraulic and operational characteristics of its main components.

4.1 Classification of Project

Distinguished by the size of its command, an irrigation system is classified as a:

- Minor irrigation project (command area 2,000 ha and below),
- Medium irrigation project (command area 2,000 - 10,000 ha),
- Major irrigation project (command area above 10,000 ha).

4.2 Classification of Scheme type

- Diversion works
- Storage works

4.3 Type of Structure

- ➢ Gravity Dam
  - Concrete
  - Masonry
- ➢ Arch Dam
- ➢ Butress Dam
- ➢ Earthen Dam

- Weir
- Barrage

4.4 Performa of Salient features of Project

4.4.1 Year of commissioning of the scheme

4.4.2 Planned GCA (ha)

CCA (ha)

ICA

Kharif (ha)

Rabi (ha)

4.4.3 Water allocation

Kharif (M.Cu.m) :

Rabi (M.Cu.m) :

Total (M.Cu.m) :

4.4.4 Canals

Canals	Right	Left
Head discharge (cumecs)		
Length (km)		
Lining C.C. (M.Sqm.)		
Masonry (M.Sqm.)		
CCA ('000 ha)		
Distributaries (km)		
Minors/subminors (km)		
Outlets (No.)		

Cross Drainage works

Cross drainage works

Canal over the drainage		Drainage over canal		Discharging drain into canal		Combining canal & drainage
Aqueduct	Syphon aqueduct	Canal syphon	Super passage	Syphon super passage	Inlet	Level crossing

4.4.5 Structures

	Main canal (No.)	Other canals (No.)
Cross regulators		

Offtake regulators

Syphons

Aqueducts

Super passages

Escapes

Drops

Measuring devices

Bridges

4.4.6 Drains

Catch drains and toe drains (km)

Constructed collecting drains (km)

Drops & other structures (No.)

Natural arterial drains (km)

4.4.7 Inspection roads	Main canal (km)	Other canals (km)
On the canal banks Elsewhere		

4.4.8 Flow Measuring structures

Notches

- V Notch
- Rectangular notch

Long base weirs

- Vertical fall
- Trapezoidal fall

Flumes

- Standing wave flume
- Parshall flume
- Cut throat flume

4.4.9 Other

4.5 PREPARATION OF AN OPERATION PLAN BASED ON CROP WATER REQUIREMENT

-A CASE STUDY-

4.5.1 Introduction

Most crops vary in their water requirements over the growing season. This is generally due to changes in lead area and climatic parameters.

It is generally noticed that when a farmer irrigates his field from the tubewell, he achieves the optimum water utilization efficiency but in the command area in most of the cases farmers do not achieve this much efficiency. Perhaps, because they are not applying right amount of water at right time. An appropriate canal schedule help to provide good crops and would encourage the farmers to make judicious use of water.

Water releases into the irrigation system during the season should match the demands of the farmers who follow a cropping pattern most appropriate to them. Preparation of an irrigation system operation plan therefore is most important activity of its management. A skillfully prepared operation plan can

- induce discipline amongst its operators and users
- gain creditability
- ensure social justice, predictability
- supplies right amount of water at right time to crop

Pre-requisites required for arriving at most appropriate operation plans are:

a. Realistic determination of inflow into the reservoir

b. Adequate carrying capacity of conveyance system

c. Correct assessment of operational losses

d. Proper monitoring and effective feedback

e. All individual functionaries to clearly understand and perform their duties in an appropriate manner.

f. The rapport and continuous interaction between the system manager and farmers is maintained.

During the period of peak water requirement, canals should be run continuously which would thus determine the maximum irrigable area. During the times of lesser demand, prior to or after the peak period, supply could be delivered intermittently on an ON/OFF basis in such a way that crop water requirements would be followed as closely as possible and within practicable limits of operation.

4.5.2 Input data

To prepare a schedule for the canal operation according to crop water requirements, the systematic approach of water budgeting is needed and for which the following data are needed .

a. Cropping pattern in the Command Area.

b. Crop water requirements of each crop.

c. Effective rain - fall

d. Irrigation efficiencies.

4.5.3 Analysis of Input Data

The module for water delivery of a sample minor for Rabi season has been prepared to match the water supplies as per crop water requirements are as follows :

WATER REQUIREMENT & CANAL OPERATION PLAN OF A SAMPLE MINOR

Assume Irrigated Area Hectares = 251.42 ha.

Table 1 : Year wise Irrigation for last 9 years 1992-93 to 2000-2001

S.No.	Year	Kharif area Ha.	Rabi area Ha.	Total Area ha.	%
1.	1992-93	58.70	148.99	207.69	82.61
2.	1993-94	59.71	149.80	209.31	83.25
3.	1994-95	68.83	142.51	211.34	84.06
4.	1995-96	64.37	147.37	211.74	84.22
5.	1996-97	52.00	156.00	208.00	82.73
6.	1997-98	52.00	154.80	206.84	82.27
7.	1998-99	40.40	144.00	184.40	73.34
8.	1999-2000	27.34	170.62	197.96	78.74
9.	2000-2001	27.46	186.60	214.06	85.14

Table .2 : Year Wise Actual Irrigation Done From 1992-93 To 2000-2001 (Area in hectares)

S. No.	Year	Kharif crops			Rabi crops								Grand Total
		Rice	Sugar-cane	Total	Wheat	Gram	Barley	Mustard	Lentil	Pea (Veg)	Fodder	Total	
1.	1992-93	-	58.70	58.70	129.97	0.81	0.40		0.81	14.98	2.02	148.99	207.70
2.	1993-94	8.50	51.01	59.51	134.01	0.40		2.02	2.83	5.67	4.87	149.80	209.30
3	1994-95	-	68.83	68.83	122.27	1.22		8.10	0.81	6.07	4.04	142.51	211.34
4.	1995-96	1.62	62.75	64.37	115.38	2.43	0.40	0.40	0.81	24.70	3.25	147.37	211.74
5.	1996-97	-	52.00	52.00	120.00	0.40	0.40	2.00	1.60	14.80	16.8	156.00	208.00
6.	1997-98	-	52.00	52.00	118.28	3.10	2.56	3.80	2.92	11.60	12.58	154.84	206.84
7.	1998-99	-	40.40	40.40	92.40	0.40	1.60	4.00	1.60	33.20	10.80	144.00	184.40
8.	1999-2k	-	27.34	27.34	113.08	3.00	0.50	-	-	42.59	11.45	170.62	197.96
9	2000-01	-	27.46	27.46	116.21	0.36	-	0.10	1.18	57.44	11.31	186.60	214.06
Average		2.02	58.66	60.68	124.33	1.05	0.24	2.50	1.37	13.24	6.20	148.93	209.61

Table .3 : Existing & Proposed cropping pattern

S. No.	Crops	Existing Cropping pattern	Proposed cropping pattern In ha.
1.	Rice	2.02 ha.	-
2.	S.cane	58.66 ha.	60.00 ha.
3.	Wheat	124.33 ha.	148.00 ha.
4.	Gram	1.05 ha.	2.00 ha
5.	Barley	0.24 ha.	0.42 ha.
6.	Mustard	2.50 ha.	5. 00
7	Lintil	1.37	2.00
8	Pea(Veg.)	13.24	20.00
9	Fodder	6.20	15.00
10	Total	209.61	251.42

Crops	Area(ha.)	%
K.Crops.	60.68	24.13
R.crops	148.93	59.24
Total	209.61	83.37

Table 4 : Proposed Delta (mm) for different crops

Delta fixed = 17" = 425 mm, including field losses

(Delta in mm)

S. No.	Crops	Ist Watering palewa	IInd Watering	IIIrd Watering	IVth Watering	Total watering
1.	S.Cane	100	100	100	100	400
2.	Wheat	125	100	100	100	425
3.	Gram	125	100	100	-	325
4.	Barley	125	100	100	-	325
5.	Mustard	125	100	100	-	325
6.	Lentil	125	100	100	-	325
7.	Pea (Veg.)	100	100	100	-	300
8.	Fodder	100	100	100	100	400

Table 5 : Total Water requirement

(i) Area - 251.42 Ha.

(ii) Irrigation Intensity = 100%

S. No.	Crops	Proposed area ha.	Irrigation intensity in %	Delta in mm	Total water requirement in Ha. M	Total water requirement at filled in Cum.
1.	S.cane	60.00	23.86	400	24.00	240000
2.	Wheat	147.00	58.47	425	62.48	624800
3.	Gram	2.00	0.80	325	0.65	6500
4.	Barley	0.42	0.17	325	0.14	1400
5.	Mustard	5.00	1.99	325	1.63	16300
6.	Lentil	2.00	0.80	325	0.65	6500
7.	Pea (Veg.)	20.00	7.95	300	6.00	60000
8.	Fodder.	15.00	5.96	400	6.00	60000
	Total:	251.42	100		101.55	1015500

Table 6 : MONTHWISE WATER REQUQIREMENT

S. No.	Crops	Area ha.	Oct.		Nov.		Dec.		Jan.		Feb.		March		Total
			In mm	In 1000 cum	In mm	In 1000 cum	In mm	In 1000 cum	In mm	In 1000 cum	In mm	In 1000 cum	In mm	In 1000 cum	
1.	Sugarcane	60.00	-	-	100	60.00	100	60.00	100	60.00	100	60.00	-	-	240.00
2.	Wheat	147.00	125	125.00	125	58.80	100	100.00	100	147.00	100	147.00	100	47.00	624.80
3.	Gram	2.00	125	2.50	-	-	100	2.00	-	-	100	2.00	-	-	6.50
4.	Barley	0.42	125	0.50	-	-	100	0.45	-	-	100	0.45	-	-	1.40
5.	Mustard	5.00	125	6.30	-	-	100	5.00	-	-	100	5.00	-	-	16.30
6.	Lentil	2.00	125	2.50	-	-	100	2.00	-	-	100	2.00	-	-	6.50
7.	Pea(Veg.)	20.00	-	-	100	20.00	100	20.00	100	20.00	-	-	-	-	60.00
8.	Fodder	15.00	-	-	100	15.00	100	15.00	100	15.00	100	15.00	-	-	60.00
	Total:	251.42	-	136.80	-	153.80	-	204.45	-	242.00	-	231.45	-	47.00	1015.50

Wheat : Timely Sown = 100 ha.

Late sown = 47 ha.

Table 7 : Month wise Water Requirement in Cum

S. No.	Month	At field including 30% losses	At cultivators outlet with 25% losses	At Minor head with 20% losses	Overall efficiency
1.	Oct.	136800	182400	228000	42%
2.	Nov.	153800	205067	256333	1. Field app.eff = 70%
3.	Dec.	204450	272600	340750	2. Outlet to field =75%
4.	Jan.	242000	322667	403333	3. Minor head = 80%
5.	Feb.	231450	308600	385750	To cultivators
6.	March	47000	62667	78333	outlet
Total:		1015500	1354001	1692499	

Table 8 : Canal Schedule of Minor

Month	Fort night	Total water req. at minor head C.U.M.	Maximum minor discharge cusec/ cumec.	Water delivery at F.S.L. days.	Recommended operation plan at F.S.L. date/month
Oct.	I	-	9.46 cusec 0.268	-	OFF
	II	228000	cum	9.8	ON
Nov	I	158333	23155 cum/day	6.8	ON
	II	98000	,,	4.2	OFF
Dec.	I	334083	,,	14.4	ON
	II	6667	,,	0.3	OFF
Jan.	I	236667	,,	10.2	ON
	II	166666	,,	7.2	OFF
Feb.	I	219083	,,	9.5	ON
	II	166667	,,	7.2	ON
March	I	78333	,,	3.4	OFF
	II	-	-	-	OFF

4.5.4 CANAL SCHEDULE

Based on the above data the canal schedule has been fixed as under:

S.No.	Date	Month	Days
1.	26 Oct. -	15 Nov.	21 days
2.	30 Nov. -	13 Dec.	14 days
3.	4 Jan. -	17 Jan.	14 days
4.	8 Feb. -	1 March	21 days
-			70 days

4.6 Self Assessment Test

1. Describe the type of structure?
2. What is medium Irrigation Project?

◆ ◆ ◆

UNIT-5

Identification of Maintenance Needs of Canal and Preparation of Maintenance Plan

STRUCTURE

5.0 Objectives

Objective of this unit is to identify the maintenance need of canal and preparation of its plan.

5.1 Maintenance of Canal

The main activities in maintenance of Canal is as under :-

5.1.1 Jungle Clearance:

During rainy seasons or due to presence of moisture in embankment of canal, several herbs & shrubs outgrow on the bed & side slopes of canal. This vegetation interferes & blocks the passage of water causing loss of head, velocity & thus cause reduction in capacity of canal. This herbs & shrubs are popularly known as jungle by field engineers. This is recurring maintenance problem of any canal. This jungle need to be cleared every year either before operating the canal system.

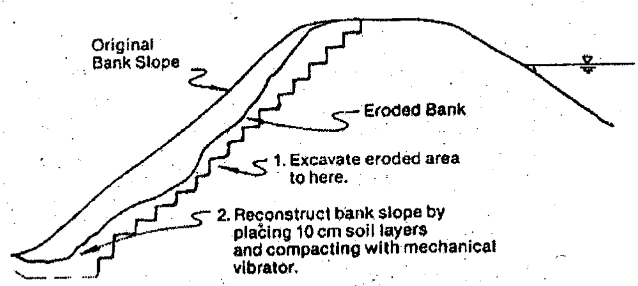
5.1.2 Aquatic and Vegetative growth:

Aquatic weeds either root in water or in earth, but their habitat is in water. Due to favorable soil moisture conditions, the weeds proliferate rapidly. They also choke the cross - section of the canal and reduce the carrying capacity of channel. The growth can be effectively controlled if weeds at tenderage are up rooted without allowing then flourish.

The common practice for removal of aquatic weed and vegetation from the irrigation channel is by manual. Pulling of weeds manually from the channel bed proved more effective then cutting by hand blade because the re-growth rate will reduce by uprooting for which special tools are not required. The vegetation in lined channel can be checked by removing the sediments in the irrigation channel and by applying measures to prevent the sediment entry into the channel. The vegetation in the expansion joints or in the broken joints can be remove manually and it can be checked by treating asphalt sealing of expansion joints and by proper repair of broken joints.

Eliminating of aquatic growth is an extremely difficult task. One alternate is to use chemicals to destroy them and another technique which is presently use is to remove the remove the aquatic growth by manual or by mechanical tools. Usually a boat with cutter, i.e. a floating platform with power driven cutter is based for this purpose. Another mechanical approach is to drag a very heavy chain along the channel using two large tractors or bulldozers, one on each side of channel. The uprooted aquatic weed can be disposed off at the either side of channel. However, the most approach is to periodically close an irrigation channel in order to minimize aquatic growth, up root vegetation by hand and then gather and burn it.

5.1.3 Erosion and sedimentation.



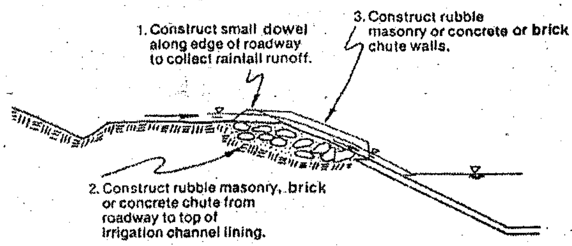
Re-entry of excavated earth is the general problem observed in canal. It can be checked with proper dowel, by providing proper surface drainage system in cutting reaches and by disposal of excavated earth on the outer face of canal embankment. The improper side slope and absence of berms in high cut and high filled reaches will concentrate the surface run-off during rains and leads to erosion or heavy rains cut. The eroded banks needs to be reconstructed, usually by excavating the small amount of the exposed eroded soil, and then replacing it with compacted good soil in the layer of 15 cm. and finally soding the exposed soil surface.

5.1.4 Surface drainage

The primary purpose of providing the surface drainage is as under and it should be repair immediately as per site condition.

1. To check the sedimentation by the soil carried by surface run-off.
2. To check the erosion.
3. To check the cavity enlargement behind the lined panel.

The road way and berm need to be graded so that surface runoff flows away from the channel and thus check the sedimentation of canal and also protect the road. On road bends, where super-elevation has to be provided to facilitate the traffic, there are two possible solutions for left turning bends which result the surface run off flowing in channel.



1. Place curb as required and convey the water from the curb to the irrigation channel in the concrete lined / masonry chute.
2. Do'nt provide the super elevation and grade the road way so that surface run - off will flow away the channel, then place a sign warming to reduce the speed of their vehicle.

In case of high embankment, the bank erosion can be checked by providing the proper surface drainage system. Erosion due to animal crossing can be checked by constructing a ramp with the slope 3:1 or by providing the culvert / bridge. Similarly bath Ghat should also be constructed near the village to facilitate the villagers for bathing and washing of clothes so that erosion can be checked on account of this activity.

5.1.5 Dowel

The dowel is constructed along the inner edge of the service road. The main purpose for providing dowel is to prevent the entry of surface run-off towards inner side of irrigation channel. The dowel is usually constructed with earth but pucca dowel i.e. dowel of masonry or concrete can be constructed. The dowel should be inspected periodically and if any leaks, cuts, or depression in top surface of dowel is observed, then it should be repaired immediately.

5.1.6 Service Road Embankments

In general, the roads are in good conditions, however, there area a few locations that definitely need attention. The major problem with roads is that they are not always graded so that surface runoff flows away from the irrigation channel. Also, inadequate maintenance results in roadway depressions and pot holes, wherein vehicular traffic further deteriorates the roadway surface. The safety of an embankment is also endangered when soil is excavated at the toe of the outside bank. This will sometimes be done in order to repair erosion on the bank. However, this should never be allowed because it creates a tremendous hazard to the embankment as sit will expose the Hydraulic Gradient Line which in turn can cause a breach. Instead, soil should be borrowed from an area adjacent to the canal boundary.

The second major problem with roads is bank erosion on the bank opposite to the irrigation channel (outside bank). This erosion can be the result of:

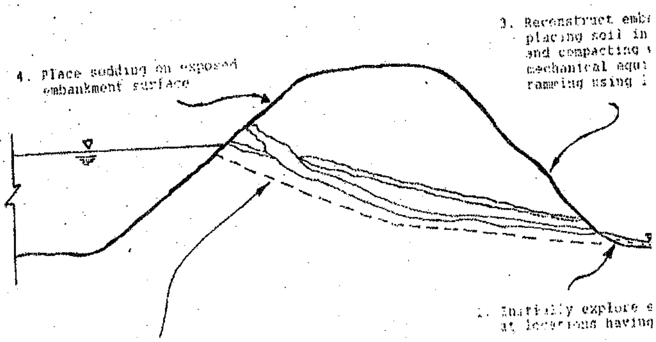
1. The cross-slope grading of the roadway being too steep so that surface runoff has a relatively high velocity;
2. The bank slope being too steep; or,
3. The bank height being too high.

Another important problem with roads is that they are often constructed too high above the top of the irrigation channels. This situation results in more surface runoff moving at a higher velocity into the irrigation channel, thereby resulting in more sediment entering the irrigation channel. Also, this condition will result in higher soil-water pressure behind the lining panels in a lined channel, which will cause more cracked, broken and failed bricks or panels.

5.1.7 Earthen Canal Embankment

5.1.7.1 Failure of canal sluice

- If failure of bund sluice is take place then a ring embankment should be constructed on upstream of sluice to close the sluice.



- If there is deep scour holes below the sluice then this should be filled with brick bats, stones, sand bags etc.
- If wing walls, abutments, pitching etc are not high enough and sluice is overtopped then raising should be done at once.
- If earth settle in sides of wing wall or at pitching then it should be refilled up to required level.

5.1.7.2 Inadequate free board

The inadequate free board due to unexpected inflow or due to other reasons, may effect in two ways-

- By overtopping and washing out the embankment
- By wave wash gradually weaving away the top and exposing it to overtopping

It should be ensured to maintain the proper free board before of canals. However, in case of emergency the raising of dowel should be done immediately to avoid overtopping. The free board should be provided as per recommendations of Bureau of Indian Standard depending upon the discharge of canal. However in actual practice it has been observed that some time free board has to be kept as per the working FSL which is sometimes higher than the designed FSL during peak water demand.

5.1.7.3 Failure due to sliding

This problem is generally occurred in high fill reaches where required section is not maintained. The inadequate cover over the saturation level with consequent heavy percolation may cause the embankment to fail by sliding or sloughing of material on the down-stream side slope. Inadequate cover over saturation line may be due to the inadequate embankment section, or flatter saturation gradient line then considered in design. Such type of failure occurs with the prior indication or warning. The first indication of likely slides are soft wet spotted on the down-stream slope followed by excessive seepage. The longitudinal cracks from upper part of wetted slope is developed and settlement of earth take place. Further, slide will increase till the large portion of earth slope disappears.

The most satisfactory method known is to add compacted earth on down stream slope by providing the required cover over the saturation line. The necessary cover can be provided by flattening the rear slope or by constructing the berm on down stream face of embankment.

5.1.7.4 Unequal settlement

If settlement canal embankments take place then it should be carefully opened up in the small reaches and it should be refilled with suitable or fine earth thoroughly rammed and thoroughly soaked with the water. The embankment should be made up to a original section with the care to properly bond the old and new earth.

5.1.7.5 Failure due to leakage

The leaks are caused by

1. Treacherous character of the soil used in embankment of embankment
2. Cracks in the embankment, or in ground and cracks due to lack of compaction
3. Faulty construction of embankment like use of clods and lack of consolidation
4. The presence of rat, rodent or snake holes in the section
5. The seepage from embankment is not fully and properly treated in time
6. The leakage should be located immediately on its occurrence and then it should be treated or closed by stamping down upon it and filling it with earth at the inlet so that leak will be temporary closed. As soon as it is done, the ring embankment should be constructed around the inlet. Now the embankment should be opened up to the cavity level and refilled with the puddled earth or with the consolidated earth.

5.1.7.6 Underground leaks or blow out

The water may leak through the sand stratum in the foundation of embankment and break through the ground surface at down-stream of embankment in the form of bubbling spring. The blow out carry the sand which is mainly deposited around the edge of hole. If the water flowing from under ground leak is clean, then there is no danger of embankment failing immediately. But when water is muddy, it indicates that the embankment is being undermined and thus there is a danger to collapse of embankment. The underground leaks are caused by the fact that the soil particles can not offer the necessary resistance to the pressure due to the head of water in the embankment. A earthen embankment of earth filled bags should be constructed around the hole and allow the water to pond up. The subsequent treatment is similar as describe above for treatment of leakage.

5.1.8 Lined Channel

The physical environment of an irrigation channel embankment plays a tremendous role in expected maintenance problems. The most ideal situation is the balanced cut-fill embankment. For earthen channels, the fill embankment will likely present the most serious maintenance problems. For lined channels, a cut embankment presents a serious threat to the lining, where frequently failure of the lining occurs, because of hydraulic pressures behind the lining walls and seepage flow into the channel through the lining joints; whereas, a fill embankment is an ideal physical situation for a lined channel. For earthen channels, cut embankments also present maintenance problems due to erosion from rainfall (and sloughing of cut natural ground due to hydraulic pressures resulting from saturation). Local people may remove some tile/blocks from the small channel lined with tile/concrete blocks.

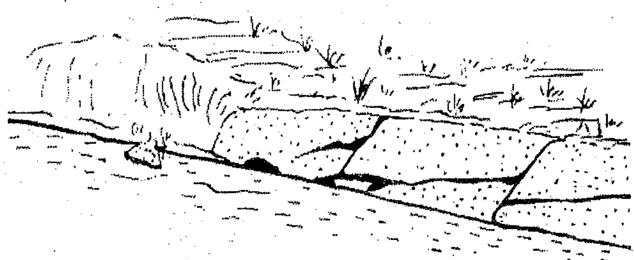
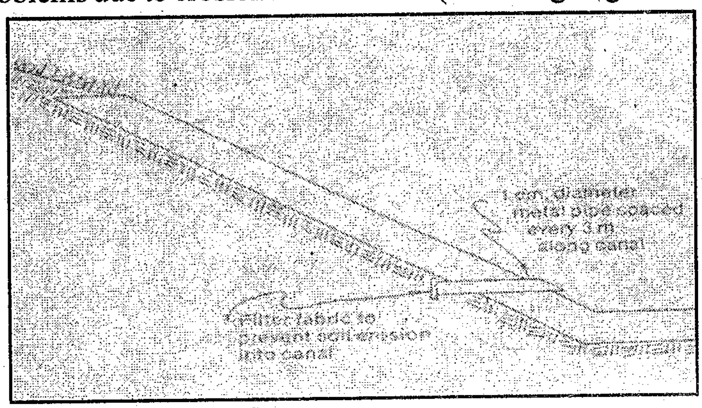


Fig: Cracks in Lining



The routine maintenance of lined canal is replacement of tiles or concrete blocks and repair of joints. Canals are lined to improve the coefficient of roughness for increasing the velocity of flow and to have less absorption and seepage losses. Material used for lining is concrete or bricks or tile section. Velocity of flow is such that it does not allow sediment deposition except near cross-regulators. The lining material is strong enough to take care of erosion of the side and bed. It, therefore, require little maintenance, provided it has been properly constructed.

However, if the lining is not properly designed and constructed, then it creates the maintenance problems. Back water or surface water pressure behind the lining can cause cracks and bulging and eruption of lining some times, the damage to lining is so extensive that the repairs can not be done as routine maintenance. It can be properly repaired by providing sub-surface drainage and pressure release valves during long closures periods, but the cost involve is also quite high. The dry rubble masonry that is porous, or any other porous material can be used to release the pressure behind the lined panel.

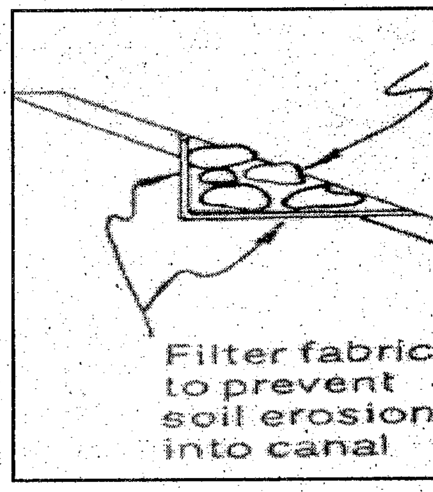
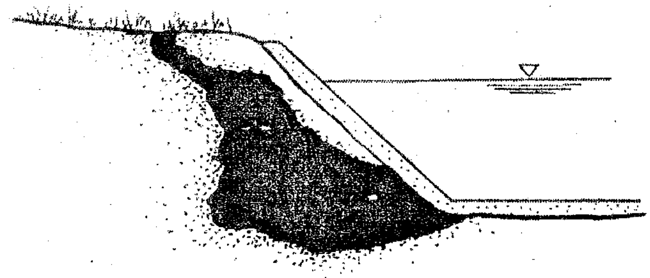


Fig-Porous R.R. masonry to release pressure behind lining

The serious problem in the lined irrigation channel is the formation of cavities behind the wall panel, which leads to failure of lining. The process of cavity formation begin with seepage through the joints into the irrigation channel. The seepage also carries some sediment into the channel, which results in a small cavity near the joint. Since the easiest path of the seepage water is vertically along the joint, it does not take too long the cavity to progress upwards until there is an actual opening at the top of the lining wall panel. Then, as surface runoff during the monsoon rains starts running down the embankment into the open cavity, it enlarges even more.

During this process of cavity enlargement, the concrete panel begins to deteriorate. First of all, very small amounts of brick or concrete on the sides of the joint opening begin to break off, most commonly just above the floor level, but sometimes much higher, leaving a small hole in the lining. This small hole further aggravates the problem by allowing the cavity underneath to further enlarge, so that larger chunks of brick mortar, brick or concrete eventually break off. Hairline cracks will likely occur, first near the joint, but perhaps later across an extensive length of mortar between bricks or the full width or height of a concrete panel. At this point, water in the irrigation channel is also eroding the underlying soil. The filling and emptying of the irrigation channel, which occurs frequently, further aggravates this process of soil erosion. The eventual outcome of this physical phenomenon is the failure of the lining panel. This process is accelerated if surface runoff from the roadway or berm is allowed to flow towards the irrigation channel. If the cavity has formed an opening to the top of the lining, then some of the surface runoff will flow into the cavity, thereby increasing the seepage flow and sediment transport through the joint. Thus, the cavity becomes enlarged even more rapidly. If the soil surface is depressed below the top of a panel, then the surface runoff will pond behind the panel and is likely to move along the interface between the soil and concrete, eventually reaching a joint as an outlet.

Lined irrigation channels located in **cut areas are highly susceptible to cavity formation and eventual failure** of the lining panels.



The cut banks are easily eroded and eventually surface runoff containing high sediment concentrations are being transported into the irrigation channel. Also, the soil is saturated to a height higher than the top of the panels; this results in seepage flow over the panels in some cases, as well as definitely increasing the seepage rate and sediment transport through the joints. In addition, seepage continues to occur for many more days after a rainfall event or canal closure because of the large volume of stored soil - water.

If cavity is large, then it is recommended to remove the panel concrete and place the suitable soil in the cavity portion and compact it manually. The earth-work should be done to maintain the original profile of earth-work and then repair the panel with the suitable concrete mix. If cavity is small then it can be treated with the soil cement grout or fill the soil cement mixture manually.

Expansive Soils: The problem of lining failure is more vulnerable in expansive soils because it exerts pressure on lining due to change volume of expansive soils due to shrinkage & swelling characteristics. In the past various measures have been adopted to protect the lining, different types of linings were introduced. However experience reveals that for long term sustainability, the part soil beneath lined surface should be removed & replaced by non swelling soil popularly known as CNS treatment with proper drainage arrangements.

5.1.9 PUCCA WORKS:

5.19.1 Bridges / culverts and invert syphon

The pucca works are made of concrete or masonry and quality of works are generally good, therefore, these structures are required only minor maintenance as under:-

(i) Maintenance of parapet wall

(ii) Maintenance of pointing plaster

(iii) Removal of debris at the inlet

(iv) Incase of syphon, pipe line is used between the inlet and outlet, then the major problem is leakage at one or two joints due to settlement of subgrade below the pipe or due to faculty construction. The visual evidence of such leakage is the formation of cavity in the soil above pipe line. In this case, the overlying soil should be excavated, the pipe line should be inspected and repaired and again soil cover with the proper compaction should be placed.

(v) The syphon required to be inspected for cavities along the walls and transition zone. If cavities exist or erosion is occurring, then appropriate repair should be done. Further pitching on the embankment towards nallah / river should also be inspected and repair should be done if required.

5.19.2 Fall structures

If scour is occurring below a fall structure then a concrete, rubble masonry or rip rap lined stilling basin should be constructed to dissipate the hydraulic energy. Adequate free board, pointing / plaster of masonry, should be checked and if required it should be repaired.

5.19.3 Bridges and Aqueduct

The under mining of embankment of canal bank or foundation of pucca work can be possible by running water in the river and it can be checked by any river - training method, such as construction of spurs and revetments. Further the method is depend on the type of erosion and damages occurred. Sometimes heavy stones or sand fill bag are dumped to check the erosion temporary.

Further maintenance problem in the aqueduct is the seepage through the body of trough or leakage from the expansion joints of trough. Some times, vegetation or tree grows in the expansion joints, which may leads to heavy seepage. Thus trough of the aqueduct should be repaired as per the site requirement and vegetation should be removed from the expansion joints and it should be treated properly by filling it with asphalt.

5.2 Preparation of maintenance plan

5.2.1 Identification of maintenance problems

Thoroughly conduct walk through survey from head of the system to tail & note down the deficiencies as per the table below:

Checklist for maintenance

Name of irrigation channel: Date of inspection:

Inspected Reach: Km ( ) Inspected by:

Category: O/S/E (0: ordinary repairs, S: special, E: emergent)

Signature:

SN	Item inspected	Condition when inspected	Category of repair O/S/E	Specify location	Apprximate qty	Unit
1.	**Earthwork**					
a)	gully erosion					
b)	slips					
c)	bed silt					
d)	seepage					
e)	piping					
f)	Re sectioning					
g)	other					
2.	**Lining**					
a)	panels					
b)	joints					
c)	subgrade					
d)	other					
3.	**Masonry**					
a)	pointing					
b)	plastering					
c)	revetment					
d)	cavities					
e)	Replacement					
f)	other					
4.	**Concrete structures**					
a)	plastering					
b)	cracks					
c)	cavities/erosion					
d)	foundation erosion					
e)	other					
5.	**Mechanical Structures**					
a)	shutters/gates					
b)	gate seals					
c)	piping					

d)	painting gates					
e)	other					
6.	**Drains**					
a)	silt clearance					
b)	repairs to masonry					
c)	revetment					
d)	vegetation					
e)	other					
7.	**Inspection road**					
a)	surface pot holes					
b)	resurfacing					
c)	side drains					
d)	other					
8.	**Miscellaneous**					
a)	shrub clearance					
b)	aquatic plants					
c)	painting marker boards and marker					
d)	oiling/greasing					
e)	other					

5.2.2 Preparation of maintenance plan

Based upon the data collected through walk through survey, a maintenance plan is to be prepared for budget allocation, construction/rehabilitation of the system. The guidelines for preparing maintenenca plan are as below:

Outline content Report to accompany maintenance estimate

1. The project

   Historical background

   Salient features of the scheme

2. Performance (previous year)

   The number of days for which the canals operated;

   Delivery pattern (total number of outlets, number of outlets which did not deliver water; number that delivered less water than authorised).

3. Carryover works

   Comment on maintenance needs attended to the previous year

Carryover works from previous year(s).

4. Inspection summaries

   Maintenance works planned in current year based on the inspection reports

5. Rates and costs

   Analysis of rates Estimated cost of departmental works and works on contract

   Cost summary :

	Amount	Percent
Irrigation		
Drainage		
Tools and plant (T&P)		
Establishment		

Following needs to be enclosed with the maintenance plan

- Abstract of estimate Detailed
- estimate or bill of quantities
- Line diagram of the system and other plans as needed

5.3 Self Assesment Test

1. What is surface drainage?
2. What you will do in case of Failure due to leakage in canal?

◆ ◆ ◆

UNIT-6

HOW TO MEASURE FLOW BY VARIOUS FLOW MEASURING DEVICES

STRUCTURE

6.0 Objective

Objective of this unit is by using various flow measuring devices, how to measure flow.

6.1 Area Velocity Method

In this method discharge is computed as

Q = A X V, where Q is the discharge,

A is the cross sectional flow area & V is the mean velocity of flow

In this method, two stages are required

(i) Measurement of Area

(ii) Measurement of mean velocity

6.1.1 **Measurement of cross sectional area** is done using chain, tape, scale etc. Total cross sectional flow area is determined

Procedure:

(i) Identify a straight reach of not less than 30 M in length with fairly uniform cross-sectional area.

(ii) Select two convenient points on the length of the channel and establish two land marks at the sites selected at A and B points at a distance of 10 M apart.

(iii) Run a rope across a channel at site A and site B and fix it on, either side of the channel bank.

(iv) Divide the length of rope into suitable number of equal parts and tie the ribbons at these points.

(v) Measure the depths from the rope level to the bed of the channel at each of these points and record in the note book.

(vi) Plot the points with reference to the horizontal rope level marking distances from left end, depths measured at these points on graph paper to a scale.

(vii) Join all the bottom points to the land mark points on either banks. This will form the cross section of canal

(viii) Draw horizontal line cutting the two banks either side at (different depths in relation to the central point) say at 0.5 M, 1.0 M, 2.0 M depths.

(ix) Find out the area at 0.5 M, 1.0 M, 2.0 M depths at section A and section B.

(x) Average the areas of channel at section A and section B at 0.5 M, 1.0 M, 2.0 M depths respectively, which represents average cross-sectional areas of the channel at 0.5 M, 1.0 M, 2.0 M depths respectively.

(xi) Prepare a table showing channel cross-sectional areas at 0.5 M, 1.0 M and 2.0 M depths (Depth Vs cross-sectional area, table).

6.1.2 Measurement of mean velocity

The Velocity of flow in an open channel is not uniformly distributed in any X-section. It varies across the depth of flow. The velocity is zero at bottom of canal while at surface it is nearly maximum. The mean velocity is computed be determining the flow velocity at different depths & thereafter plotting the variation. The mean velocity is the total area divided by depth of flow. This is quite cumbersome process & hence practically, mean velocity can be computed as one of the following:

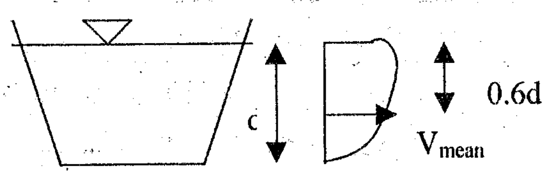


Fig:1 Variation of velocity across depth

1. $V_{mean} = (V\ 0.2d + V\ 0.8d)/2$

2. $V_{mean} = V\ 0.6d$

Where V_{mean} = mean velocity of flow

$V_{0.2d}$ = Velocity at 0.2 depth from top

$V_{0.8d}$ = Velocity at 0.8 depth from top

$V_{0.6d}$ = Velocity at 0.6depth from top

The average velocity (V_{mean}) at any X-section lies at about 0.6 times the depth of flow from top surface.

Discharge (Q) = V_{mean} x A

All that is needed now is to measure Vmean and X-section area (A).

6.1.2.1 Using Surface Float method

Procedure

1. Select a float, example: a piece of wood, flower or leaf and leave it about 1 M upstream ,of the section A (mentioned above).
2. Note the time in seconds, using a watch, wherein the float just crosses the site section A.
3. Note the time in seconds when the float just reaches the site 13.
4. Note the time taken by float to travel from site A to site B. Find out the velocity of float by dividing the distance between sites A and B by the time taken by float in seconds to travel from site A to B. This velocity represents the surface velocity only (meters per second).
5. Repeat the same 3 to 4 times.
6. Average of surface velocities obtained 3 or 4 times represents average surface velocity (SV) in the channel.
7. Multiply average surface velocity thus obtained (SV) by correction factor as per the hydraulic mean depth of canal & manings coefficient or roughly by 0.85 to provide for correction in the average velocity of flow in the channel in m/ s.
8. Obtain the average cross-sectional area (sqm) and multiply with average velocity of flow (m/ s) in the channel. This gives the discharge flowing in cubic meters per second cum/s. Multiply the discharge obtained the cum/s with 1000 to get discharge in liters/ sec
9. To sum up, the calculations with above data for assessing discharge are follows:

Distance between point A and point B = L Meters

Time taken by the float to travel from A to B (Average of 3 or 4 trials) = L / T (seconds).

Surface velocity float = L/T (m/s)

Average velocity = L/T X correction factor or 0.85 (m/ s)

Cross-sectional area of channel at 2 M depths at section A = A1 (sq m)

Cross-sectional area of channel at 2 M depths at section B = B1 (sq m).

Average cross-sectional area at 2 M depth = [A1 +B1/2] (sqm).

Discharge through the channel = [A1 + B1]/2 * 0.85 * (L/T) cum/ second.

Repeat the above procedure and compute the discharges in the channel at 0.85 M and 1.0 M depths respectively. Prepare table for depth, discharge relationship.

6.1.2.2 Using Double float method & velocity rod

Procedure is same as that of surface float

6.1.2.3 Using Current meters

Current meter is a mechanical device that measures directly the velocity of flow of filament of water in which it is suspended.

Procedure :

1. Determine the depth of water flowing.
2. Set the current meter at a depth equals to 0.6d from top to measure mean velocity directly.
3. Lower the current meter in the stream with its tip pointing towards the flow directions.
4. Start the timer along with the counter provided in the control box of current meter.
5. Record number of revolutions in measured amount of time.
6. Repeat the observations 3 to 4 times till consistent results are obtained.
7. As per the number of revolutions & time, note the velocity of flow from the calibration chart supplied with the current meter.
8. Obtain the average cross-sectional area (sqm) and multiply with average velocity of flow (m/ s) in the channel. This gives the discharge flowing in cubic meters per second cum/s. Multiply the discharge obtained the cum/s with 1000 to get discharge in liters/ sec

Some important instruction for observation by current meters are:

(i) For measurements made at one point current meter should be exposed for 120 seconds or 150 revolutions whichever occurs later.

(ii) When measurements are taken at more than one point in a vertical direction, it should be exposed for at least 30 seconds at each point.

(iii) It velocity is subjected to periodic pulsation current meter should be exposed for at least two consequent periods of 50 seconds each.

(iv) Minimum interval of each reading should be one minute.

(vi) Curved reach should be avoided.

(vii) Avoid heavy breeze and turbulent flow.

(viii) If it is essential to take reading during heavy breeze, avoid readings at 0.2d.

(ix) Let the instrument re-calibrated after 6 months or 300 working hours which ever occurs earlier.

6.2 Using Hydraulic Structures

This method differs from other methods to the fact that a standard type hydraulic structure is erected across the flow and used. Certain rules of hydraulic are followed and once standardised, no field calibration or measurements other than regular recording of water levels are needed to obtain a continuous or instantaneous discharge.

Three main categories of such structures are.

(A) Thin plate devices usually made from metal, set vertically and perpendicular to the direction of flow.

(B) Long base weirs made of concrete or masonry or any such material.

(C) Flumes made up of any material e.g. concrete, metal, timber or fibre glass of standard shape and size depending upon their location and performance required.

6.2.1 Thin plate devices (Notches & orifices):

These are standard thin plate weirs and have thin crest profile and are installed where sufficient fall is available. The notch is designated according to the shape of opening eg V votch, rectangular notch etc.

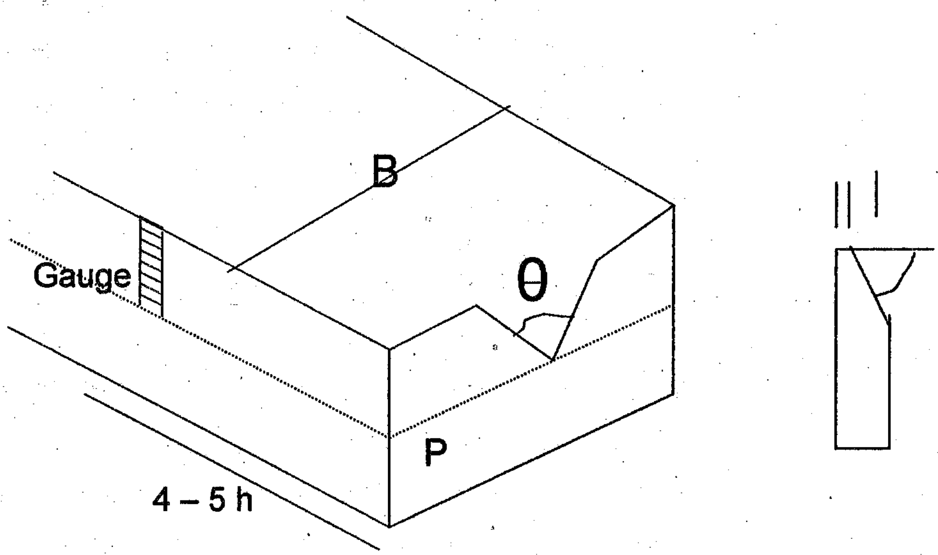
(i) V notch :

Precautions for installation

(i) Should be installed absolutely vertical and perpendicular to direction of flow.

(ii) Vertical bisector of the notch shall be equidistant from both banks.

(iii) Crest of rectangular notch must be perfect horizontal and sides true vertical.



(iv) Crest thickness should not exceed 2mm.

(v) Chamber face must be on d/s side.

(vi) Crest of notch must be at least 10 cm. above d/s water level to have free fall conditions.

The discharge formula is

$Q = C_e (8/15) (\tan\propto/2) (2g)^{1/2} h_e^{5/2}$

Where $C_e = (h/B , b/B, \propto)$

$H_e = h + h_k$. also $h_k = (h/p , p/B)$

For $\propto = 90°$, for irrigation channels

h_k = 0.0085 M is negligible and for $\propto = 90°$, C_e is function of angle a only and can be adopted from the table-1 below.

Table -1 Values of Ce for V/S h (rounded off to 3rd place)

Head (h)	Crest Angle (α)			Head (h)	Crest Angle (α)		
(Cms.)	90°	53°8'	28°4'	(Cms.)	90°	53° 8'	28°4'
6	0.603	0.661	0.642	25	0.585	0.590	0.600
8	0.596	0.606	0.632	30	0.585	0.588	0.598
10	0.592	0.602	0.622	35	0.585	0.588	0.596
15	0.586	0.596	0.610	38	0.585	0.587	0/595
20	0.585	0.591	0.604				

Observation sheet :

SNo	Upstream head over crest (h_e)	Included angle ($\propto$)	Value of C_v	Discharge $Q = C_e (8/15)(\tan\propto/2)(2g)^{1/2} h_e^{5/2}$
	(m)	degree		Cum/secs
1				
2				
3				
4				

Limitations :

(i) Water must be free from sediments to prevent damage to crest.

(ii) Adequate fall must be available.

(iii) Higher discharges may cause energy dissipation problems d/s of fall.

(ii) Rectangular Notch.

General formula for Rectangular notch is

$Q = C_e \times (2/3) \times (2g)^{1/2} \times b_e \times H_e^{3/2}$

Where $b_e = b + K_b$

$h_e = h + K_h$

and $C_e =$ (b/B, h/p)

For channels

$K_h = 0.001$ is negligible.

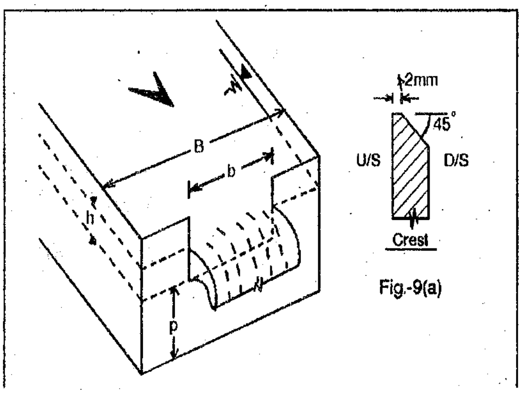


Fig.-9(a)

Therefore $h_e = h.$

and $C_e = a + a' (h/p)$

Values of a, a' and K_b as worked out experimentally and are given in tables 2 & 3 below

Table-2. a and a' values w.r.t b/B ratio.

b/B	1.0	0.4	0.2	0
a	0.602	0.591	0.589	0.587
a'	0.075	0.006	0.002	(-)0.002

Table - 3: K_b Values w.r.t. b/B ratio

b/B	0.0	0.2	0.4	0.8	1.0
K_b	2.4	2.7	3.6	4.2	(-)0.9

Limitations

(i) Crest thickness & d/s chamfer should be strictly according to figure7 (a).

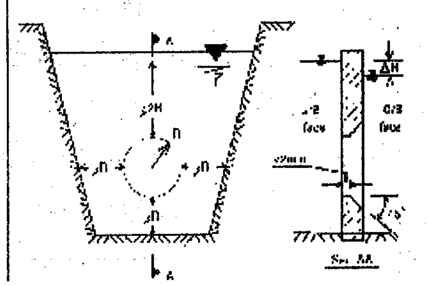
(ii) $b/p < 2.5$; $h > 0.03m$; $b > 0.15m$;

$p > 0.10m$ and $(B-b) > 0.2m.$

Observation sheet :

Items to be observed	Value	Unit
Upstream head over crest (H_e)		M
Width of Canal (B)		m
Width of opening (b)		m
Height of crest over bed level of canal (p)		m
b/B		
Value of a		
Value of a'		
Value of Kb		
Value of Cv		
Effective Width of opening (b_e)		m
Value of g	9.81	m/s^2
Discharge $Q = C_e \times (2/3) \times (2g)^{1/2} \times b_e \times H_e^{3/2}$		Cum/secs

(B) Submerged Orifices



An orifice used as a flow measuring device is a well defined, sharp edged opening in a wall or bulkhead which is placed perpendiculars to the sides and bottom of a straight reach. The orifice may be circular or rectangular and for true orifice flow to occur, the U/S water level must be always well above the top of the opening such that vortex flow with air entrainment is not evident

(i)-Circular Submerged orifices:

The standard formulae in use are:

(i) Without velocity of approach.

$$Q = C_d \times A \times (2g \times \Delta H)^{1/2}$$

Where Q = discharge A = X-Sectional area of orifice g = acceleration due to gravity

C_d = Coeff. of discharge and ΔH = difference in U/S & D/S Water levels.

(i) With velocity of approach.

$$Q = C_d \times A \times \{2g \times (\Delta H + h)\}^{1/2}$$

$h = V_a^2/2g$ is Velocity head

V_a = approach velocity

Average values of discharge coefficients C_d as actually worked out are given in table-4 below.

Table - 4 : Discharge coefficients in circular submerged orifices

Orifice diameter (cm)	2	2.5	3.5	4.5	5.0	6.0	> 6.
C_d	0.57	0.58	0.61	0.61	0.61	0.60	0.60

Limitations of Circular Orifices :

- To ensure full contraction and accurate flow measurements, the limits of applications of submerged circular orifices are:
- The edge of the orifice should be sharp and smooth and in accordance to the profile shown in figure 9(a).
- The distance from the edge of the orifice to the bed and sides of approach channel an tail should be not less than radius 'R' of the orifice as shown in figure 9(b)
- Water level u/s of the orifice plate should be above the crown of orifice by at least 2R is the diameter of the orifice as shown in figure 9(b)
- U/S face of the orifice plate must be vertical and smooth and placed perpendicular to the direction of flow.
- For avoiding effect of velocity of approach, x-sectional area of channel must be at least 10 times the area of orifice.
- The lower limit of differential head ΔH is 3 Cm.

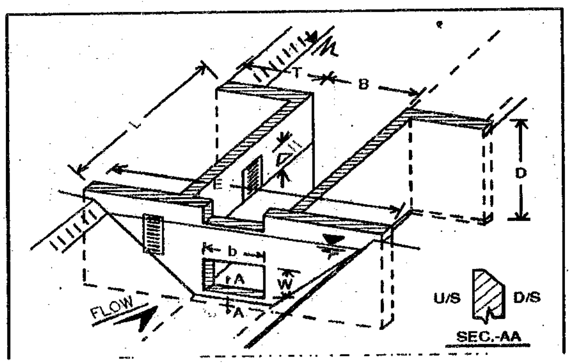
Advantages :

- These are simple, inexpensive and easy to install and are best suited to measure low discharges in furrows and small field channels up to about 2.5 cusecs. In a properly fabricated orifice, accuracy to the order of 99% can be obtained.

Observation sheet :

SNo	Difference of upstream & downstream head (ΔH)	Diameter of orifice	Cross sectional area = $\pi d^2/4$	Value of C_d	Discharge $Q = C_d \times A \times (2g \times \Delta H)^{1/2}$
	(m)	m	sqm		Cum/secs
1.					
2					
3					
4					

(ii) - Rectangular Submerged Orifices



Since the ratio of depth of flow to width in irrigation channel is generally small and change of depth of flow has no influence on discharge coefficient in rectangular orifices, height of rectangular orifices is considerable less than width of the opening. Figure give standard dimensions of rectangular orifice as recommended by U.S.B.R.

The discharge formulae for various conditions of flow are:

(a) Standard Submerged Rectangular Orifice (fully contracted)

(i) Without effect of velocity of approach.:

$$Q = 0.61\ A\ \{2g\ (\Delta H)\}^{1/2}$$

(ii) With effect of velocity of approach.:

$$Q = 0.61\ A\ \{2g(\Delta H + h)\}^{1/2}$$

Where $h = V_a^2 / 2g$

(b) Standard Submerged Suppressed Orifice :

(i) Without effect of velocity of approach.

$$Q = 0.61(1+0.15r)\ A\ \{2g\ \{\Delta H + h)\}^{1/2}$$

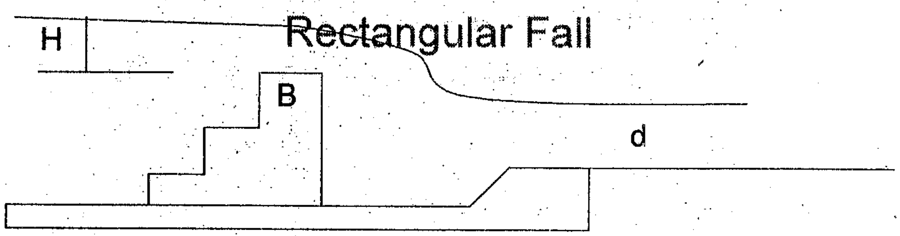
Where 'r' is a ratio of suppressed portion of the perimeter of the orifice to the total perimeter.

(ii) With effect of velocity of approach.

$$Q = 0.61(1+0.15r)\ A\{2g(\Delta H + h)\}\ 1/2$$

6.2.2 Long base weir (Falls)

(i) Rectangular fall



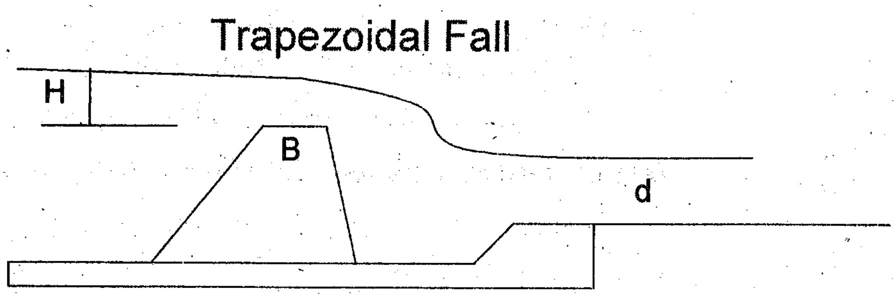
$$Q = 1.84\, L\, H^{3/2} ($$

$$B = 0.5\ \sqrt{d}$$

Observation sheet :

SNo	Head over crest (H)	Length of crest (L)	Width of crest (B)	Discharge $Q = 1.84\, L\, H^{3/2}\, (H/B)^{1/6}$
	m	m	m	Cum/secs

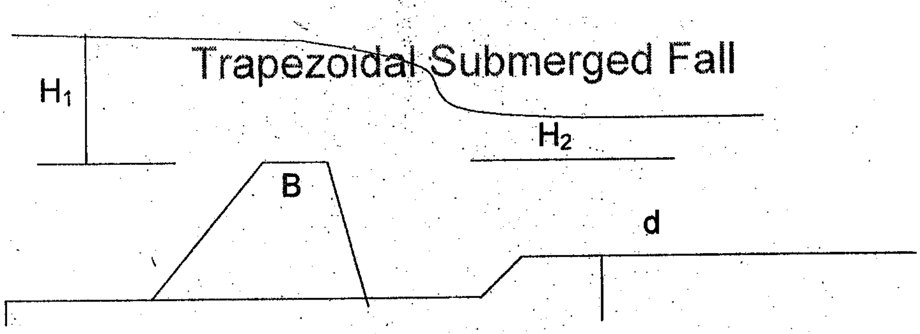
(ii) Trapezoidal fall



Observation sheet :

SNo	Head over crest (H)	Length of crest (L)	Width of crest (B)	Discharge $Q = 1.99\, L\, H^{3/2} (H / B)^{1/6}$
	m	m	m	Cum/secs

(iii) Submerged Trapezoidal fall



Observation sheet :

S No	Upstream Head over crest (H_1)	Length of crest (L)	Width of crest (B)	D/S Head over crest (H_2)	Head loss (H_L) = H_1-H_2	Discharge $Q = (2/3) C_{d1} (2g)^{1/2} L[(H_L+V_a^2/2g)^{3/2} - (V_a^2/2g)]^{3/2} + C_{d2} hL[2g\{H_L+(h/2)+(V_a^2/2g)\}]^{1/2}$
	m	m	m	m	m	Cum/secs

Where

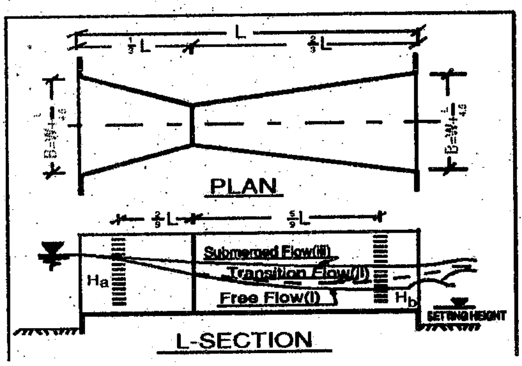
C_{d1} = 0.577 C_{d2} = 0.80 V_a = Velocity of approach.

G = Acceleration due to gravity L = Length of the Crest

6.2.3 Flumes

(i) Cut throat flume

Cut throat flumes consist of only a Converging Inlet Section followed by a Diverging Section on a flat bottom. Being easy to fabricate and install, they give fairly accurate discharge both under Free Flow and Submerged Flow conditions.



Free Flow conditions in a cut throat occurs when the flow is critical near the throat and under this condition, the D/S flow conditions do not influence U/S Depth-discharge relationship which is given by :

$Q = K \times W^{1.025} H_a^n$

Where

Q = Discharge in cumec W = Throat width in metres

K = Free flow Discharge Coefficient.

N = Exponent for free flow and Ha = U/S gauge in Metres.

The flow is termed as submerged when at all points through the flume, depth of flow is greater than critical depth. In this case both U/S and D/S gauges H_a and H_b are measured and discharge is given by formula.

$$Q = K_s \times W^{1.025} \times (H_a - H_b)^n \times [(-) \log S]^{(-ns)}$$

Where

K_s and n_s are discharge coefficient and exponents for submerged flow conditions and n is exponent for free flow,

W = throat width in metres ,

H_a & H_b are U/S and D/S gauges in metres and

$S = H_b/H_a$ the submergence ratio.

Table 5,gives relationship between Cut-throat flume length (L); the transition submergence coefficients (S_t), the ratio for values lower than which the discharge is free and at higher values the flow becomes submerged.) and exponents 'n' for free flow & ' n_s ' for submerged flow.

Table - 5 : Summary of coefficients and transition submergence for Selected Flumes:

L	St	Free Flow Conditions		Submerged Flow Conditions	
(m)	(%)	n	K	ns	Ks
0.5	60.7	2.08	6.15	1.675	3.50
0.6	62.0	1.989	5.17	1.600	2.90
0.7	63.0	1.932	4.63	1.550	2.60
0.8	64.2	1.880	4.18	1.513	2.35
0.9	65.3	1.843	3.89	1.483	2.15
1.0	66.4	1.810	3.60	1.456	2.00
1.2	68.5	1.756	3.22	1.427	1.75
1.4	70.5	1.712	2.93	1.407	1.56
1.6	72.0	1.675	2.72	1.393	1.45
1.8	73.8	1.646	2.53	1.386	1.32
2.0	75.5	1.622	2.40	1.381	1.24
2.2	77.0	1.600	2.30	1.378	1.18
2.4	78.4	1.579	2.20	1.381	1.12
2.6	79.5	1.568	2.15	1.386	1.08
2.7	80.5	1.562	2.13	1.390	1.06

Observation sheet :

S N o	Throat width (W)	H_a= U/S gauge	H_b= D/S gauge	Hb/Ha	Flow condition (weather free flow or submerged flow)	Coefficients from table 5		Discharge
						n/n_s	k/K_s	
	m	m	m		Free Flow			$Q = K \times W^{1.025} H_a^n$
					Submerged flow			$Q = K_s \times W^{1.025} \times (H_a - H_b)^n \times [(-) \log S]^{(-ns)}$

Example: To install a 10 Cm x 90 Cm Cut - throat in a water course to measure maximum discharge of 60 liters per second. Depth of watercourse is 45 Cm. and maximum F.S.D. is 30 Cm.

Solution : (to calculate Setting height for free flow)

From table 5 :

$K = 3.8;\quad n = 1.843 \quad \& \quad S_t = 65.3\%$

From equation - - $Q = KW^{1.025} H_a^n$

We get

$0.06 = 3.89\ (0.1)^{1.025} H_a^n$

or $H_a = 0.374$ Cm.

Therefore,

$H_b = 0.653 \times 0.374 = 0.244 \text{ M} < d_{max} = 30 \text{ Cm.}$

& Setting height $= 0.300 - 0.244 = 0.056$ M. (or 5.6 Cm.)

Install Cut - throat at 5.6 Cm. (or more) above canal bed.

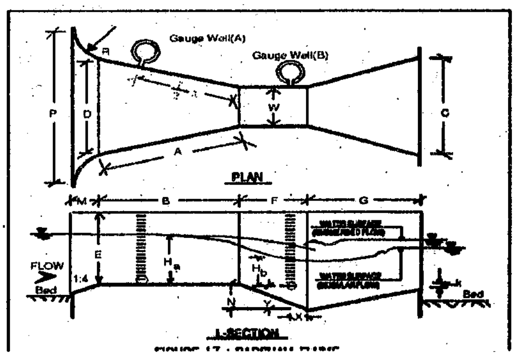
Total U/S depth = H_a + Setting height

$= 0.374 + 0.056 = 0.43 \text{ M} < 0.45 \text{ M}$

(Safe -as Canal banks will not over top)

(ii) Parshall flume

The width 'W' of the throat is used to designate size of the flumes. Parshall flumes can be used to measure discharges ranging from 1 cusec to 3000 cusecs for which Parshall had developed following empirical relationship.



Throat Width	Discharge equation.
3"	$Q = 0.992\ H_a^{1.547}$
6"	$Q = 2.06\ H_a^{1.58}$
9"	$Q = 3.07\ H_a^{1.53}$
1'-8'	$Q = 4W\ \{H_a\}^{1.522}\ W^{0.026}$
10'-50'	$Q = (3.6875W+2.5)\ H_a^{1.6}$

The relationship is true for F.P.S. System only and

Where W represents Throat Width and H_a the Up Stream gauge reading and

Modular flow occurs when:

H_b / H_a > 0.6 for 3",6" and 9" Flumes.

> 0.7 for 1' to 8' Flumes.

> 0.8 for 10' to 50' Flumes.

and that to in case flume is fabricated and installed strictly according to dimensions.

For submergence ratio higher than those specified above the flow no more remains free and discharge gets reduced. Parshall has suggested correction methods explained below. It is however advised that submergence ration not exceeded 0.65.

Table - 6 correction factor for flumes 1' - 50'

Flume Size (ft.)	1	1.5	2	3	4	6	8	10	12	15	20	25	30	40	50
Correction factors	1	1.4	1.8	2.4	3.1	4.3	5.4	1.0	1.2	1.5	2.0	2.5	3.0	4.0	5.0

For submergence ratio higher than those specified above the flow no more remains free and discharge gets reduced. Parshall has suggested correction methods explained below. It is however advised that submergence ration not exceeded 0.65.

Observation sheet :

S N o	Throat width (W)	H_a= U/S gauge	H_b= D/S gauge	Hb/Ha	Flow condition (weather free flow or submerged flow)	Discharge as per the formulae applicable according to throat width of flume
	Inch /Feet	Inch /Feet	Inch /Feet			
					Free Flow	
					Submerged flow (apply correction factor as indicated in table 6 above)	

6.3 Self Assessment Test

1. What is the General formula for rectangular notch?
2. How to measure flow by using parshall flume?

◆◆◆

UNIT-7

TO AWARE ABOUT DIFFERENT METHODS OF WATER APPLICATION & ASSESSMENT OF SUITABLE IRRIGATION METHOD

STRUCTURE

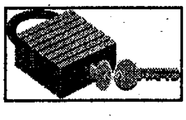
7.0 OBJECTIVES

To choose an irrigation method, the farmer must know the advantages and disadvantages of the various methods. He must know which method suits the local conditions best. Unfortunately, in many because there is no single best solution: all methods have their advantages and disadvantages. Testing of the various methods-under the prevailing local conditions-provides the best basis for a sound choice of irrigation method.

Since the objective is to apply water efficiently to provide favourable environment for the plants, it is therefore, essential to consider the factors, which have significant effect in the process of water application. The important factors effect in the process of water application.

To optimise the crop production it is very necessary to use irrigation water with suitable irrigation method to maximise the crop production per unit area per unit cm of water application depth.

Dear friend, you will certainly realise the importance of selection of the appropriate irrigation methods by reading the following case study.



A comparison of applied depth in border experiments conducted in IWAM plots in Chambal Command Area through RAJAD project reveals that the depth applied under conventional water application following with flooding (with surface runoff checked) showed that an average 40% in first irrigation and 64% in second irrigation, more water has been applied in conventional irrigation over border irrigation.

Looking to the above results, you may easily understand, if correct irrigation method is selected, a lot of water will be saved. The same water can be utilised for irrigating the tail end area and non-command area.

7.1 DIFFERENT METHODS OF WATER APPLICATION

Now, please recall the memory for the different irrigation methods. I think, you all will agree that we can classify the irrigation methods as follow:

7.1.1 SURFACE (GRAVITATION) IRRIGATION METHODS

- by flooding, thus wetting all the land surface
- (Border & Basin);
- by furrows, thus wetting only part of the ground surface;

7.1.2 PRESSURISED IRRIGATION METHOD

- by sprinkler, in which the soil is wetted in much the same way as rain;
- by localised irrigation, in which water is applied at each individual plant.

7.1.3 SUBSURFACE IRRIGATION

- by sub-irrigation, in which the surface is wetted little, if any, but the subsoil is saturated;

7.2 SELECTION CRITERIA

Since the objective is to apply water efficiently to provide favourable environment for the plants, it is therefore, essential to consider the factors, which have significant effect in the process of water application. The suitability of various irrigation methods depends mainly on the following factors:

- Natural conditions (soil type, Soil texture, soil depth, Slope or land topography, climate, water availability and water quality)
- Type of crop
- Type of technology
- Previous experience with irrigation
- Required labour inputs
- Costs and benefits.

7.3 METHODOLOGY

A detailed survey of the area is necessary with walk through traversing and discussion with farmers. Accordingly suitable irrigation method can be recommended.

The following quarries are very helpful in deciding the suitable irrigation method:

7.3.1 NATURAL CONDITIONS

The natural conditions such as land holdings, land topography or slope, soils, climate, the quantity and quality of water supply, have the following impact on the choice of an irrigation method:

7.3.1.1 Land holding

Take information regarding different land holding size and accordingly classify in small, medium and large farmers as per following guidelines:

Description	Irrigated land
Small farmers	< 1 ha
Medium farmers	between 1 to 2 ha
Large farmers	> 2 ha

7.3.1.2 Land use pattern

Land use pattern and land ownership survey is necessary to decide the farmers capability to accept the improved justified irrigation method. The percentage of total ternary to total area is sometime directly proportional to land capability classification.

7.3.1.3 Land topagraphy

Out of total volume of water applied at a given point on the soil surface, water in excess of soil intake rate will remain over the land surface, depending on the topography or slope of the land. More the slope, more rapid will be movement of water towards the lower end of the field. Undulating topography also has its effect on the selection of irrigation methods. In an undulating field water will stagnate at low points and at the same time high spots will not receive adequate water if this situation cannot be remedied by levelling/shaping because of shallow soils, it will not be possible to adopt gravity of surface irrigation methods in such fields.

So in nut shell, the land topography is another main factor for deciding the method of irrigation water application. If ground surface is very rough, mostly undulated and land levelling is not beneficial than certainly surface irrigation method cannot be justified over pressurised irrigation system.

7.3.1.4 Soil

Information regarding soil texture, structure, porosity, depth, water holding capacity and soil erosion characteristics is necessary as it is the governing factor for deciding the suitable irrigation method. The soil texture, structure, porosity have a great influence on the water intake (infiltration) and water holding properties of the soil. Light textured soils with limitations of depth and hardpan will allow moisture freely to deeper section in a given time period as compared to heavy textured soils.

Likewise, soils having single grain structure will allow water freely to move downward compared to play and other structures. The movement of water over the land surface (in surface irrigation methods) is also affected by the soil properties. Soil depth is another important factor, as it affects the land levelling/shaping operations, so vital for the success of the surface irrigation methods. In shallow soils, it may not be possible to undertake deep cuts required for levelling the fields, as it might expose the subsoil and render the field infertile for a long time.

Sandy soils have a low water storage capacity and a high infiltration rate. They therefore need frequent but small irrigation applications, in particular when the sandy soil is also shallow. Under these circumstances, sprinkler or drip irrigation are more suitable than surface irrigation. On loam or clay soils all three irrigation methods can be used, but surface irrigation is more commonly found. Clay soils with low infiltration rates are ideally suited to surface irrigation.

When a variety of different soil types is found within one irrigation scheme, sprinkler or drip irrigation are recommended as they will ensure a more even water distribution.

7.3.1.5 Climate:

Rainfall, temperature, humidity and wind velocity play a major role in deciding suitable irrigation method because of tier effect on evapo-transpiration. Wind velocity and direction as well as temperature greatly affect the performance of sprinkler irrigation method. Strong wind can disturb the spraying of water from sprinklers. Under very windy conditions, drip or surface irrigation methods are preferred. In areas of supplementary irrigation, sprinkler or drip irrigation may be more suitable than surface irrigation because of their flexibility and adaptability to varying irrigation demands on the farm. For windy and arid regions sprinkler system cannot be recommended.

In this condition uniformity of water application is very poor and considerable evaporation losses (10-15%) occurs. If the area lies in a area where erratic and uncertain rainfall is there than pressurised irrigation system is the best suitable method, otherwise surface irrigation method.

7.3.1.6 Water availability:

The quantity and quality of irrigation water play a major role in deciding suitable irrigation method. Water application efficiency is generally higher with sprinkler and drip irrigation than surface irrigation and so these methods are preferred when water is in short supply. However, it must be remembered that efficiency is just as much a function of the irrigation as the method used.

The information can be gathered in the following format:

Location	Source wise irrigated area			
	canal	Canal+well	well	total area

In canal irrigated area certainly farmer use surface irrigation method i.e. border, basin and furrow depending on type of soil & crop to be grown. If available flow is too small to be used for gravity methods, pressure methods may be the only solution. During summer season when there is water scarcity certainly farmer have to use supplement irrigation with pressurised irrigation system. The survey of irrigation status helps in deciding the probable constraints and remedial measures to justify the improved irrigation method.

7.3.1.7 Water quality

The quality also affects the method of irrigation water application. The presence of salt in water is other factor of importance for the selection of appropriate irrigation methods, since the accumulation of salts in the root zone will adversely affects the production. In such a case a method, which will push the salt out of the root zone should be preferable. If surface irrigation method is the only option and irrigation water is having low salinity, than certainly furrow irrigation method is the best suitable method. Highly saline water can be used with the help of drip irrigation system with slight improvement to avoid the salt crust formation near the root system.

Surface irrigation is preferred if the irrigation water contains much sediment. The sediment may clog the drip or sprinkler irrigation systems. If the irrigation water contains dissolved salts, drip irrigation is particularly suitable, as less water is applied to the soil than with surface methods. Sprinkler systems are more efficient that surface irrigation methods in leaching out salts.

7.3.2 CROPS

Type of crops has very significant role to play in the selection of irrigation method. Surface irrigation can be used for all types of crops. Sprinkler and drip irrigation because of their high capital investment per hectare, are mostly used for high value cash crops, such as vegetable and fruit tress. They are seldom used for the lower value staple crops. Drip irrigation is suited to irrigating individual plants or tress or row crops such as vegetables and sugarcane. It is not suitable for close growing crops (e.g. rice).

The flow of water on the field surface is greatly influenced by the resistance offered to the low by the crop (Manning's n), which in turn depends on crop spread horizontally and vertically, as well as sowing/planting methods such as broadcasted, drilled, row planted, etc. The value of crops is also very important. High value crops may provide enough returns to justify the use of pressure irrigation methods, such as drip and sprinkler, but the use of these methods for low value crops may not be economical.

In row crop furrow irrigation method may be recommended if the area lies in canal irrigated area otherwise pressurised irrigation method like drip irrigation. In close growing crop border and basin is the only suitable method of water application.

Cropping and irrigation intensities decide the suitable irrigation method. If the area is targeted for very high cropping intensities than certainly the area is to be fed with the pressurised irrigation system for supplemental conjunctive use of water with surface irrigation system.

7.3.3 TYPE OF TECHNOLOGY:

The type of technology affects the choice of irrigation method. In general, drip and sprinkler irrigation are technically more complicated methods. The purchase of equipment requires high capital investment per hectare. To maintain the equipment a high level of know-how has to be available. Also, a regular supply of fuel and spare parts must be maintained which together with the purchase of the equipment may require foreign currency. Surface irrigation systems in particular small-scale schemes usually require less sophisticated equipment for both construction and maintenance. The equipment needed is often easier to maintain.

In mechanized cultivation the ease of machine operation and movement should also be taken account, while considering the selection of method of irrigation. The movement of machinery for operations such as inter-culture, application of chemicals and harvesting, should not get restricted on account of the method of irrigation. The Ease of operation and movement decide the suitable irrigation method. The size of machine sometimes decides the surface irrigation system (Border, Basin) width and furrow spacing in case of furrow irrigation.

7.3.4 PREVIOUS EXPEREIENCE WITH IRRIGATION:

The choice of an irrigation method also depends on the irrigation tradition within the region or country. Introducing a previously unknown method may lead to unexpected complications. It is not certain that the farmers will accept the new method. The servicing of the equipment may be problematic and the cost may be high compared to the benefits.

Often it will be easier to improve the traditional irrigation method than to introduce a totally a new method.

7.3.5 REQUIRED LABOUR INPUTS

Surface irrigation often requires a much higher labour input-for construction, operation and maintenance, than sprinkler or drip irrigation. Surface irrigation requires accurate land levelling, regular maintenance and a high level of farmer's organization to operate the system. Sprinkler and drip irrigation require little land levelling; system operation and maintenance are less labour intensive.

7.3.6 COST AND BENEFITS

Before choosing an irrigation method, an estimate must be made of the costs and benefits of the available options. On the cost side not only the construction and installation, but also the operation and maintenance (per hectare) should be taken into account. These costs should than be compared with the expected benefits (yields). It is obvious that farmers will only be interested in implementing a certain method if they consider this economically attractive.

Last but not the least in conclusion, the surface irrigation is by far the most widespread irrigation method. It is normally used when the conditions are favourable: mild and regular slope, soil type with medium to infiltration rate, and a sufficient supply of surface or ground water. In the case of steep or irregular slopes, soils with a very high infiltration rate or scarcity of water, sprinkler and drip irrigation it must be ensured that the equipment can be maintained.

7.4 FACTORS IN PLANNING

7.4.1 PRELIMINARY PLAN

- Locate the high points in a field and determine the direction of irrigation and drainage.
- Determine soil boundaries, probable crop rotations and feasibility of land levelling
- Locate field boundaries and farm roads
- From this preliminary plan it should be possible to determine the best delivery point for the water.

7.4.2 PLANNING PROCEDURE

After a preliminary plan has been made, studied and discussed with the farmers, detailed plans for any area on the farm then can be prepared. First select a method of water application for each field and prepare a layout. The design the delivery, application, and disposal facilities as well as necessary roads.

7.4.3 LAYOUT

Planning a general layout for subdividing and irrigating the area in the units of suitable dimensions is the next step. Area delineated according to slope and soil characteristics provide a basis for selecting the best field arrangements and for locating field ditches. Consider alternate layout.

7.4.4 APPLICATION

Design the application facilities. Determine

- The amount of water that must be applied in a normal irrigation
- The time allowed for applying it and
- The rate at which it can be applied.

Then determine the amount of water that must be delivered to field. Plan for land levelling if it is needed. Locate and design the head ditch or pipeline to fit the method irrigation used. Locate and design ditches, pipes levees and the other structures needed to apply water to field in the amount and rate required by the crop and soil.

7.4.5 DELIVERY

Plan the delivery facilities so that they permit delivery of water to the different fields in the volume and rate required by the method of application-previously selected. Select and design the method of conveyance-either ditch or pipe line. Locate and design all the necessary grade control or distribution - control structures, including measuring devices.

7.4.6 DISPOSAL

Plan for the disposal of any irrigation wastewater and excess rainfall promptly and safely. Consider recovery of wastewater for reuse. Include all necessary disposal facilities= channels, pipelines, tiles and pumps.

7.5 TO STUDY ABOUT FIELD APPLICATION SYSTEM

Objective of this study is to investigate the irrigation sub system comprising of water application and drainage system. This will include investigation of different system parameters like outlet on minor, condition of water course & field channel on farm structures, roughness coefficient, section of water course, on farm water application efficiency, water application method, section of water course, presence & condition of drainage system profile survey of field drainage system, etc.

7.5.1 METHODOLOGY

- Take a walk through of the area to reconnaissance the area, Mark the chak boundary roughly on the sazara map.
- Note down the details of outlet off taking from the minor.
- Measure the discharge of the outlet.
- Mark the existing network of watercourses & field channels used to irrigate the area.
- Mark all the on farm structures like division box, diversion structure, culvert, nakka, lined / unlined section of watercourse. If required propose new structures.
- Note down the condition of watercourse at every reach.
- Note down the water application method used by the farmers, also note down the details (like size, slope of border/basin) of method used.
- Take the L-section of watercourse along with cross - section at every 50 m interval.
- Measure the discharge at the tail of watercourse to know the conveyance losses while keeping all outlets closed.
- Measure the time taken to irrigate a field of about 0.25 ha. or 0.5 ha. or 1.0 ha.
- Note down the presence of natural or artificial drainage system.
- Mark the alignment and condition of existing drainage system.
- Take the L-section and X-section of existing drain at every 50 m, turns, etc.
- Mark the structure on drains.
- Note down the topography of fields for land development.
- Measure the roughness coefficient of watercourse as per procedure described later in this unit.
- Note the un-command area in the chak due to natural topography or due to shortage of water.
- Note down irrigation status including position of open wells, tube wells etc. used for irrigation.

- ➢ Note down the depth of ground water by observing water levels in the existing the open wells.
- ➢ Measure the water table installing water table wells as per procedure described later in this unit.
- ➢ Compute the total water delivered by the outlet during the whole year.
- ➢ Note down average, length, width & slope of border & basins used for water application.

7.5.2 ESTIMATION OF ROUGHNESS COEFFICIENT FOR WATER COURSES

1. Select two cross section of water course such that
   - the water course is straight between these two sections.
   - No off taking from this section.
   - water course should be straight about 50 m u/s and d/s of these 2 section s.
   - water course should not have any fall structure these 2 sections.
   - Minimum length between those sections should be 1000 m. Mea sure the accurate distance between these two sections, let it be L meter.
2. Measure cross - sections at both locations. Let it to be A1 & A2.
3. Measure wetted perimeter at both sections
4. Measure discharge at both cross sections using suitable method. Let it be Q1 & Q2.
5. Measure elevation difference in water surface at both points. Let it be E1 & E2.
6. Calculate Hydraulic radius.

   Hydraulic radius $R = \frac{(A1 + A2)/2}{(P1+P2)/2} = \frac{(A1 + A2)}{(P1+P2)/2}$
7. Calculate the water surface slope i.e. S = (E1-E2)/2
8. Calculate Manning's **n** using formula

$$Q = \frac{A}{n} R^{2/3} S^{1/2}$$

OR

$$n = \frac{A}{Q} R^{2/3} S^{1/2}$$

9. Measure velocity of flow using float method. The average velocity in the channel is approx. 0.8 times the float velocity.

7.6 WATER TABLE MONITORING AND IDENTIFICATION OF WATER LOGGED AREA

Observation wells and Piezometers are needed to furnish information concerning the character of soils materials and to provide a means for periodic observation of the location, fluctuations and pressure of ground water bodies.

Installation of observation wells and piezometer required for a number of situations depending upon the objective, such as:

- To detect areas of recharge and discharge
- To measure the static water level
- To measure the pressure of the water at a given point in an aquifer
- To determine the watertable rise due to seepage from water bodies.

7.6.1 LOCATIONS OF WATERTABLE PIPES

Selection of hole locations should be made in the field where conditions that might affect the general water table can be readily observed. Piezometrs are located where needed to provide information on vertical movement of water. They are always installed in clusters of two or more, each terminating at a different depth.

The watertable pipes (observations wells) are generally installed in a square grid pattern. The density of observation network depends upon the topography as well as geological and hydrological conditions of the area. The minimum number of observation wells is given in Table-1.

Size of area, ha	Number of observation points	Number of observation points per 100 ha
100	20	20
1000	40	4
10000	100	1
100000	300	.03

The following precautions should be made during selection of location of watertable pipe:

- Pipe should be located at a place that can be readily observed
- Holes should be located to eliminate the effect of ponds, lakes, ditches, rivers, canals on the general water table
- watertable pipe should be located nearby some reasonably permanent structure to ensure their permanence
- should be located at readily accessible place throughout the year
- Should not be located on high non-irrigated divides
- Should be located based on landform and local topography

7.6.2 SPECIFICATIONS AND FABRICATIONS OF WATERTABLE PIPES

Material	:	Slotted or perforated PVC or steel pipe
Length	:	1.5 to 2 m
Diameter	:	50-100 mm
Casing	:	

- 8 mm dia holes at an interval of 7.5 cm along its lower 3/4 length
- 3mm wide slot alternating on opposite sides of the pipe at about 150 mm interval extending from the bottom of the pipe to within 1 m of ground surface
- Casing should be extended 300 to 450 mm above ground surface for easy visibility(additional aid is to paint the extended portion with yellow, orange)
- To avoid sealing of the holes, the pipes are covered with filter cloth

7.6.3 REQUIRED MATERIAL

Auger 50 to 100 mm dia.

7.6.4 INSTALLATION OF WATERTABLE PIPES

- If the materials are unconsolidated and the hole is not deep, a hand auger may be used
- For deep and large number of holes, power auger is required

7.6.4.1 Procedure

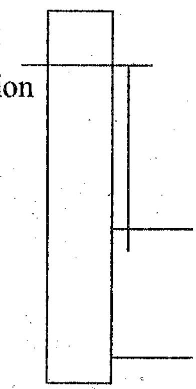
1. Make auger hole of proper size at selected site by appropriate auger to required depth.
2. Bail out the water untill the hole is clear.
3. Place sand or gravel cushion of 100 mm in the bottom of the hole before perforated casing is installed.
4. The annular space is than filled with sand(passing the no.8 sieve and retained on no. 18 sieve) to the top of perforations.
5. From this point to ground surface a 1:1 bentonite-soil mixture should be tamped around the casing to prevent direct entry of surface water flow. Sometimes cover with polythene sheet or a cork and than provide soil embankment.
6. The depth of an observation hole usually should be below the lowest expected water levels.
7. To identify the artesian aquifer deeper holes are required.
8. A careful log of each hole should be made to showing texture, structure, colours, moisture, etc.

7.6.5 MONITORING PROCEDURE

There are several devices for measuring the depth to water in an observation hole. Most widely used is the weighted, chalked line. An ordinary steel tape with suitable weight attached to the end is chalked for the first 0.5 to 1.0 meter with ordinary blackboard chalk. When immersed in water, the chalk will change color, and the point to which the tape penetrates the water surface can easily be read. The tape is lowered into the hole until it reaches the water. Another method of measuring watertable is blow tube method, which is as follows:

- Watertable levels are observed by as blow tube. A centimetre scale is glued to a 5mm outside diameter aluminum pipe of 1.5 m length. The aluminum pipe is inserted inside a plastic tight fit with an extra length of about 30 cm.
- In measuring the watertable, the aluminum tube is inserted in the watertable pipe(WTP) and lowered slowly while blowing through the plastic tube
- The position of the watertable in WTP is identified by the sound of the air bubbling.
- The depth of water level in the WTP is noted by reading the scale on the aluminum pipe.
- The elevation of the top of WTP and the ground surface near the pipe are taken with the help of an engineers level with reference to a bench mark in area. From these, the elevation of watertable and its depth below the ground surface are computed.
- The following relations are used to compute the WTD and the hydraulic head:

WTD	=	observed reading-(WTP elevation-ground elevation)
WT elevation	=	WTP elevation-observed reading
Hydraulic head	=	WT elevation-drain centre elevation
WTD	=	1.60 - (100.3 -100)
	=	1.6 -0.3
	=	1.3 m
WT elevation	=	100.3 - 1.60
	=	98.70 m



7.6.6 RECORDS OF OBSERVATION HOLES

A permanent record should be made of all observation holes.. This record should include such items such as the location and depth of the hole type, dept, diameter, perforated length, and total length of the casing installed.; a log of the hole showing a complete textural description of the material encountered; elevation of natural ground surface at the top of the hole and of the measuring point from which measurement of the depth to water will be made (usually the top of casing); and the periodic measurement of depth to water.

7.6.7 WATER TABLE MONITORING

Well No. :

Location : N W corner of field of Shri ___________

S/o_________ Village :

Depth of hole : 2.00 m

Dia of pipe : 72 mm (ID) PVC, Corrugated perforated pipe

Length of pipe installed : 2.30 m

Elevation of natural ground surface near the hole : 100.00 m

Elevation of top of pipe : 100.30 m

S. No	Date	Time	Depth of Water table from top of pipe	Water table depth below NSL	Water table elevation

7.7 SAQ ACTIVITY

Please go through your working field area, and find out, by which method the farmers are irrigating their field?

1. Are they following as per technical guidelines?
2. How you can justify their approach?
3. Do you feel that they need improvement?
4. How you can study about field application system?
5. How you can estimate the roughness coefficient for watercourse?
6. How you can assess the suitable irrigation method?

7.8 SUGGESTED READINGS

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UNIT-8

How to calculate irrigation efficiencies - A case study of Border Irrigation in heavy soil of Chambal Command, Rajasthan

STRUCTURE

8.0 Objectives

The ever increasing demand for irrigation water has focused attention on the study of efficient use of water. Water losses during irrigation may considerably be reduced if the irrigation system is properly planned, designed and operated in relation to soil, crop, and available water supply.

Operation of ponded border strips vegetated with wheat crop was studied in three sites under Integrated Water and Agricultural Management(IWAM) program during 1994 to 1996. Data on crop yield, irrigation water applied and advance & recession of irrigation water were studied for 6 to 12 m wide borders and conventional method.

A comparision of applied depth in border experiments with the depth applied under conventional water application following wild flooding (with surface runoff checked) showed that an average 40 percent in first irrigation and 64 percent in second irrigation, more water has been applied in conventional irrigation over the border irrigation.

The analysis of wheat yield and water applied show that the water use efficiency was

284 kg per ha per cm of irrigation water in 6 m border, 265 kg per ha per cm in 9 m border, 202 kg per ha per cm in 12 m border and 130 kg per ha per cm of irrigation in conventional irrigation.

The study indicates that border width of 6m with a cutoff ratio of 75 percent may be adopted for border lengths of 50 m to 150 m for the available discharge of 2 to 4 lps per meter border width.y width.

8.1 Introduction

Irrigation management is often designed to maximize efficiencies and minimize the labor and capital requirements of that particular irrigation system while maintaining a favorable growing envionment for the plant. Some managerial inputs are dependent on type and desgn of irrigation systems. The various irrigation methods used in different crops may be grouped as follows:

- Surface irrigation (by flooding on the field surface)
- Subsurface irrigation (by applying beneath the soil surface).
- Sprinkler irrigation (by spraying water under pressure)
- Drip irrigation (by applying water in drops at the plant)

The choice of the system depends upon the water availability, soil characteristics, land topography, crop to be irrigated and expected level of irrigation efficiency. Whatever the method of irrigation, it is necessary to design the system for the most efficient and effective use of water by the crops under the prevailing local condition.

8.2 Surface irrigation

Proper land preparation to permit uniform distribution of water over the entire field and properly constructed water distribution system are essential to obtain high efficiency in surface irrigation methods. The surface methods may be :

- Border strip irrigation
- Check basin irrigation
- Furrow irrigation

8.2.1 Border irrigation

Border irrigation method ensures high water application and distribution efficiency if border strips are properly designed and operated. Ponded border method is widely adopted for irrigation of relatively flat land by Indian farmers. In ponded borders, a cross ridge is constructed at the lower end of the border to retain advancing water. Ponding occurs on the soil surface in a certain reach in the end portion if inflow is terminated after the water front reaches at the end of the border. If supply is terminated after appropriate advance coverage, the excessive ponding at the downstream end can be avoided.

Suitability i) Close growing crops like wheat, barley, fodder crops and legumes.

ii) Soils having moderately low to moderately high infil tration rates.

ii) Well graded land.

These may be straight graded borders (down the slope border) or contour borders (laid across the general slope of the field).

General Border specifications

Proper design of borders requires consideration of the following factors which govern the hydraulics of flow in borders.

- Infiltration characteristics of the soil
- Water requirement of crop each application
- Stream size
- Border Grade
- Bed roughness

There are various theories available to compute the size of a border for given parameters mentioned above. Some general recommendations are given below:

Border width : 3 to 15 m depending upon cross slope and stream size. Smaller the size of stream, smaller will be the border width.

Border length : For moderate slopes and small to moderate size of irrigation stream, the border length may be chosen as 50-150 m in clay loam to clay soil

Size of stream and land slope for border irrigation

Soil type	Infiltration cm/hr	Border slope %	Flow per metre of border (litres per second)
Sandy loam	2.5-5	0.2-0.4	10-15
		0.4-0.6	7-10
Loamy sand	1.8-2.5	0.2-0.4	7-10
		0.4-0.6	5-8
Sandy loam	1.2-1.8	0.2-0.4	5-7
		0.4-0.6	4-6
Clay loam	0.6-0.8	0.15-0.3	3-4
		0.3-0.4	2-3
Clay	0.2-0.6	0.1-0.2	2-4

Cutoff Ratio in Border irrigation

If supply is terminated at the appropriate advance coverage, the excessive ponding at the downstream end can be avoided. The ratio of length of border covered with advancing front when supply is cutoff to the total border length is defined as cutoff ratio. It varies in the range of 70 to 90% depending upon soil, inflow and crop characteristics

Advance and Recession in Borders

The opportunity time is the contact time (ponding time) of irrigation water with the soil during which infiltration takes place. For a theoretically sound border design, the opportunity time should be uniform through out the border length. This would result in 100 per cent distribution efficiency. However it is practically not possible in surface irrigation. Still reasonably high efficiency may be obtained by the proper combination of various design parameters (infiltration characteristics, border garde, stream size and crop water requirement).

Irrigation Efficiency

Irrigation efficiency indicates how efficiently the available water supply is applied and used. There are a number of factors influencing the irrigation efficiency but the most dominant are irrigator awareness, land levelling and method of irrigation. The water use efficiency reflects the end results. Water use efficiency is defined as the ratio of crop yield (Y) to the amount of irrigation applied (IR) during the crop growth season, i.e.

Crop Water use efficiency = Y (q/ha) / IR (ha-cm)

It thus gives grain yield (q/ha) per ha-cm of water applied.

8.3 Experimental Layout and Procedure on Border Irrigation

8.3.1 Soil and Topography

The experiments were conducted in Integrated Water and Agricultural Management(IWAM) pilot project sites at IWAM-1, 2, 3 & 4. The general features of the IWAM sites are summarized in Table 1. The experimental fields (shown in Figure-1 to 4) were levelled by farmers as advised and provided a one directional slope of 0.1-0.3 percent. The slope was selected considering the general slope of the land in the area.

The soils of the experimental plots were generally Chambal, Kota variant and Kota series. The area is mostly put under soybean during Kharif and under wheat during Rabi. The soils of the area are clay and clay loam in the top 1 m soil depth. The average field capacity and wilting point moisture content are 30 and 15 percent respectively as measured from the pressure plate membrane apparatus and apparent specific gravity/bulk density is 1.5.

8.3.2 Border layout

Different border widths and lengths were studied (Table: 2) in different IWAM sites as per available average watercourse discharge.The criteria was to use a border width as a function of inflow in the range of 2 to 3 lps per metre width for border lengths of 50-100 m and 3-4 lps per metre width for border of around 100-150 m length. A cross ridge was constructed at the lower end of each border. Wooden pegs were put at every 10 m distance along the length of the border to observe advance and recession time during irrigation. All the borders were sown with wheat crop on the dates as shown in Table-5.

8.3.3 Irrigation of Borders and Flow measurement

The watercourse discharge was measured using 20cm (8inch) cut-throat flume installed in the watercourse at the head end. The average discharge rates were in the range of 10 to 35 l/s in all the IWAM sites. Three irrigations were applied during the period of the growth of wheat crop in all the IWAM sites. The experiments were conducted on first two irrigations.

8.3.4 Cutoff ratio

The inflow cutoff ratios of 80, 75, 70 and 65 percent were studied to determine uniformity of distribution and determining the crop yield response for different cutoff ratios.

8.3.5 Rate of Advance, Recession and Opportunity Time

Time of advance was noted after every 10m distance from the head end of the border after diverting the inflow into the border. The inflow was cutoff as soon as the wetting front reached the desired length. The time of advance of the water to the remaining length after the termination of the inflow was also noted. The time of recession of water at every 10 m distance after inflow termination was noted. The advance and recession time relationship with border length was plotted and opportunity time for every 10 m length along the border was obtained from the ordinates between recession and advance curves for the corresponding points along the border length.

8.4 Results & Discussions

8.4.1 Depth of water needed and depth applied

Usually in Chambal Command Area clay or clay loam is found in the top 1m soil depth. The soil moisture retention tests conducted for test plots show that the water holding capacity generally varies in between 20 cm to 25 cm per m. The effective root zone depth of wheat in these heavy soils may be taken as 50 cm. So the available water by taking an average water holding capacity of 22cm/m is only 11 cm.

Irrigation in wheat is recommended at 50% depletion of available water in the rootzone. Therefore 5.5 cm of irrigation depth should be applied for 100% irrigation water application efficiency. By adopting improved method of irrigation the irrigation efficiency can be maximised up to 70-80%. By assuming 75% irrigation efficiency the actual application depth would be 7.5 instead of 5.5 cm.

The summarized data of depth of irrigation applied for various IWAM sites in the border irrigation experiments for 1994-95 & 1995-96 can be seen in Table-2A & 2B. The irrigation was done at approximately 50 percent depletion of available water.

It may be seen from the border irrigation experiments conducted during 1994-95(Table-2A) that in first irrigation except IWAM-2, the applied depth is in the range of 8 to 9.6 cm. In second irrigation, the applied depth is generally low than the first irrigation and also lower than the required depth of 7.5 cm for 70 percent cutoff ratio.

While in 1995-96 experiments(Table-2B) it may be seen that in IWAM-1 & 2 in first irrigation (except IWAM-2{R5}) treated with 70% cut off ratio , depth of water applied=7.14cm), the applied depth is in the range of 8 to 10 cm. In second irrigation, the applied depth is generally low than the first irrigation and varies between 7.1 and 9.01 cm. While in case of IWAM-3 and IWAM-4 the low depth of water application was observed(6.15 cm to 8.16 cm). In second irrigation, the applied depth is generally low than the first irrigation and varies between 5 and 6.47 cm.

A comparison of applied depth in border experiments conducted during 1994-95 & 1995-96 with the depth applied under conventional water application (with surface runoff checked) is shown in Table 3A & 3B. It may be observed that on an average 28 percent in first irrigation and 70 percent in second irrigation, more water has been applied in IWM-1 in conventional irrigation over the border irrigation(Table-3A). The 1995-96 border irrigation experiments(Table-3B) reveals that on an average 58 percent in first irrigation and 87 percent in second irrigation, more water has been applied in all the IWAM sites in conventional irrigation over the border irrigation.

8.4.2 Crop Yield

The crop yield samples were taken in 4m X 2m plot size in upstream, middle and downstream of 6 m and 12 m wide borders irrigated with 80 percent and 75 percent cutoff ratio in I & II irrigations in IWAM-1. The yield data are given in Table-4A & 4B for 1994-95 & 1995-96 irrigation season.

BORDER IRRIGATION EXPERIMENTS IN 1994-95(TABLE-4A)

Between 6 and 12 m border of IWAM-1, it may be seen that the crop yield is nearly same throughout the border length in case of 6 m border while in case of 12 m, the yield has decreasing trend with border length towards the lower end. the variation may be attributed to relatively non-uniform storage of water along 12 m border length. The 6 m border yielded 8 percent higher yield than 12 m border. Comparison between conventional irrigation and 6 m border irrigation shows that the border irrigation resulted in 12 percent higher yield than the conventional irrigation. In case of 12 m border, yield was 4 percent more over conventional irrigation.

BORDER IRRIGATION EXPERIMENTS IN 1995-96(TABLE-4B)

In IWAM-1(experiment-1), the border width is found to play an important role in crop yield. In 6 & 9m border the crop yield was found almost same (35 Qtl/ha), while in 12 m border it was found 33.75 Qtl/ha. The crop yield in 6 & 9 m border is 18% and in 12 m border it is 14% higher than conventional field. The crop yield in conventional field was 29.7 Qtl/ha.

In R5 of IWAM-2(experiment-2) the highest yield was observed in 6m border width for given discharge. The difference in yield in case of 9m & 12m was also not significant. The crop yield at u/s and d/s side was more or less same. The crop yield difference at d/s and u/s side can be seen in conventional irrigation experiment. The yield of wheat crop in 6, 9 and 12 m wide borders was 41, 32 and 24 percent higher over the yield from the field irrigated by conventional method. The crop yield in conventional field was 25.63 Qtl/ha.

In case of second experiment of R5 in IWAM-2 on demonstrating the effect of different irrigation cutoff ratios on crop production for given discharge, highest yield (average of upstream and downstream yield) was observed in case of 80% cutoff ratio in comparison to other cutoff ratios but cutoff ratio of 70% gave the highest water use efficiency. LOK-1 variety of wheat was grown, which required more water in comparison to other varieties. In case of 65% cutoff ratio low availability of irrigation water at downstream side caused less yield at downstream side. The crop yield in 6m border with cutoff ratio of 80% in first & second irrigation is found 46%, in 75% cutoff ratio in first & second irrigation it is found 37% and in 70% cutoff in first & second irrigation, it is found 44% higher than conventional field. The crop yield in conventional field was 25.63 Qtl/ha.

In R13 of IWAM-2(experiment-3) on demonstrating the combined effect of different irrigation cutoff ratios and border widths on crop production for given discharge, it was observed that the crop yield in 6m border with cutoff ratio of 80% & 75% in first & second irrigation was 22% higher while in the border of 6m with 75% & 70% cutoff ratio in first & second irrigation it was 27% higher than conventional field yield. In 12 m border the crop yield with cutoff ratio of 80% & 75% in first & second irrigation was found 20% higher while in the border of 12m with 75% & 70% cutoff ratio in first & second irrigation the crop yield was 4% higher than conventional field yield. The crop yield in conventional field was 25.63 Qtl/ha. The effect of irrigation cutoff ratio on crop yield in case of 6m border in comparison to 12m border was clear that the crop yield in 6m border with cutoff ratio of 75% & 70% was 4% higher than the crop yield in 6m border with 80% & 75% in first & second irrigation. In 12 m border the crop yield with cutoff ratio of 80% & 75% in first & second irrigation was found 15% higher cutoff ratio of 75% & 70% in first and second irrigation.

To study the effect of different irrigation cut off ratios on crop production the experiments were conducted in IWAM-3(experiment-4) and the results show that the crop yield in 6 m border with 80% cutoff ratio in first and second irrigation was found 18% higher, in case of 75% cutoff ratio it was found 24% higher, in case of 70% cutoff ratio in first and second irrigation it was 37%, and in case of 65% cutoff ratio it was found 19% higher than yield from the field irrigated with conventional method. The results of experiment-4 clearly show that for 6m border and 55-60m border length in IWAM-3, the irrigation water should be applied with a cutoff ratio of 70% in first and second irrigation.

In IWAM-4(experiment-5), the same trend was observed as in case of IWAM-1. The yield in upstream side of the field was comparatively better in comparison to downstream side of the field. The crop yield taking average from two replicates was found 33% higher in 6m & 9 m border, and in 12 m border it was 15% higher than conventional field(30.63 Qtl/ha). In all the borders, the cut off ratio 80% in first irrigation and 75% in second irrigation was followed. The 6m border width gave the highest crop yield and water use efficiency in both the replicates. It may be concluded that 6m width of border with irrigation water applied following cutoff ratio of

80% & 75% in first and second irrigation is suitable for IWAM-4 with border length more than 100m.

Water Use Irrigation Efficiency

Among the various indicators of irrigation application, in the present analysis, the crop water use efficiency has been analyzed and tabulated in Table-4A & 4B.

DURING 1994-95 BORDER IRRIGATION EXPERIMENTS (TABLE-4A)

The analysis of IWAM-1 yield shows that the water use efficiency was 194 kg per ha per cm of irrigation water with 6 m border width, 172 kg per ha per cm with 12 m border and 116 kg per ha per cm of irrigation in conventional irrigation.

DURING 1995-96 BORDER IRRIGATION EXPERIMENTS (TABLE-4B)

The water use efficiency in IWAM-1 was found 228 kg/ha/cm for 6m border, 214.5 kg/ha/cm for 9m border and 185.2 kg/ha/cm for 12m border. In conventional field it was found 100.7 kg/ha/cm.The highest water use efficiency was observed in 6m border.

In case of first experiment of IWAM-2 in R5(Demonstrating the effect of border width on crop production for given discharge) the highest yield was observed in case of 6 m. The cutoff ratio in 6, 9 & 12m borders was 80% in first irrigation and 75% in second irrigation. The water use efficiency was 226.4 kg/ha/cm of irrigation water in 6m border, 197.8 kg/ha/cm in 9m border, 167.6 kg/ha/cm in 12m border and 110.1 kg/ha/cm of irrigation water in conventional irrigation.

The analysis of second experiment in R5 of IWAM-2 yield (Table-4B) shows that the water use efficiency was similar in all the borders of 6m with different combination of cutoff ratios (80 & 80,75 & 75 and 70 & 70% cutoff ratio in I & II irrigation). In case of 80% cutoff ratio for first and second irrigation, the water use efficiency was found 236.4 kg/ha/cm, 75% cutoff ratio in first & second irrigation the water use efficiency was 238 kg/ha/cm and 264.5 kg/ha/cm of irrigation water in 6m border with 70% cutoff ratio in first and second irrigation. The water use efficiency was found 110.1 kg/ha/cm in conventional irrigation.

In R13 of IWAM-2(experiment-3) for demonstrating the combined effect of different irrigation cutoff ratios and different border width on crop production for given discharge, it was observed that the water use efficiency in 6m border with cutoff ratio of 80% & 75% in first & second irrigation was 177 kg/ha/cm while in the border of 6m with 75% & 70% cutoff ratio in first & second irrigation it was 204 kg/ha/cm. In 12 m border the water use efficiency with cutoff ratio of 80% & 75% in first & second irrigation was found 165 kg/ha/cm while in the border of 12m with 75% & 70% cutoff ratio in first & second irrigation the water use efficiency was 162.9 kg/ha/cm. The water use efficiency in conventional field was found 110.1 kg/ha/cm.

To determine the effect of different irrigation cutoff ratio (80%, 75%, 70

& 65%) two replicates of experiment were conducted. In first replicate (Mohan Lal's field) the water use efficiency in conventional field was 142.9 kg/ha/cm. The water use efficiency in 6 m border with 80% cutoff ratio in first and second irrigation was found 246.3 kg/ha/cm, in 75% cutoff ratio in first and second irrigation was found 279 kg/ha/cm, in 70% cutoff ratio in first and second irrigation was found 309.4 kg/ha/cm, in 65% cutoff ratio in first and second irrigation found 266.5 kg/ha/cm. The highest water use efficiency was observed in case of 6m border with 70% cutoff ratio first and second irrigation.

In second replicate (Jagan Nath's field) the water use efficiency in conventional field was 116.5 kg/ha/cm. The water use efficiency in 6 m border with 80% cutoff ratio in first and second irrigation was found 198 kg/ha/cm, in 75% cutoff ratio in first and second irrigation, water use efficiency was found 241.2 kg/ha/cm, in 70% cutoff ratio in first and second irrigation water use efficiency was found 280 kg/ha/cm, in 65% cutoff ratio in first and second irrigation the water use efficiency was found 274.2 kg/ha/cm.

The highest water use efficiency was observed in 6m border strip in comparison to other borders. The crop water use efficiency in first replicate in 6m border was 356.7 kg/ha/cm, in 9 m border it was 310.1 kg/ha/cm and in 12 m border the water use efficiency was 265.8 kg/ha/cm. The water use efficiency in conventional field was found as 182.8 kg/ha/cm. In all the borders, the cut off ratio of 80% in first irrigation and 75% in second irrigation was followed.

The water use efficiency in second replicate in 6m border was found 346 kg/ha/cm, in 9 m border the water use efficiency was found 337.4 kg/ha/cm and in 12 m border it was 268.7 kg/ha/cm. The water use efficiency in conventional field was found as 182.8 kg/ha/cm. In all the borders, the cut off ratio of 80% in first irrigation and 75% in second irrigation was followed.

8.5 Conclusion

Operation of ponded border strips vegetated with wheat crop was studied in different IWAM sites. Data on crop yield, irrigation water applied and advance & recession of irrigation water were observed.

The border irrigation exoeriments conducted during 1994-96 indicate, that 6 m border width of borders gave the highest crop water use efficiency in all the IWAM sites, in which the irrigation water was applied at cutoff ratio of 80% in first and 75% in second irrigation at some locations(IWAM-2) and 75%(IWAM-1) in first and second irrigation at other locations where soils were relatively heavier.

8.6 References

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Table-1 Summarized view of Integrated Water and Agriculture Management sites

Name of site	Area	SSD status	OFD status	No. of outlet	No. of farmer	W/C length (Km)	F. D. length (km)	S. D. length (km)	C. D. length (km)	M. D. length (km)	Remark
IWAM-1	26 ha	No SSD	OFD installed in 1981-82 under Vijay Nagar Catchment	1	21	1.30	1.55	1.6	---	----	High water table, Clay loam, Kota & Kota variant soil series
IWAM-2	40 ha	Installed in June, 1993 with drain depth of 1.2 m and drain spacing of 15,30,45, 60 & 75 m	OFD installed in 1985-86 under Rangpuria-II catchment	1	28	2.777	1.554	1.246	---	1.3	Clay & clay loam soil texture and chambal variant soil series
IWAM-3	19 ha	Installed in June, 1994 with drain depth of 1.2 m and drain spacing of 45 m	OFD installed in 1991-92 under Chitawa-A catchment	1	16	1.338	1.154	---	----	0.288	SSD installed on CON-1 pattern, clay loam soil texture and Kota & Kota variant soil series
IWAM-4	23.9 ha	No SSD	OFD installed in 1995-96 under Mundala-A catchment	1	18	1.75	0.97	Nil	0.49	---	Low water table as compared to IWAM-1

Here W/C : Water course F.D. : Field drain S.D. : Seepage drain
C.D. : Carrier drain
M.D : Main drain

Table:2A

BORDER IRRIGATION EXPERIMENT'S DETAILS

Rabi (Irrigation Season) 1994 - 95

Crop - Wheat

Site	Information about experimental field border strip			Date of sowing	FIRST IRRIGATION					SECOND IRRIGATION				
	Length (m)	Width (m)	Slope %		Cutoff ratio	Advance Time		Average depth of application (cm)	Date of irrigation	Cutoff ratio	Advance Time		Average depth of application (cm)	Date of irrigation
						Upto cutoff length (min)	Upto end of border (min)				Upto cutoff length (min)	Upto end of border (min)		
IWM1	180	6	0.13	9 Dec 1994	80 %	69.50	96.00	9.40	27.1.95	75 %	45.00	72.00	7.27	4.3.95
IWM1	180	6	0.13	"	75 %	63.00	102.00	9.22	27.1.95	70 %	30.00	51.00	5.87	4.3.95
IWM1	180	12	0.11	"	80 %	140.00	198.50	9.61	27.1.95	75 %	96.00	124.00	7.62	4.3.95
IWM2	35	5	0.22	22Nov 1994	75 %	8.70	12.00	6.51	31.12.94	70 %	6.75	9.75	3.92	9.2.95
IWM2	35	10	0.31	"	75 %	18.50	26.00	6.92	31.12.94	70 %	15.00	21.50	4.36	9.2.95
IWM3	42	5	0.09	9 Dec 1994	75 %	34.75	45.50	7.99	25.1.95	70 %	17.00	30.00	5.16	26.2.95
IWM3	42	10	0.10	"	75 %	71.25	92.50	8.80	25.1.95	70 %	38.00	65.00	5.76	26.2.95

Table-2B
BORDER IRRIGATION EXPERIMENT'S DETAILS
Rabi (Irrigation Season) 1995 - 96 (Crop - Wheat)

Date of Sowing: IWAM1-5 Dec 95, IWAM2(R13)- 3 Dec, 95, IWAM2(R5)- 2 Dec,95, IWAM3(A)& IWAM3(B)- 10 Dec, 95, IWAM4(A)& IWAM4(B)- 7 Dec, 95
Date of I irr.: IWAM1-7 Jan 96, IWAM2(R13)-30 Dec 95, IWAM2(R5)-31Dec 95, IWAM3(A)-6 Jan 96& IWAM3(B)- 9 Jan 96, IWAM4(A)-9 Jan 96& IWAM4(B)- 10Jan 96
Date of II irr.: IWAM1-5 Dec 1995, IWAM2(R13)- 3 Dec, 1995, IWAM2(R5)- 2 Dec, 1995, IWAM3(A)& IWAM3(B)- 10 Dec, 1995, IWAM4(A)& IWAM4(B)- 7 Dec, 1995

Site	Information about experimental field border strip			FIRST IRRIGATION					SECOND IRRIGATION				
	Length l(m)	Width (m)	Slope %	Cutoff ratio	Advance Time		Av. depth of application (cm)	Date of irrigation	Cutoff ratio	Advance Time		Average depth of application (cm)	Date of irrigation
					Upto cutoff length (min)	Upto end of border (min)				Upto cutoff length (min)	Upto end of border (minutes)		
IWAM 1	175	12	0.11	80%	82.25	112.00	9.99	7.1.96	75 %	70.89	102.00	8.23	20.2.96
IWAM 1	175	9	0.13	80%	53.75	69.00	8.69	7.1.96	75 %	49.48	71.00	7.63	20.2.96
IWAM 1	175	6	0.11	80%	34.00	44.50	8.25	7.1.96	75 %	30.70	42.50	7.10	20.2.96
IWAM -2(R13)	117	6	0.15	80%	36.00	50.00	9.32	30.12.95	75%	32.50	65.00	8.33	1.2.96
IWAM -2(R13)	117	6	0.13	75%	31.50	54.50	8.16	"	70%	30.33	72.50	7.77	"
IWAM -2(R13)	117	12	0.11	80%	82.10	140.00	9.83	"	75%	86.00	138.60	8.69	"
IWAM -2(R13)	117	12	0.16	75%	78.50	152.00	8.35	"	70%	78.90	154.00	7.95	"
IWAM -2(R5)	90	6	0.11	80%	25.50	37.60	8.29	31.12.95	80%	22.50	33.90	7.58	6.2.96
IWAM -2(R5)	90	6	0.09	75%	23.50	38.80	7.63	"	75%	21.00	34.60	7.07	"
IWAM -2(R5)	90	6	0.10	70%	22.00	44.70	7.14	"	70%	20.20	38.50	6.80	"
IWAM -2(R5)	90	6	0.11	80%	26.50	40.60	8.60	"	75%	22.00	35.90	7.41	"
IWAM -2(R5)	90	9	0.11	80%	39.00	62.80	8.89	"	75%	35.00	54.30	8.17	"
IWAM -2(R5)	90	12	0.12	80%	58.50	87.50	10.01	"	75%	51.50	79.50	9.01	" cont.
IWAM 3(A)	55	6	0.09	80%	39.5	50.5	7,31	6.1.96	80 %	44.67	59	5.63	10.2.96
IWAM 3(A)	55	6	0.11	75%	33	48.5	6.20		75 %	38.33	56.5	5.00	"
IWAM 3(A)	55	6	0.11	70 %	34.33	56.5	6.15		70 %	35.00	64.9	5.16	"
IWAM 3(A)	55	6	0.10	65%	31.5	62.5	5.64		65 %	31.75	59.1	5.15	"

Site	Information about experimental field border strip			FIRST IRRIGATION					SECOND IRRIGATION				
	Length (m)	Width (m)	Slope %	Cutoff ratio	Advance Time		Av. depth of application (cm)	Date of irrigation	Cutoff ratio	Advance Time		Average depth of application (cm)	Date of irrigation
					Upto cutoff length (min)	Upto end of border (min)				Upto cutoff length (min)	Upto end of border (minutes)		
IWAM3(B)	57	6	0.11	80%	52.17	67	8.16	9.1.96	80 %	35.58	45.6	6.47	12.2.96
IWAM3(B)	57	6	0.10	75%	46.17	69.5	7.22	"	75 %	36.17	51.1	6.25	"
IWAM3(B)	57	6	0.10	70 %	42.33	70.1	7.15	"	70 %	32.17	49.5	5.56	"
IWAM3(B)	57	6	0.10	65%	40.00	79.5	6.66	"	65 %	27.33	48	5.19	12.2.96
IWAM4(A)	115	6	0.21	80 %	98.00	125.5	6.17	9.1.96	75 %	68.00	92	5.57	16.02.96
IWAM4(A)	115	9	0.29	80 %	150.00	195	6.74	"	75 %	113.00	152.5	6.36	"
IWAM4(A)	115	12	0.20	80 %	180.00	231	6.93	"	75 %	163.00	225.5	6.59	"
IWAM4(B)	105	6	0.21	80 %	62.00	81	6.09	10.1.96	75 %	66.00	91.5	5.29	17.02.96
IWAM4(B)	105	9	0.21	80 %	95.00	123.5	6.29	"	75 %	88.00	120.6	5.75	"
IWAM4(B)	105	12	0.20	80 %	136.00	176	6.82	"	75 %	130.00	175.5	6.09	"

Table 3A : Conventional VS Border Irrigation during 1994-95(First & Second Irrigation)

	First irrigation				Second irrigation		
Details	Area (Sqm)	Cutoff ratio (%)	Water applied (cum)	Depth of water (cm)	Cutoff ratio (%)	Water applied (cum)	Depth of water (cm)
Conventional							
IWM-1	18920	-	2283.849	12.071		2414.360	12.761
IWM-II	1750	-	170.700	9.754		106.798	6.103
IWM-III	2310	-	322.056	13.942		218.595	9.463
Border							
IWM-1							
6m	1080	80	101.486	9.397	75	78.557	7.274
6m	1080	75	99.526	9.215	70	63.406	5.871
12m	2160	80	207.492	9.606	75	164.567	7.619
IWM-2							
5m	175	75	11.881	6.789	70	6.866	3.923
10m	350	75	25.264	7.218	70	15.257	4.359
IWM-3							
5m	235	75	18.787	7.994	70	12.118	5.157
10m	470	75	41.407	8.810	70	27.086	5.763

Table-4A : Crop Yield 1994-95 (IWM # 1, RABI)
Sample Size = 4*2

Details	Border width	Samp le	Bio Mass wt.	Grain Wt.	Grain Wt.	Grain Wt
	(m)	No.	(Kg)	kg	kg(av.)	q/ha
Conventional	110.000	A	4.850	2.115		
	110.000	B	5.600	1.841	2.313	28.91
	110.000	C	6.650	2.983		
Border	6.000	A	6.650	2.504		
	6.000	B	6.200	2.747	2.582	32.27
	6.000	C	6.400	2.495		
	12.000	A	8.500	2.888		
	12.000	B	6.550	2.378	2.393	29.91
	12.000	C	5.250	1.912		

Table-4B

Crop Yield 1995-96 (Rabi) Sample Area=4m * 2m=8 sqm

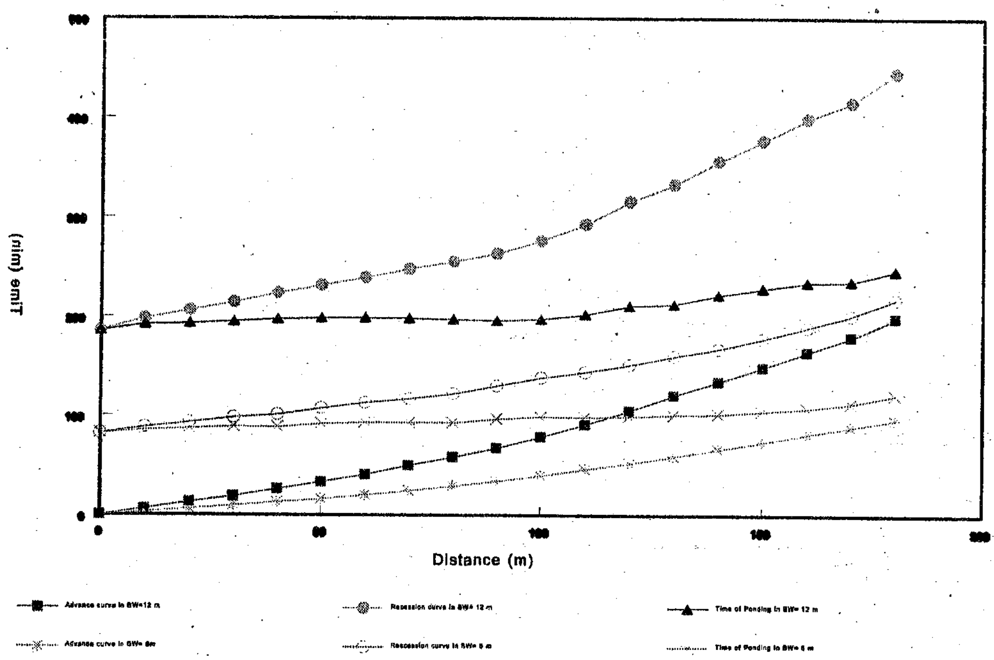
Site Details	Farmer's Field Name	Treatment Details		Sowing Date	Harvesting Date	Crop Period	IrrigationDepth			Head Yield	Tail Yield	Av. Yield	Av. Yield	W.U.Eff
		Width,length	CR (I & II irr.)				I irrigation	II irrigation	Total	kg	kg	kg/m^2	Qtl/ha	kg/ha/cm
IWM-1	Shobha Ram	6m & 175m	80 & 75	5/12/95	27/3/96	113	8.25	7.1	15.35	2.85	2.75	0.35	35.00	228.013
	Shobha Ram	9m & 175m	80 & 75	5/12/95	27/3/96	113	8.69	7.63	16.32	2.65	2.95	0.35	35.00	214.4608
	Shobha Ram	12m & 175m	80 & 75	5/12/95	27/3/96	113	9.99	8.23	18.22	2.6	2.8	0.34	33.75	185.236
	Hardeep Singh	Conventional	Conventional	6/12/95	1/4/96	117	16.41	13.08	29.49	2.6	2.15	0.30	29.69	100.6697
IWM-3	Mohan Lal	6m & 55m	80 & 80	9/12/95	3/4/96	116	7.31	5.63	12.94	2.4	2.7	0.32	31.88	246.3292
	Mohan Lal	6m & 55m	75 & 75	9/12/95	3/4/96	116	6.2	5	11.2	2.4	2.6	0.31	31.25	279.0179
	Mohan Lal	6m & 55m	70 & 70	9/12/95	3/4/96	116	6.15	5.16	11.31	3.1	2.5	0.35	35.00	309.4607
	Mohan Lal	6m & 55m	65 & 65	9/12/95	3/4/96	116	5.64	5.15	10.79	2.6	2	0.29	28.75	266.4504
	Mohan Lal	Conventional	Conventional	9/12/95	3/4/96	116	9.74	8.19	17.93	2	2.1	0.26	25.63	142.9169
	Jagan Nath	6m & 57m	80 & 80	9/12/95	1/4/96	114	8.16	6.47	14.63	2.29	2.35	0.29	29.00	198.2228
	Jagan Nath	6m & 57m	75 & 75	9/12/95	1/4/96	114	7.22	6.25	13.47	2.5	2.7	0.33	32.50	241.2769
	Jagan Nath	6m & 57m	70 & 70	9/12/95	1/4/96	114	7.15	5.56	12.71	3	2.7	0.36	35.63	280.2911
	Jagan Nath	6m & 57m	65 & 65	9/12/95	1/4/96	114	6.66	5.19	11.85	2.7	2.5	0.33	32.50	274.2616
	Jagan Nath	Conventional	Conventional	9/12/95	1/4/96	114	11.27	10.99	22.26	2.15	2	0.26	25.94	116.5207
IWM-4	Mali Modulal	6m & 115m	80 & 75	7/12/95	2/4/96	116	6.17	5.57	11.74	3.2	3.50	0.42	41.88	356.6865
	Mali Modulal	9m & 115m	80 & 75	7/12/95	2/4/96	116	6.74	6.36	13.1	3.4	3.10	0.41	40.63	310.1145
	Mali Modulal	12m & 115m	80 & 75	7/12/95	2/4/96	116	6.93	6.59	13.52	2.95	2.80	0.36	35.94	265.8099
	Mali Modulal	Conventional	Conventional	7/12/95	2/4/96	116	8.42	8.33	16.75	2.6	2.3	0.31	30.63	182.8358
	Mali Modulal	6m & 105m	80 & 75	7/12/95	2/4/96	116	6.09	5.29	11.38	2.9	3.40	0.39	39.38	346.0018
	Mali Modulal	9m & 105m	80 & 75	7/12/95	2/4/96	116	6.29	5.75	12.04	3.4	3.10	0.41	40.63	337.4169

	Mali Modulal	12m & 105m	80 & 75	7/12/95	2/4/96	116	6.82	6.09	12.91	2.85	2.7	0.35	34.69	268.6871
	Mali Modulal	Conventional	Conventional	7/12/95	2/4/96	116	8.42	8.33	16.75	2.6	2.3	0.31	30.63	182.8358
IWM-2	Sohan lal	6m & 90m	80 & 80	2/12/95	31/3/96	120	8.28	7.58	15.86	3	3	0.38	37.50	236.4439
	Sohan lal	6m & 90m	75 & 75	2/12/95	31/3/96	120	7.63	7.07	14.7	2.5	3.1	0.35	35.00	238.0952
	Sohan lal	6m & 90m	70 & 70	2/12/95	31/3/96	120	7.14	6.8	13.94	2.9	3	0.37	36.88	264.5265
	Sohan lal	Conventional	Conventional	2/12/95	31/3/96	120	10.65	12.62	23.27	2.1	2	0.26	25.63	110.1203
	Sohan lal	6m & 90m	80 & 75	2/12/95	31/3/96	120	8.6	7.41	16.01	3.1	2.7	0.36	36.25	226.421
	Sohan lal	9m & 90m	80 & 75	2/12/95	31/3/96	120	8.89	8.17	17.06	2.6	2.8	0.34	33.75	197.8312
	Sohan lal	12m & 90m	80 & 75	2/12/95	31/3/96	120	10.01	9.01	19.02	2.6	2.5	0.32	31.88	167.5868
	Sohan lal	Conventional	Conventional	2/12/95	31/3/96	120	10.65	12.62	23.27	2.1	2	0.26	25.63	110.1203
	Devi lal	6m & 117m	80 & 75	3/12/95	31/3/96	119	9.32	8.33	17.65	2.3	2.7	0.31	31.25	177.0538
	Devi lal	6m & 117m	75 & 70	3/12/95	31/3/96	119	8.16	7.77	15.93	2.4	2.8	0.33	32.50	204.0176
	Devi lal	12m & 117m	80 & 75	3/12/95	31/3/96	119	9.83	8.69	18.52	2.2	2.7	0.31	30.63	165.3618
	Devi lal	12m & 117m	75 & 70	3/12/95	31/3/96	119	8.35	7.95	16.3	2.05	2.2	0.27	26.56	162.9601

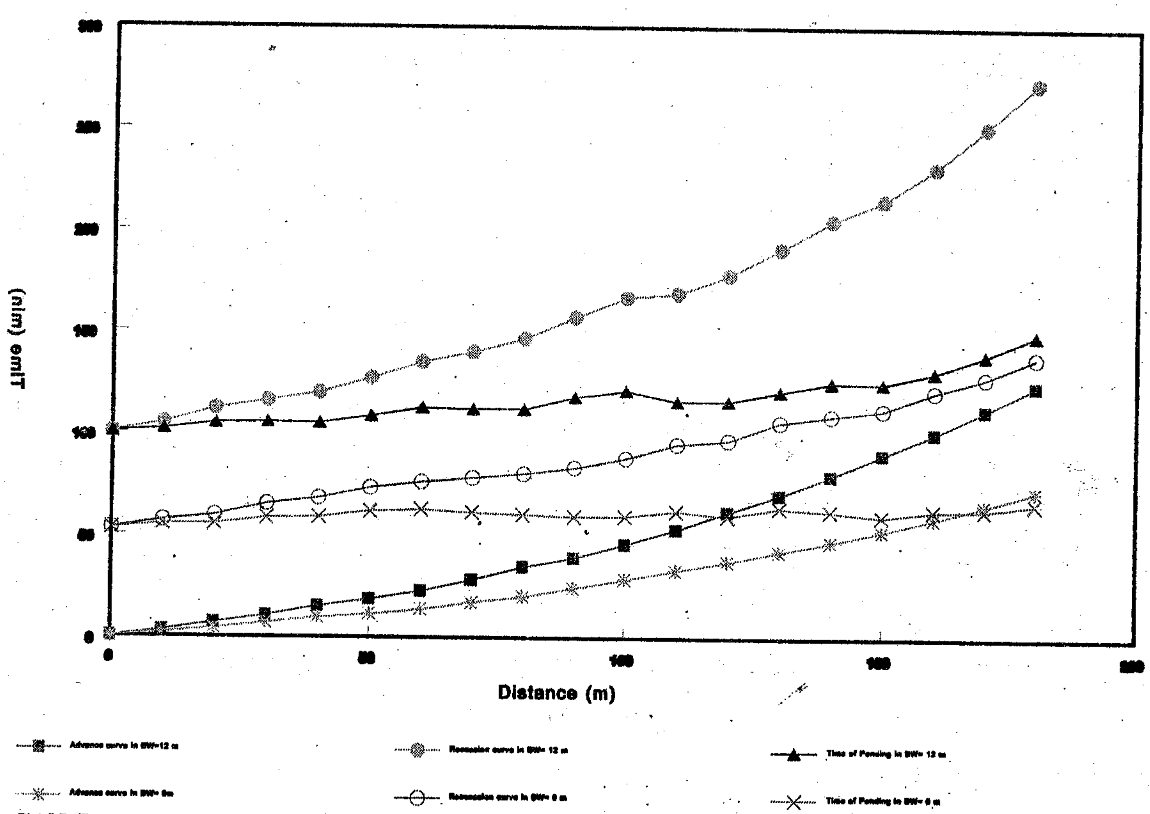
Table 3B

Conventional VS Border Irrigation (1995-96)

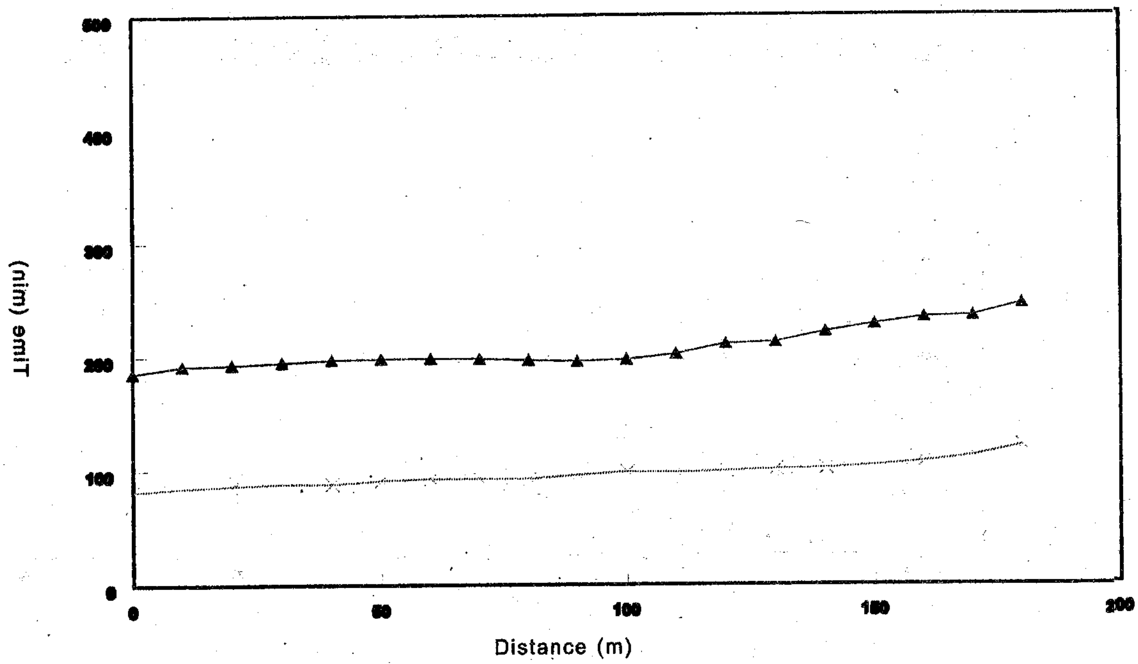
Details	Area (Sqm)	FIRST IRRIGATION			SECOND IRRIGATION		
		Cutoff ratio %	Water applied (cum)	Depth of water (cm)	Cutoff ratio %	Water applied (cum)	Depth of water (cm)
Conventional							
IWAM-1	2400.00	-	394.000	16.41	-	314.000	13.08
IWAM-II	8200.000	-	873.040	10.65	-	1035.000	12.62
IWAM-IIIA	1750.000	-	170.518	9.74	-	143.369	8.19
IWAM-IIIB	1287.000	-	145.067	11.27	-	141.425	10.99
IWAM-IV	5250.000	-	442.302	8.42	-	437.175	8.33
Border							
IWAM-1							
6m	1050.000	80	86.625	8.25	75	74.550	7.100
9m	1575.000	80	136.868	8.69	75	120.173	7.630
12m	2100.000	80	209.790	9.99	75	172.830	8.230
IWAM-2 (R13)							
6m	702.000	80	65.426	9.32	75	58.477	8.33
6m	702.000	75	57.283	8.16	70	54.616	7.78
12m	1404.000	80	138.013	9.83	75	122.007	8.69
12m	1404.000	75	117.1234	8.35	70	111.618	7.95
IWAM-2 (R5)							
6m	540.000	80	44.712	8.28	80	40.932	7.58
6m	540.000	75	41.202	7.63	75	38.178	7.07
6m	540.000	70	38.556	7.14	70	36.720	6.80
6m	540.000	80	46.440	8.60	75	40.014	7.41
9m	810.000	80	72.009	8.89	75	66.177	8.17
12m	1080.000	80	1080.000	10.01	75	97.308	9.01
IWAM-3							
6m	330.000	80	24.123	7.31	80	18.579	5.63
6m	330.000	75	20.460	6.20	75	16.500	5.00
6m	330.000	70	20.295	6.15	70	17.028	5.16
6m	330.000	65	18.612	5.64	65	15.257	5.15
IWAM-4							
6m	630.000	80	38.346	6.09	75	33.330	5.29
9m	945.000	80	59.441	6.29	75	54.338	5.75
12m	1260.000	80	85.932	6.82	75	76.734	6.09



Plot # 7 ,(Parmanand)
Cutoff ratio-80%, W/C discharge- m^3/sec



Plot # 7 ,(Parmanand)
Cutoff ratio-75%

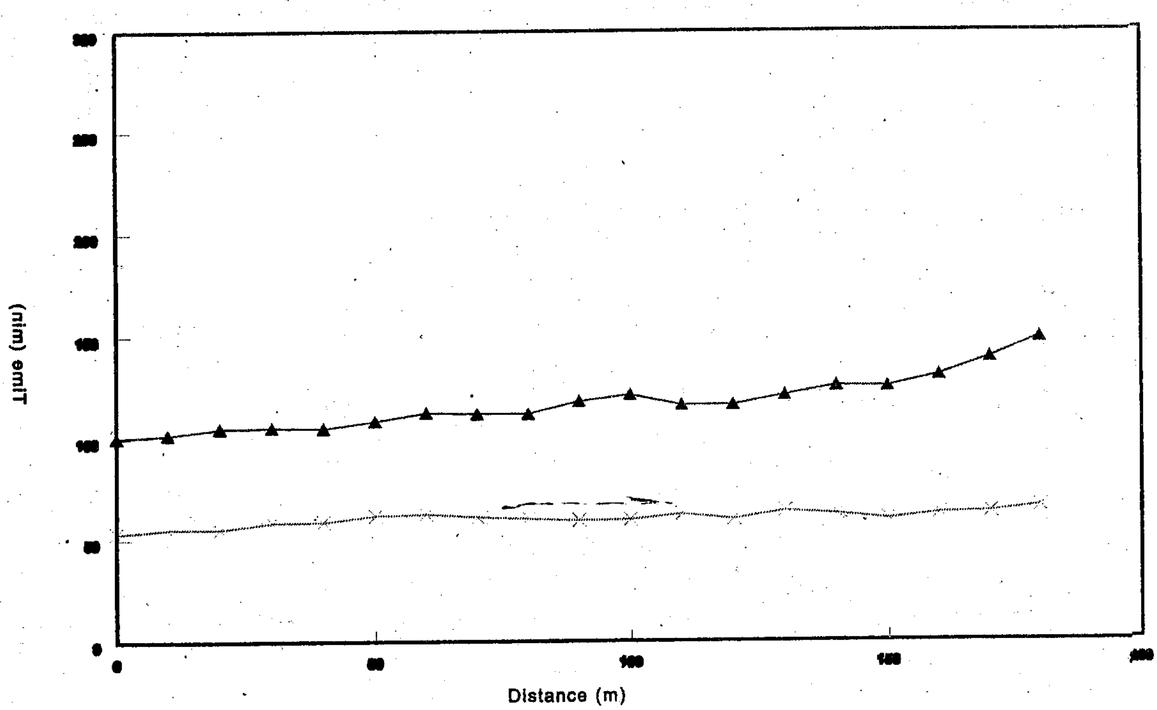


Time of Ponding in BW= 12 m

Time of Ponding in BW= 6 m

Plot # 7 ,(Parmanand)

Cutoff ratio-80%, W/C discharge- m^3/sec



Time of Ponding in BW= 12 m

Time of Ponding in BW= 6 m

Plot # 7 ,(Parmanand)

Cutoff ratio-75%

UNIT-9

A CASE STUDY OF SPRINKLER IRRIGATION

STRUCTURE

9.0 Objective

Objective of this chapter is to demonstrate the practical approach for the design of sprinkler irrigation system. Step by step design is self-explanatory.

9.1 Introduction

The details regarding the fields, crops to be grown, water resources, sprinkler system are given in subsequent paras for the design of sprinkler irrigation system.

a) Area of field - 8 ha

b) Probable cropping pattern as per the users wish.

Crop	Kharif	Rabi	Summer
Sorghum	4 ha	-	-
Pearl millet	4 ha	-	-
Wheat	-	4 ha	-
Sunflower	-	4 ha	-
Groundnut	-	-	4 ha

Thus the cropping intensity during kharif and rabi is 100 percent and during summer it is only 50 percent.

c) Daily crop water use

Kharif	-	5 mm/day
Rabi	-	4 mm/day
Summer	-	7 mm/day

Peak demand 20 percent higher, MAD = 50%.

d) Soil type silt loam, having water holding capacity 170 mm/m and basic infil tration rate 9.5 mm/h, Root zone depth 40-45 cm.

e) Source of water is a well in one corner of field.

f) Electric supply is available for 12 hr a day for six days a week.

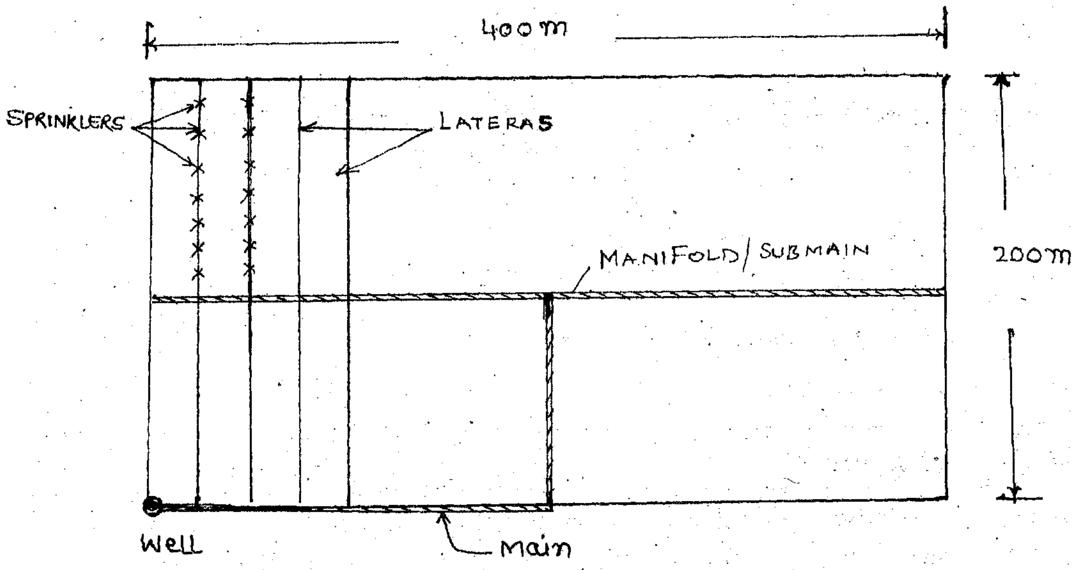


Figure 1. Layout of Sprinkler Irrigation System in the Field.

9.2 DESIGN OF SPRINKLER IRRIGATION SYSTEM

(i) **Net irrigation depth** = $\frac{\text{MAD x Water holding Capacity x root zone depth}}{100}$

$$= \frac{50 \times 170 \times 0.45}{100} = 38.25 \text{ mm}$$

(ii) **Irrigation interval**

During kharif $\frac{38.25 \text{ mm}}{5 \text{ mm/day}}$ = 7.65 say 8 days

Net irrigation interval for kharif = 8-1 = 7 days

During rabi = $\frac{38.25}{4}$ = 9.56 10 days

Net irrigation interval for rabi = 10-1 = 9 days

and during summer $\frac{38.25}{7}$ = 5.46 6 days

Net irrigation interval for summer = 6-1 = 5 days

(iii) **Area to be irrigated per day**

Kharif = $\frac{8 \text{ ha}}{7 \text{ day}}$ = 1.14 ha/day

$$\text{Rabi} = \frac{8}{9} = 0.88 \text{ ha/day}$$

$$\text{Summer} = \frac{8}{5} = 1.6 \text{ ha/day}$$

(iv) **Peak demand and gross demand per day**

Considering 20% higher peak demand and 80% field efficiency gross demand

$$\text{During kharif } \frac{5 \times 1.2}{0.8} = 7.5 \text{ mm/day.}$$

$$\text{During Rabi } \frac{4 \times 1.2}{0.8} = 6 \text{ mm/day}$$

$$\text{and During summer } \frac{7 \times 1.2}{0.8} = 10.5 \text{ mm/day}$$

(v) **Volume of water required per day V (m^3)**

Area to be irrigated / day x Gross depth X Irrigation Interval

During Kharif, $V = 1.14 * 10^4 * 7.5 * 10^{-3} * 8 = 684 \text{ m}^3$

During Rabi, $V = 0.88 \times 10^4 \times 6 \times 10^{-3} \times 10 = 528 \text{ m}^3$

During summer, $V = 1.6 \times 10^4 \times 10.5 \times 10^{-3} \times 6 = 1008 \text{ m}^3$

(vi) **System discharge required (m3/h) considering pumping for 12 hours/day.**

During kharif $57 \text{ m}^3/\text{h}$ i.e. 15.833 lps

During rabi $44 \text{ m}^3/\text{h}$ i.e. 12.222 lps

During Summer $84 \text{ m}^3/\text{h}$ i.e. 23.333 lps

Information available about the sprinkler system

Nozzle Size (mm)	Operating pressure (m)	Discharge per sprinkler (lps)	Wetted diameter (m)	Rate of Precipitation (mm/hr)		
				12 x 12 (m)	12 x 15 (m)	12 x 18 (m)
4 x 3.2	25	0.42	26	10.8	8.5	6.9
	30	0.455	28	11.3	9.2	7.5
	40	0.525	29	13.0	10.6	8.6
4.6 x 3.2	25	0.494	30	12.3	10.0	8.2
	30	0.539	32	13.4	10.9	8.9
	35	0.557	32	14.4	11.6	9.6
	40	0.617	32	15.3	12.4	10.2

Considering the infiltration rate of given soil, the sprinkler head of size 4.6 x 3.2 mm with operating pressure 35 m and spacing 12 x 18 m is selected.

(vii) **Rechecking the operating time required during peak demand in different seasons.**

$$\text{Time required} = \frac{\text{Gross depth}}{\text{rate of ppt}}$$

$$\text{During Kharif} = \frac{7.5 \text{ (mm/day)} \times 8 \text{ (day)}}{9.6 \text{ (mm/hr)}} = 6.25 \text{ h}$$

$$\text{During Rabi} = \frac{6 \times 10}{9.6} = 6.25\text{ h}$$

$$\text{During Summer} = \frac{10.5 \times 6}{9.6} = 6.56\text{ h}$$

As available of power is for 12 ha a day for 6 days, the irrigation can be applied easily.

(Viii) No. of sprinklers required to be operated, No. of laterals per setting of irrigation and discharge required in differed seasons.

(a) No. of sprinklers per day

$$= \frac{\text{Area / day}}{\text{spacing of sprinkers}} = \frac{1.14 \times 10^4}{12 \times 18} \quad \frac{0.88 \times 10^4}{12 \times 18} \quad \frac{1.6 \times 10^4}{12 \times 18}$$

	Kharif	Rabi	Summer
	= 52.77	= 40.74	= 74.07
	53	41	74
(b) Design discharge required, lps	53 x 0.557	41 x 0.557	74 x 0.557
(No. of sprinklers x discharge of one sprinkler)	= 29.521	22.837	41.218
No. of laterals / day	= 7	5	10

Considering length of lateral 96 m and 8 sprinklers on each lateral.

(ix) Design of leteral

a) Length of leteral = 96 m

b) No. of sprinklers on lateral = 8

c) Discharge of lateral = 8 x 0.557 = 4.456 lps

d) Operating pressure for sprinkler = 35 m

e) Height of riser = 1.2 m

f) Constant, C = 140

g) Head loss due to friction through lateral of aluminium, assuming lateral diameter 50 mm.

$$hf(m/100m) = 1.212 \times 10^{12}\left(\frac{Q.lps}{C}\right)^{1.852}(d,mm)^{-4.87}$$

$$= 1.212 \times 10^{12}\left(\frac{4.456}{140}\right)^{1.852}(50)^{-4.87}$$

$$= 10.88\text{ m}$$

head loss per 96 m of lateral = 10.88/100 x 96 = 10.44 m

Outlet factor for 8 outlets = 0.38

h) Head loss along the lateral = 10.44 x 0.38 = 3.97 m

Ha = 35 m. 20 % of Ha = 7m

Head loss along lateral should be less then 20% of Ha. As this condition is fulfilled, the diameter is appropriate.

(x) Design of manifold

The critical condition is during summer when 10 laterals are operating at a time.

a) Discharge of manifold = 10 x 4.456 = 44.56 lps.

b) Length of each manifold = 198 m

c) Head loss due to friction through manifold considering manifold diameter as 75 mm.

$$hf = 1.212 \times 10^{12}\left(\frac{Q}{C}\right)^{1.852} (d)^{-4.87}$$

$$= 1.212 \times 10^{12}\left(\frac{44.56}{140}\right)^{1.852} (75)^{-4.87}$$

= 107.44 m / 100 m.

$$\therefore \text{Head loss for 198 m of manifold length} = \frac{107.44}{100} \times 198 = 212.73 \text{ m}$$

Outlet factor = 0.37

Head loss across the manifold = 212.73 x 0.37 = 78.73 m

Since this head loss is too high, the diameter of manifold is to be increased. Considering diameter as 150 mm.,

hf = 3.67 m/100 m.

For 198 m length of manifold head loss is 7.27 m.

Head loss across manifold = 7.27 x 0.37 = 2.69 m

This head loss is within the permissible limit of 20 % of the Ha.

(xi) Design of main

a) Discharge through main = 44.56 lps

b) Length of main = 200 + 100 = 300 m

c) Considering diameter 150 mm,

$$hf = 1.212 \times 10^{12}\left(\frac{Q}{C}\right)^{1.852} (d)^{-4.87}$$

= 3.67 m / 100 m

Head loss in 300 m length of main = 11.01 m.

Add 20 % losses due to fitting 0.2 x 11.01 = 2.202 m.

Total head loss = 11.01 + 2.202 = 13.212 m.

Total head required = Static head + water level fluctuation in well + head loss + operating head + Riser ht.

= 5 + 2 + 13.212 + 35 + 1.2

= 56.412 m

Static head and water level fluctuation are assumed.

Add 10 % for losses due to bends and reducers, etc. ;

56.412 x 0.1 = 5.641 m

Total dynamic head required = 62.053 m

= 62 m.

$$\text{HP required} = \frac{Q \times H}{75 \times h}$$

Considering total pumping efficiency as 60 %

$$= \frac{44.56 \times 62}{75 \times 0.6} = 61.39 \text{ hp}$$

Say 65 hp.

Select the pump giving 45 lps discharge against 62 m head for the sprinkler system.

9.3 Suggested Readings

- Atre, 1998. Sprinkler Irrigation Design - a Case Study. Short course on Pressurised Irrigation Systems, M.P.K.V. Rahuri (Maharastra).

◆ ◆ ◆

UNIT-10

A CASE STUDY OF DRIP IRRIGATION

STRUCTURE

10.0 Objective

Objective of this chapter is to demonstrate the practical approach for the design of sprinkler irrigation system. Step by step design is self-explanatory.

10.1 Introduction

Designing a drip system of irrigation for 1 ha of an orchard planted with pomegranate (G-137).

Details:

The spacing of pomegranate is 5 m x 5 m.

1.	Size of land	:	100 m x 100 m
2.	Type of soil	:	Light textured
3.	Land slope	:	0.30 percent (S-N)
4.	Maximum evaporation	:	12.5 mm/day
5.	Water source	:	Wall situated at east south corner.
6.	Available discharge	:	3.5 lps
7.	Static head	:	10 m
8.	Wetted area for p.g.	:	20%
9.	Life of orchard	:	3 years

10.2 Design Procedure

(i) Net depth of water

i.e. Evapo- transpiration of crop (ET)

$$ET = Ep \times Kp \times Kc$$

in which,

Ep = Pan evaporation, mm

Kp = Pan factor, taken as 0.7

Kc = Crop factor, depends on stage of a crop

ET = 12.5 x 0.7 x 0.75

= 6.56 mm/day

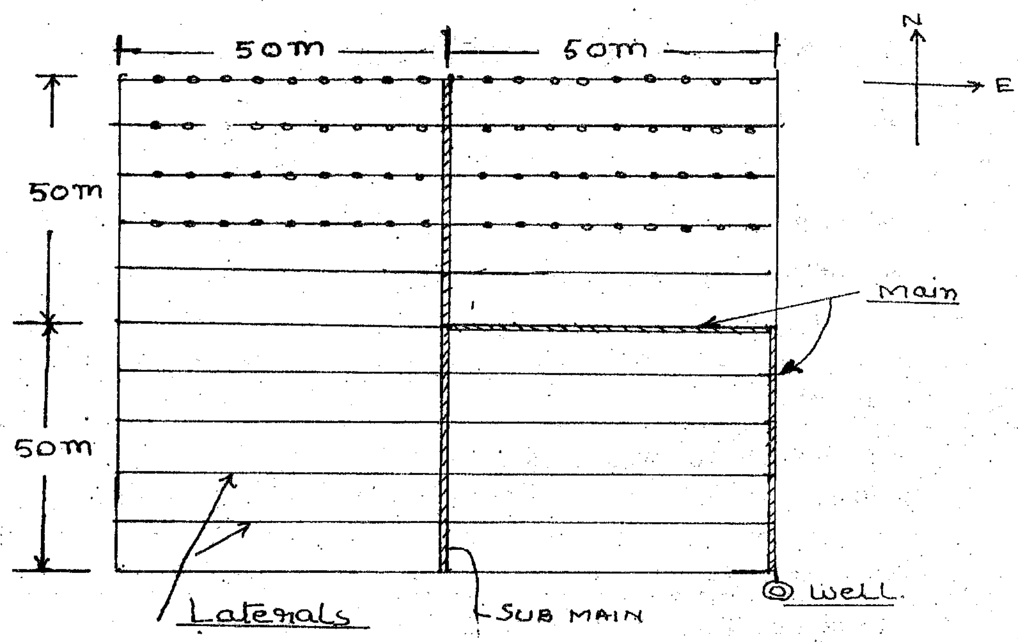


Figure-1: Layout of drip irrigation system in field

(ii) Volume of water

Total volume of water required per day

= Plant spacing (m) x Row spacing (m) x Wetted area (fraction) x Depth of water (m)

= 5 x 5 x 0.20 x (6.56/1000)

= 0.0328 cum/day/ plant.

= 32.8 lit/day/plant

(% wetted area is the area which is shaded due to its canopy cover, when the sun is overhead, which depends on the stage of crop growth).

Considering 90% emission uniformity of the drip system,

Volume of water required = 32.8/0.9

= 36.5 lit/day/plant.

(iii) Emitter selection and positioning

The age of pomegranate trees is 3 years i.e. the trees are grown fully. The soil is light textured.

Use of 4 drippers, each of 4 liter per hour discharge will be necessary.

The total discharge rate will be 16 lit/hr.

(iv) Operation time of system

$$\text{Operation time} = \frac{\text{Volume of water to be applied/tree}}{\text{Total drip per discharge}}$$

$$= \frac{36.5}{16}$$

$= 2.28$ hrs.

$= 2$ hr. 17 min.

(v) Layout of system

As per figure-1

i. Length of lateral = 50 m

ii. Number of trees per lateral = 10

iii. Number of drippers per lateral = 40 (4 drippers per tree)

iv. Total number of laterals = 20 + 20 = 40

v. Total number of dripper per ha = 40 x 40 = 1600

vi. Total length of lateral

= 50 x 40 laterals = 2000 m

(vi) Number of shifts

Discharge through one lateral

= 40 drippers x 4 lph

= 160 lph

Discharge available = 3.5 lps * 3600 sec

= 12600 lit per hour.

Number of laterals that can be operated at a time

$$= \frac{\text{Discharge available per hour}}{\text{Discharge through one lateral}}$$

$$= \frac{12600}{160}$$

$= 78.75$

i.e. all forty laterals can be operated at a time. The excess water in the system can be diverted into the well using by-pass system.

(vii) Size of lateral

The permissible had loss due to friction by taking into account 10% head variation will be 10 x 0.10

= 1 m (for 4 lph dripper operated at 10 m head).

The Hazen-William equation used for determining the head lost due to friction is :

$$J = 1.526 * 10^4 * (Q/C)^{1.852} * D^{-4.87} * (L + Le) * F$$

in which,

J = Head loss due to friction, m

Q = Flow rate, m3/hr

C = Constant, depends on pipe material

D = Inside pipe diameter, cm

L = Length of pipe or tubing, m

Le= Increase in length of pipe or tubing due to connections of emitters, m

F = Reduction coefficient, dimension less

Table-1: Reduction factor (F) for multiple outlet pipeline friction loss com putations.

No. of outlets	F Value	No. of outlets	F Value
1	1.00	9	0.42
2	0.65	10-11	0.41
3	0.55	12-15	0.40
4	0.50	16-20	0.39
5	0.47	21-30	0.30
6	0.45	31-37	0.37
7	0.44		
8	0.43	38-70	0.36

From Table-1, for 40 number of outlets on lateral,

F = 0.36

L = 50 m

Le = emission holes x Factor

= 40 x 0.36

= 14.4 m

C = 140

Now, assuming D = 12 mm,

$$J = 1.526 \times 10^4 \left(\frac{0.160}{140}\right)^{1.852} (1.2)^{-4.87} (50 + 14.4) * 0.36$$

= 0.52 m

As computed J = 0.52 m is less than 1 m, lateral of 12 mm size is sufficient to meet the hydraulic requirements.

(viii) Size of submain

Head loss at the outlet of submain = 10.0 + 0.52

= 10.52 m

Number of submains = 2

Length of each submain = 50 m

Discharge (Q) through one submain

= Q lateral x Number of laterals

= 160 x 20

= 3200 lph

Qs = 3.2 m3/hr

From Table-1, for 20 outlets, F = 0.39

L = 50 m, Le = 20 x 0.39 = 7.8 m,

C = 140

Now assuming D = 40 mm

$$J = 1.526 \times 10^{4} \left(\frac{3.2}{140}\right)^{1.852} (4)^{-4.87} (50 + 7.8) * 0.39$$

= 0.37 m

Head at the inlet of main

= Hsubmain + Hlat + Hemitter + Hslope

= 0.37 + 0.52 + 10.00 + 0.15

= 11.04 m

(where Hslope = 50*0.3/100 = 0.15 m)

Head loss in submain = 11.04 - 10.52

= 0.52 m

$$\text{Variation in heads} = \frac{0.52}{11.04} \times 100$$

= 4.71%

As the head loss is less than 20%. Hence the size of 40 mm diameter PVC pipe for submain can be accepted.

ix) Size of Main

Length of main = 50 m + 50 m

= 100 m

Total discharge of main = 3.2 + 3.2

= 6.4 cum/hr

F = 0.65 for 2 outlets

Le = emission holes x Factor

= 2 x 0.65

= 1.30 m

C = 140

Now, assuming D = 50 mm,

$$J = 1.526 \times 10^{4} \left(\frac{6.4}{140}\right)^{1.852} (5)^{-4.87} (100 + 1.3) * 0.65$$

= 1.307 m Say 1.31 m

Head at the inlet of main = 11.12 + 1.31

= 12.43 m

Therefore variation in head

= (1.31/12.43)*100

= 10.54 %

As the head loss is less than 20%. Hence the size of 50 mm diameter PVC pipe for main can be accepted.

(x) Total Dynamic Head (TDH)

i.	Pressure head at emitter	=	10.00 m
ii.	Head loss in lateral	=	0.52 m
iii.	Head loss in submain	=	0.60 m
iv.	Head loss in main line	=	1.31 m
v.	Static head	=	10.00 m
vi.	Head losses due to filters	=	7.00 m
vii.	Fertilizer injection	=	1.00 m
viii.	Main control valve	=	0.50 m
	Sub Total	=	30.93 m
ix.	Head losses due to other fittings 10% for safety factor	=	3.09 m

TDH = 34.02 m

(xi) H.P. of Pump

$$H.P. = \frac{Q.H.}{75 * n}$$

in which,

Q = Discharge of mainline, lps

H = Total dynamic head, m

n = Efficiency of pump = 65%

$$H.P. = \frac{(\frac{6400}{3600}) \ x \ 34.02}{75 \ x \ 0.65} = 1.24$$

H.P. of pump = 1.5 (say)

Use 1.5 H.P. pump for running a drip system for 1 ha of pomegranate.

(xii) Details of drip unit required

1. Drippers : 1600 No., 4 lph discharge, 4 drippers per tree.
2. Laterals : 40 No., each 50 m, total length 2000 m, dia. 12 mm, LLDPE
3. Submain : 2 No., each 50 m, total length 100 m, dia. 40 mm, PVC
4. Main : 100 m long, dia 50 mm, PVC
5. Pump : 1.5 H.P.
6. Sand and screen filter coupled with by-pass and back flush system.
7. Fittings and accessories : tees, bends, control values and take-off, end caps, flushing caps, cement solution, pressure gauges, etc.

10.3 Suggested Readings

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UNIT-11

PRACTICAL APPROACH OF LAND GRADING

STRUCTURE

11.0 Objectives

The main objective of the land preparation is to provide a well graded shaped smooth plane surface to help the irrigator to achieve uniform application of water throughout the field. Reshaping the surface of land to a planned grade with smooth surface is called land grading. Land grading and smoothing permit uniform and efficient application of irrigation water and removal of excess water without erosion. This chapter gives practical approach of land grading.

11.1 Introduction

Reshaping the surface of land to a planned grade with smooth surface is called land grading. Land grading and smoothing permit uniform and efficient application of irrigation water and removal of excess water without erosion. Land grading in combination with surface drainage system provides adequate surface drainage protection.

11.2 Land Grading Survey and Design

Once the fields/plots have been laid and demarcated, land grading/shaping is carried out within individual plots, by doing cutting and filling with earth moving machinery. The earth movement is restricted to individual plots only.

Following procedure is used to carry out the survey and design for land grading.

Step 1

Divide the field/plot into suitable grids to carry out the survey for land grading. The usual grid spacing is 25 m in each direction. Other spacing such as 30*30 m, 20*20 m, and 15*15 m are also sometimes used, depending on the nature of surface relief of the area and the precision required in levelling. First grid lines in the X and Y directions are at a distance of half the grid spacing, Figure 1.

Step 2

Fix wooden stakes (usually of size 1 cm by 4 cm by 1 m) at the grid points (Figure 1). Stakes are driven into the ground far enough to ensure that they will withstand strong wind. Each grid point is at the center of the grid square and represents nearly equal area. Extra stakes may be fixed on the points where topography changes abruptly.

For convenience in identification, the row lines are lettered and the column lines numbered.

Step 3

After all points have been staked, determine the ground elevation (using a dumpy level) at each stake and record on the grid map. A temporary bench mark, located on a nearby pucca structure, may be used for calculations of elevations.

Step 4

To make the survey information more readily understood and studied, contour lines are drawn at suitable intervals. The recommended contour interval for land slope ranging between 0 to 1%, 1 to 2%, 2 to 5% and 5 to 10% are 6 to 15 cm, 15 to 30 cm, 30 to 60 cm and 60 to 150 cm, respectively.

With the help of the contour map the land is divided into fields that can be graded and irrigated individually to the best advantage.

Step 5

Land levelling design is usually done using Plane method. In this method the average elevation of the field is determined and this elevation is assigned to the centroid of the area.

Step 6

Determination of the Centroid of the field: The centroid is located by taking moments about two perpendicular reference lines, at right angles to each other as shown in Figure 1. The distance of the centroid of the field from any line of reference is equal to the sum of the products obtained by multiplying the area of each part times the distance from the line of reference to its centroid, divided by the area of the entire field.

Step 7

Determination of the Average Elevation of the field: The average elevation of the field is determined by adding the elevations of all the grid points in the field and dividing the sum be the number of points. The average elevation of the field is assigned to the centroid. Any plane passing through the centroid at this elevation will produce equal volume of cut and fill. With the elevation of the centroid known and the downfield grade and cross slope selected, the elevation required at each grid point can be calculated.

Step 8

Determination of the Slope of the Plane of best fit: The slope of any line in the X or Y direction on the plane, which fits the natural ground surface, can be determined by the least-squares method. The least squares plane by definition is that which gives the smallest sum of all squared difference in elevation between the grid points and the plane. It is called the 'plane of best-fit'.

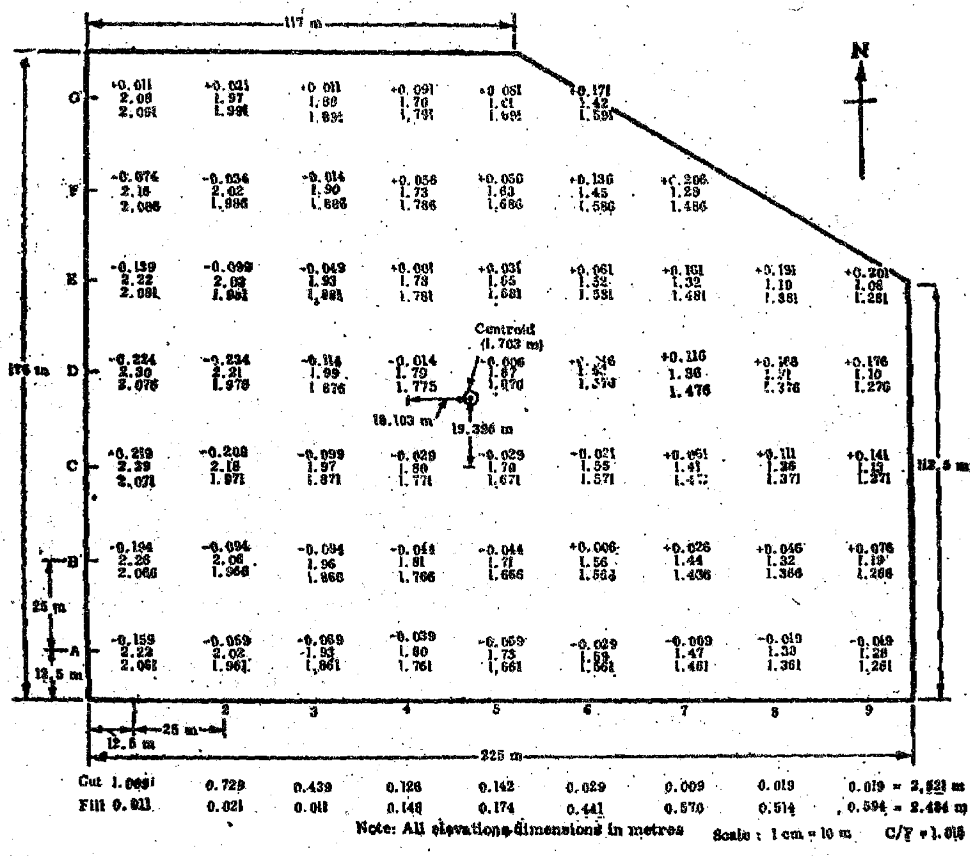

Figure 1 Land levelling design using the plane method.

The slopes of this plane can be calculated, using the following two equations:

$$(\Sigma X^2 - n X_c^2)S_x + \{\Sigma(XY) - n X_c Y_c\}S_y = \Sigma(XE) - (n X_c E_c) \quad \text{.............(1)}$$

and

$$(\Sigma Y^2 - n Y_c^2)S_y + \{\Sigma(XY) - n X_c Y_c\}S_x = \Sigma(YE) - n(Y_c E_c) \quad \text{..........(2)}$$

For rectangular fields, the slopes are:

$$S_x = \frac{\Sigma(XE) - n X_c E_c}{\Sigma X^2 - n X_c^2} \quad \text{..................................(3)}$$

$$S_y = \frac{\Sigma(YE) - n Y_c E_c}{\Sigma Y^2 - n Y_c^2} \quad \text{..................................(4)}$$

Where,

n	=	total number of grid points
Sx	=	Slope in the X-direction
Sy	=	Slope in the Y-direction

Xc	=	distance of centroid along X-axis
Yc	=	distance of centroid along Y-axis
E	=	elevation at any grid point
Ec	=	elevation of the centroid (average elevation of all points)

Step 9

Determination of the Formation Levels, Cuts and Fills: With the elevation of the centroid determined, the formation level of any point (the elevation which the point should attain after land grading operation) may be determined, using the computed or assumed values of S_x and S_y. Then cuts and fills at the grid points is calculated.

If designed elevation is less than the original elevation, it is a cut point, similarly if designed elevation is more than the original elevation, it is a fill point. Mark cut/fill at each stake.

Step 10

Determination of Cut-Fill Ration: Experience in land grading with modern earthmoving equipment has shown that the cut-fill ratio should be greater than one. This means that a greater volume of cut than fill must be allowed. ΣCut and Σ Fill give the ΣC/ΣF (ratio), which generally varies from 1.1 to 1.6, depending on the soil texture and type of machinery used in land grading/shaping. For each situation, it is necessary to work out local criterion. If ΣC/ΣF is less than 1.1, then elevation of the centroid should be lowered and cut fill should be workout at each grid point again and recalculate ΣC/ΣF. This process is undertaken till desired ΣC/ΣF is obtained.

Step 11

Earth work volume calculations: A common procedure for calculating earth-work volume is known as 'Four Point' method, which is sufficiently accurate for land levelling. Volume of cut, Vc, for each grid square is given by the formula:

$$V_c = \frac{L^2 (\Sigma C)^2}{4 (\Sigma C+\Sigma F)} \quad \ldots\ldots(5)$$

Similarly, the volume of fill, Vf, can be calculated by the formula:

$$V_f = \frac{L^2 (\Sigma F)^2}{4 (\Sigma C+\Sigma F)} \quad \ldots\ldots(6)$$

where

V_c	=	volume of cut, m3
V_f	=	volume of fill, m3
L	=	grid spacing, m
C	=	cut on grid corners
F	=	fill on grid corners

For incomplete grids, appropriate multiplication factors are used.

As a simple 'thumb rule', the following formula is also used for earthwork volume:

$\Sigma Vc = L2\ \Sigma C$

where, ΣVc and ΣC refer to the total volume and total cuts for the entire plots.

11.3 Summary

Reshaping the surface of land to a planned grade with smooth surface is called land grading. Land grading and smoothing permit uniform and efficient application of irrigation water and removal of excess water without erosion. Land grading in combination with surface drainage system provides adequate surface drainage protection. Land grading have a cumulative effect on improving crop yields and net returns. Proper land grading, coupled with surface drainage measures, can reclaim unproductive poorly drained areas. Land grading is also beneficial in un irrigated areas to conserve moisture, reduce soil erosion and provide for surface drainage. In low rainfall areas, land grading will result in a smooth uniform land surface, which reduces runoff and induces a greater amount of the rainfall to infiltrate the soil and assures even moisture distribution.

11.4 Self Assessment Test

- Explain survey & design procedure for land grading.
- How slope of the plane of best fit can be determined?
- How cut-fill ration is determined?
- How earthwork volume can be calculated for land grading?

11.5 Key Words

- **Land Grading:** Reshaping the surface of land to a planned grade with smooth surface is called land grading.
- **Plane Method:** In this method it assumes that the area is to be graded to a true plane. In this method the average elevation of the field is determined and this elevation is assigned to the centroid of the area.
- **Plane of best fit:** The least squares plane which gives the smallest sum of all squared difference in elevation between the grid points and the plane is called the 'plane of best-fit'.

11.6 Suggested Reading

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UNIT-12

PRACTICAL ASPECTS OF NETWORK PLANNING BELOW OUTLET

STRUCTURE

12.0 OBJECTIVES

Principal requirements of a good irrigated farming area are controlled distribution of water from source to all the fields; preparation of the field surface for efficient irrigation i.e. grading; drainage of all unwanted water from rainfall, irrigation and drainage of water required for reclamation, if any; access for vehicles and agricultural equipments to all farms; conservation of soil and water, protection from erosion; possibility of the use of improved/modern cultivation and harvesting methods; possibility of reclamation of saline or eroded lands; ability to grow all types of crops suitable to respective agro-climatic zones and the water application/removal system to occupy the least amount of land in comparison to other alternative layouts.

Consideration of the requirements listed above shows that unless planning is done as an integrated whole, it is impractical or extremely expensive to provide one requirement at a time, i.e. if the water distribution network is first constructed, it will be difficult or at least very expensive, to superimpose a drainage network, and then a road network later. This article describes the practical approach for the designing and planning of Irrinage system.

12.1 DESIGNING AND PLANNING OF IRRINAGE SYSTEM

Before planning a irrinage system L-sections of canals irrigating the area to be planned, the Sajra map of the area, planned outlet positions and their CCA and the drainage plan of the area (if available) should be collected along with the L-sections of seepage, carrier, sub-main and main drains of the area. Cultivator list along with the revenue map of the area should also be collected. After collection of the record, survey work is taken up for planning and designing of irrinage system.

12.1.1 TOPOGRAPHICAL SURVEY AND MAPPING

The degree of accuracy of the topographic survey and mapping directly affects the efficiency of irrinage layout and therefore:

i) Survey must be done as per standard methods prescribed in any standard textbook and taught in educational institutions and not according to traditions, which sometimes get established in various departments as shortcuts.

ii) The correctness of the survey depends very much on the accuracy of the survey instruments used and the skill of the staff man, hence instruments must be checked for correctness periodically and raw hands must never be used as staff man.

iii) Survey must be closed daily on a benchmark at the end of the day's work and errors rectified.

iv) The specification for horizontal and vertical control must be specified and rigidly followed.

v) Plotting of the survey must be done the same day so as to ensure timely detection of errors, if any.

vi) Mapping scales chosen must provide sufficient space to write the ground elevation. Maps may be prepared at a scale of 1:1000 to 1:3000 having a vertical contour interval of 15 to 25 cm. Maps to the scale of 1:1000 are too large to handle if command of minor as a whole is to be studied. It is therefore necessary to reduce and compile these maps to the scale of 1:2000 to 1:4000 to facilitate overall planning of chaks.

vii) All maps should be prepared on the same size sheet - advantageous for use in field as well as appearance and ease of filing.

viii) The area under survey, i.e. command area, must be properly subdivided and indexed and each map be numbered accordingly - similar to the indexing of topo sheets.

ix) Occasional checking of survey work and survey instruments under use in the field by senior officers will improve the quality of survey work considerably.

For the purpose of preparing block contour plan of area, it will be better to adopt minor as a unit. Command of the minor can then be subdivided into different sub-units interlinked by base lines. For facility of closing day's work, it is advisable to fix number of temporary benchmarks by double leveling in the command. This also facilities intermediate checking of contour survey. At least one T.B.M. for 4 ha of area is desirable. It is also necessary that the instruments used for survey be in good condition and adjustment. Accuracy of levels equally depends on surveyor as well as on instrument. If two groups are working in the area under survey it is necessary to cross check, spot levels at the junction of two sub areas. This may be done at the beginning of the survey. Plotting of the survey may be done on the same day so as to ensure timely detection of errors, if any.

Grid Surveys

Grid surveys are particularly applicable to surveys of small areas and where substantial topographic data are needed. The system is simple in that a level, rod and tape are all necessary but it may require more time plane-table and alidade or transit and surveys

Obtaining topography by use of the grid system consists of selecting and laying out a series of lines on the ground that can be reproduced to scale on paper. All topography, including elevation, is then obtained in the field with referenced to these lines and later plotted. Contour lines can be drawn by interpolating between plotted ground elevations.

In any survey for a topographic sketch, a survey plan must be determined in advance. The following factors should be considered:

- What ground features are conveniently located for use as baselines?
- Can the baselines be reproduced on a drawing in their true relationship to each other?
- How far apart shall gridlines be set?
- How close together will ground elevations need to be taken?
- What is the most efficient procedure to use?

In planning the survey procedure, it should be remembered that rod reading for elevations cannot be read with accuracy over approximately 100 m with the ordinary level and level rod. If a stadia rod is used, it can be read at a distance of up to 200 m. Ordinarily there should not be over approximately 60-70 m between any two adjacent shots for ground elevations. On very flat, uniform terrain this distance might be increased to 100m. These factors will help to determine how far apart ground elevations should be taken.

In some instances it will be necessary to establish right angles for making grid layouts. If the surveying instrument does not have a horizontal circle for turning off right angles, they can be established by the 3-4-5 method. An alternative procedure is to use a right angle prism. The prism saves time and is sufficiently accurate for grid layouts and taking cross-sections.

Contour Line

A contour is an imaginary line of constant elevation on the surface of the ground. Contours are represented on the map by contour lines; the terms contours and contour lines are often used inter-changeably. On the given map, successive contour lines represent elevation differing by a fixed vertical distance called one contour interval. Contour intervals usually vary from 25 to 250 cm in engineering works. In comparatively flat country, 25 to 50 cm contours are used, while in rough country, the distance between contours must be greater.

Characteristics of contour lines

- All points on a contour line have the same elevation
- Contour lines close to each other on a plan view represent very steep ground, if far apart they indicate that the land is relatively flat. It may be noted that steepness of hill is indicated by contour lines spacing.
- On uniform slopes the contour lines are spaced uniformly and along plane surface these lines are straight and parallel to one another.
- A contour lines represent at level lines, they are perpendicular to the lines of steepest slope.
- Contour lines cannot end anywhere but close on themselves either within or outside the limits of the map.
- As series of the closed contour lines on the map indicates a depression or a hill depending on whether the successive inside contours have lower or higher values inside.
- Contour lines cannot cross each another, except in the case of an over hanging cliff. Contour lines cross a ridge line or valley line at right angles. The same contour appears on either side of valley. At ridge line the contour lines form curves of U shape and the higher values are inside the loop or bend in contour. At valley line they form sharp curves of V shape and the lower values are inside the loop.

Use of contour maps

By inspection of a contour map, information regarding the character of a trade of the country is obtained whether it is flat, undulating of mountainous, etc. In agricultural work, contour maps are useful a guidelines in planning many types of improvements. Tile drainage systems can be conveniently planned on contour maps, and cost estimation can be made from such plan. Maps, which show bottom topography and land use capability classification, are important in the development of conservation plans for farmland. Watershed areas measured from maps are used in estimating runoff to be handled by waterways, gully control structures and farm pond spillways. Preliminary selection of the most economical or suitable alignment for channels, drainage ditches, and roads may be based on contour maps.

Contour maps are used for the measurement of drainage areas. A drainage area for a given point in a stream or river can be defined as the area that contributes the flow to that point.

Preparation of contour map

The grid system is the simplest and is commonly used in average agricultural surveying, requires only skill in using a level and chain or tape. In grid system, the area is divided into a series of squares. The elevations of the ground at the cross of the square are taken and then contour lines are drawn by interpolation. Elevation of extra points within the square may be taken when required to show irregularities, depressions and other features.

12.1.2 PLANNING AND DESIGNING

Good planning calls for maximum coverage of the irrigable lands at minimum construction cost, operation and maintenance expenses. Desirable location should therefore be determined principally on topographic consideration and therefore adequate information on topographic conditions, soil characteristics, intended irrigation methods and water delivery arrangements, etc. be collected.

A well-designed irrigation system delivers the required amount of water to all parts of the area to be irrigated at the required rate without damage to the soil or excessive loss of water. It should be easily accessible and easy to operate without obstructing other farming operations. Laying out fields of workable size and shape is important to successful irrigation farming. The fields should be laid out as nearly rectangular as possible. Sharp turns in field boundaries should be avoided as far as possible in order to facilitate the use of modern farm equipment.

Before planning an irrigation system, reconnaissance survey the area to find out any variation between survey and planning such as excavation of drain, canal capacity works, construction of structures, power line, etc. If any variation is found then it should be marked on the grid map.

12.1.3 DESIGN OF CHAK

It is a piece of command area of a canal, which receives irrigation from a single outlet in the canal. It may generally comprise of few hectares to about 40 ha. The main factor for deciding the layout of the chaks is the topographical features like ridges, natural drains and the prescribed size of chak. The natural ridge and valleys are marked on the block contour map to divide the command under the minor in to different chaks. The area between two valleys will normally be the topographic limits or boundaries of a chak. If any of the chaks exceed the prescribed size of the chak, it should be further subdivided. The size of the chak should be such that the irrigation in the chak must be completed in the specified flow period with the design flow rate. The size of the chak is mainly governed by cropping pattern and peak water requirement of crops.

The objective of planning and design of a chak is to divide the command area of a distributory or minor into suitable sizes (known as chaks) and to find a suitable alignment of water course in that area so that the cost of water course per unit of culturable command area is minimum and convey water to the farms in the shortest possible time, or in best efficient manner. Objectives of good chak design are:

(i) Equitable distribution of water to individual fields in the command.

(ii) Improved water management.

(iii) Improved irrigation efficiency, by minimizing operational losses.

(iv) Increased potential and agriculture production.

To achieve the above objectives, the planning and design of chaks involves mainly the following items of work:

(1) Location and fixing the outlet level of the watercourse.

(2) Marking of chak boundaries.

(3) Selection of alignment and section of watercourse as well as field drains.

(4) Fixing of location of structures.

- **Marking of Chak Boundaries**

The chak boundary of a watercourse of an outlet, taking off from a canal is marked in such a way that maximum area can be irrigated. The size and shape of chak is fixed in such a way that the cost per ha is minimum. This can only be achieved when the length of water course per ha. of culturable command area is minimum. The size and shape of the chak are important factors in keeping the length to be minimum. The chaks should also have manageable size. The size of the chak is generally kept for a discharge varying from 1 to 3 cusecs. Chaks of less than 0.5 cusecs and greater than 3 cusecs may not be generally economical. Also chaks for greater than 3 cusecs discharge are too big for reasonable management. For discharge greater than 3 cusecs a minor may be considered and chaks may be further subdivided.

Generally chaks may be square or rectangular in shape, but strip chaks (narrow width and very long) should be avoided as these chaks are generally not economical and length of watercourse per hectare of CCA is more in such chaks. In such chaks the maximum length of watercourse becomes the limiting criteria. The slope of watercourse should be fixed in such a way that there is maximum command with smallest section. Watercourses with steeper bed slopes are economical, as they require smaller section due to higher velocities. But it may loose command. For flat slopes a higher section of the watercourse is required for the same discharge or CCA.

Following are the criteria for fixing the chak size :

(i) Topographic limits: Normally chak will be between two valleys. Generally boundaries of a chak are, minor on one side and drains on remaining 3 sides. If area within these boundaries is larger than design area of chak, two or more chaks will have to be designed to serve this area. The outlet command should, where possible, be located on one side of the road, railway line or irrigation minor to avoid too many crossings.

(ii) Irrigation in the chak must be completed within stipulated flow period in peak rotation.

(iii) Number of farmers be limited to maximum 15. In canal irrigation, unlike well irrigation, there is community sharing of water. The water that is supplied at the Govt. outlet is to be shared equitably by all the beneficiaries. This needs understanding and co-operation among farmers and therefore, the number of beneficiaries has to be reasonably small. Generally 10 to 15 farmers can be organised and properly co-ordinated for water distribution. Therefore, the number of beneficiaries in a chak may be limited to maximum 15. The number of farmers within a chak will depend upon average size of holding. If holding size in a chak is about 1.6 ha (4 acres) the number of farmers in a chak of 16 ha gets limited to 10. Where the size of holding is smaller the chak size has to be reduced so that the number of beneficiaries on one outlet is limited to about 10 to 15.

(iv) Length of the watercourse from the point of cost of maintenance and transit losses be limited to about 1.0 to 1.5 km.

(v) Chak should be located in one village area. If any chak thus laid out extends over the limits of two villages, it should be subdivided so that each lies in one village only. This facilitates proper co-ordination for water distribution among farmers.

(vi) The chak command should be then be sub-divided into suitable number of sub-chaks (5 to 8 ha each) simultaneously planning for the watercourse alignment with its branches.

(vii) Within the limitation of topography, chaks and sub chaks should be made as compact as possible avoiding narrow and elongated blocks to minimise the length of the watercourse.

- **Selection of Alignment and Section of Watercourse and Field Drains**

Watercourse (Figure 1) is a network of small irrigation channels from canal outlet to the individual farm, which carries water to the fields in a chak. Generally it has a capacity of about 30 lps to 100 lps. It feeds water to each individual farm through a Nakka. Watercourse is the last link in the distribution network, which connects individual fields to Govt. outlet.

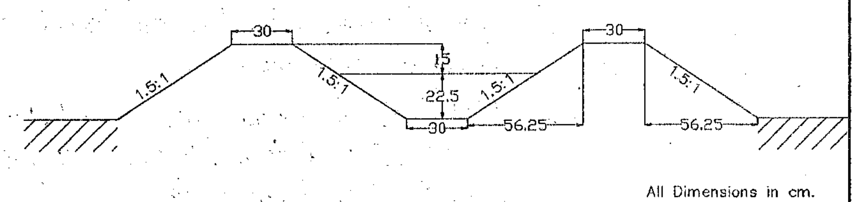

Figure 1 Typical Cross Section of a Watercourse

(a) Alignment

After the layout of the chak is finalized the tentative locations of the outlets are marked on the contour plan. If these locations are not suitable for the layout finalized earlier, changes are made by relocating the outlets and increasing the number where necessary. The alignment of the watercourse is then marked along high ground so that it can command maximum area. If channel is not taken along ridge, it creates following difficulties:

(i) Channel comes in banking which creates maintenance problems.

(ii) Drainage of fields is obstructed.

(iii) Farmers cut the bank for taking water and it is difficult to restore watercourse section in embankment

(iv) Operational losses are increased.

Wherever feasible, watercourse should be taken along the boundaries of holdings (in case of traditional method of layout) so that the channel does not fragment the farm. The alignment thus finalized should be extended so as to serve all the possible fields in the command and terminated into a natural drain to avoid accidental flooding.

At the time of planning the irrinage system alignment following points be kept in mind:

i) Minors and watercourses must end at a drain to allow disposal of surplus and wastewater during operation.

ii) From operational point of view, minors should not be spaced too far apart so as to limit the watercourse length within 1-1.5 km. This will help in dealing with "internal water rotation" among cultivators having opposite interests.

iii) Alignments must always consist of straight lines with circular curves at bends or angles to facilitate water conveyance.

iv). Minor/watercourse should be located on grades that will maintain medium velocities so as to avoid serious silting or scouring during operation.

v) Alignment should have minimum cross-drainage works.

vi) Length of water- course, which is to be proposed on ridge should not be more than 1.5 Km.

vii) The watercourse off taking point should never be proposed down stream of fall structure.

viii) As far as possible watercourse should be planned to irrigate on both sides. If the ground has steeper slope, then single side irrigation watercourse can be proposed.

ix) More than two bifurcations in a watercourse should be avoided.

x) Command area of an outlet should not be less than 30 ha, as far as possible.

xi) The outfall of field drain should not be given in seepage drain as far as possible.

xii) Reverse grade should be avoided as far as possible. If an extra watercourse and drain is needed to avoid reverse grade then it can be proposed.

xiii) 90° turn should be avoided in watercourses.

xiv) Planning should be done in such a manner that watercourse should not cross old village boundary as far as possible.

xv) The old existing watercourse position should be taken into consideration, while planning the irrigation system. The existing outlet position of all existing watercourses should be marked on the map along with their CCA and type & size of outlet.

xvi) Command area of one canal should normally be not put under the command of other canal.

xvii) The watercourse and field channel alignments should generally be planned along the ownership boundaries.

(b) Design

Hydraulic design of watercourse and field drain must be done as per standard guidelines.

System must be designed to suit the operational plan to be followed, i.e. continuous flow, rotation system or demand system and therefore the foremost requirement is to get the operation plan framed first. Once it is done, then the following points needs to be kept in mind while designing:

i) Water level must be planned such that it is maintained at a level higher than the fields to be irrigated by an amount sufficient to allow efficient delivery of water - generally 15 cm in watercourses and 15-30 cm in parent channels.

ii) The embankment height of the watercourse should generally not exceed one meter higher than the surrounding ground.

iii) Earthen section should be designed for a rugosity coefficient n = 0.035, but the velocity must be checked for n = 0.025.

iv) Normally topography controls the chak size but as far as possible, it should be designed on the basis of the area that can be irrigated by the stream size within a given rotation and should also be capable of meeting the peak crop water requirement in a given area.

v) Generally 10-15 farmers can be organized properly for water sharing and therefore the chak size chosen should not have more than 15 farmers.

vi) Watercourse bed gradient should generally follow the natural ground slope except in case of steep topography where it should be controlled by appropriate drops. The bed slope in watercourses should generally be 1:1000 but it may vary from 1:500 to 1:2500 depending upon the natural topography. In case of flatter slopes, more than 1:3000 and discharge not more than 28 lps, it is advisable to line the water courses failing which considerable weed growth is likely to occur.

vii) Water losses in a watercourse are observed to be 2-4 percent per 100 meter length, depending on the nature of the soil, and therefore the watercourse length, in its longest arm, should be restricted to a point where it can deliver a minimum 20 lps as shown in Table 1.

viii) All structures should be so designed that depth of flow should always equal the depth of flow in the ditch.

ix) Freeboard in earthen channels should be one-third the flow depth, or 15 cm, whichever is greater.

x) Drains should have bottom slopes steeper than canals in the same area because non-weeding velocity is higher than non-silting velocity.

xi) Different watercourses in long reaches, could be given different bed gradient; however, if it is planned with a uniform bed gradient (by introducing falls where natural slopes are steeper than the selected bed gradient), fairly uniform velocity and travel time per unit length usually prove to be advantageous.

xii) As the outlet discharge into each branch of the watercourse and the field channel (within the sub-chaks), the design section for the entire micro system should be for the same carrying capacity.

xiii) Aligning of the watercourse along the drains should be avoided as far as possible. Where, unavoidable, a berm of 2 m minimum should be allowed between the drain and watercourse.

xiv) Sometimes, two watercourses running side-by-side can also be designed each serving its independent chak command.

xv) Generally, the drainage networks should be located 200 to 400 m apart in flat countryside and closer in steep and undulating lands.

xvi) Cart tracks should preferably be provided along the field drains rather than along the watercourse.

xvii) For preventing erosion of channels the velocity in the channel is to be restricted to non-erosive limits. The velocity permissible in a channel depends upon the nature of soil through which the channel is to be constructed.

xviii) The outlets should generally be kept of 30 lps capacity but may vary between 20 lps to 40 lps depending upon the area to be irrigated specially. They should normally irrigate an area of less than 40 ha.

xix) The alignment of field channel is marked on ridge so that it can command maximum area. As far as possible it should be taken along filed boundaries (in case of traditional system of layout) to avoid the division of field. The field channel should be aligned such that each field get the water.

Table 1 Flow available at various lengths in a watercourse having 30 lps flow at head.

Distance (Meters)	Available flow considering conveyance loss at		
	2% (for heavy soil)	3% (for medium soil)	4% (for light soil)
0	30.0	30.0	30.0
100	29.4	29.1	28.8
200	28.8	28.2	27.6
300	28.2	27.3	26.5
400	27.6	26.5	25.5
500	27.1	25.7	24.5
600	26.5	24.9	23.5
700	26.0	24.2	22.5
800	25.5	23.5	21.6
900	25.0	22.8	20.8
1000	24.5	22.4	20.0
1100	24.0	21.4	19.1
1200	23.5	20.8	18.4
1300	23.0	20.1	17.6
1400	22.6	19.5	16.9
1500	22.1	18.9	16.3
1600	21.7	18.4	15.6
1700	21.2	17.8	15.0
1800	20.8	17.3	14.4
1900	20.4	16.8	14.0
2000	20.0	16.3	13.2

(shaded area shows flow not suitable for proper surface irrigation as it is less than 20 lps).

12.2 Few Steps for Better Irrinage Planning

Following are the few steps, which can be under taken for better irrinage planning:

(1) Obtain topographical map of the area at a scale of 1:2000 or 1:3000 having a vertical contour interval of 15 to 25 cm and depicting the existing layout of the main and village roads, drains, build up areas, all pucca structures, wells and existing or proposed layouts of the canals and other similar features which the layout must take account of. (The work can be done on smaller scale maps with larger contour intervals but the amount of topographical details shown will be less and the resulting layout will be more expensive to execute because the layout will not fit so exactly to ground conditions).

(2) Calculate the number of meters on the ground to a centimeter on the map as the irrigated fields should not be more than certain maximum length (200 meters in the Chambal irrigated area in Rajasthan) and keep in mind the equivalent length on the map. This length will influence which natural ridge and valley are

selected for the watercourse and drains.

(3) Study the contours shown on the map and determine first the direction of the general slope as all channels will have to flow from high to low. Understand the main depressions, the natural flow lines and the ridge system, which interlocks with the natural drainage system. Specially note depressions, which have no natural outlet and high points, which slope down in all directions (both these types of natural features are indicated by closed contours, i.e., having no free ends).

(4) Place a sheet of tracing paper over the map and fit it in place with pins, cello tape or paperweight. Take a brown pencil and carefully mark with lines or dashes the course of the main natural depressions, longer dashes or lines for the larger or major depressions and fainter lines or shorter dashes for the minor ones. The purpose is to produce a simplified picture of the direction and relative importance of the natural drainage lines. Mark the center of un-drained depressions with a brown star and ring their perimeter in brown.

(5) Take a blue-pencil and mark the lines or dashes of natural ridges in a similar way. If there are long steep falls (not normal nala banks) or steps in the land, mark the top edges of these with a continuous blue line.

(6) Examine the map as it now appears on the tracing paper. Consider which ridges should be used for the irrigation water distribution system and in which depressions the drains should run. Bear in mind that the irrigation fields will run from the watercourse ridge to the drain and its length should not be more than maximum length permissible. Avoid branching watercourses and drains as much as possible, though curves or changes in direction to suit topography are not disadvantageous.

(7) Strive always for simplicity in design. It will normally be observed that there are one or more ridges or depressions, which may be used. There may be a nala which twists and turns down the slope and which may be too expensive to fill in. It can be marked in as the first drain. Draw in the course of this proposed drain in brown, with a smooth line, which generally follows the main line of depression but ignoring the minor curves and irregularities.

(8) Look for the possible ridgelines on each side of the proposed drain and running sufficiently parallel, down which the watercourse can be taken.

(9) When such ridges are identified check for porous media on soils map and measure the distance between the ridge and valley lines. Is it acceptable or could a better ridge or even a better drain/ridge combination be found.

(10) After fixing the line of watercourse search out another drain and then another watercourse, until all the area is covered.

(11) Remember that any road running beside or through the command must or will already be provided with a drain or burrow area on each side, which can be used in the layout for drains.

(12) Also remember that all canals will also have burrows or need parallel seepage drains, which can be used and/or must be connected with the irrinage layout.

(13) Draw in any necessary link watercourses/minor or sub-minor canals to connect the ridgeline channels to the source of supply. Similarly, connect all drains to the main outfall point.

(14) Draw in rough pencil lines to indicate the direction of irrigation fields parallel to the contours.

(15) Superimpose this layout on the cadastral map and if the ridge lines are within 15 meters of a field boundary, the alignment may be taken along the field boundary, otherwise the alignment must follow the ridgelines.

(16) Draw in field tracks on either side of each drain and some link or connecting roads, joining these filed tracks to existing village or main roads passing near the area. Existing village roads or right of way passing through the command area must usually be retained though it may be realigned on a better alignment. Roads or tracks may be marked by a yellow pencil.

(17) Mark in all the culverts, siphons and other crossings, which will be necessary where roads cross canals, drains or watercourses or where watercourses cross drains, etc.

(18) Work out the service operating water level, not less than 15 cm higher than the highest point of the field to be served, in field channels and corresponding levels needed in water courses, minors, etc. providing not less than 15 cm operating heads. Demarcate any un-commanded area for want of service/operation head.

(19) Calculate the length of each watercourse and drain and mark the same on the map. Calculate the CCA of each watercourse and calculate the gross area of the block and tally it with the total CCA of each watercourse. Also, tally the gross area with the total area as per cultivator list. If there is major difference, then recheck the cultivator list and traverse of the area.

(20) The initial planning should be compared with aerial photographs available for the comparison of main features. When the initial planning is complete then get it approved by higher authorities.

(21) This layout plain should now be discussed with beneficiary farmers and suggested changes/modifications, if any, made within the technical limitations.

(22) If there is any change in initial planning then it should be incorporated and all changes in length, CCA, outlet position and FSL required and available should be marked on the layout map. Finalize the layout, water level requirements and the command area.

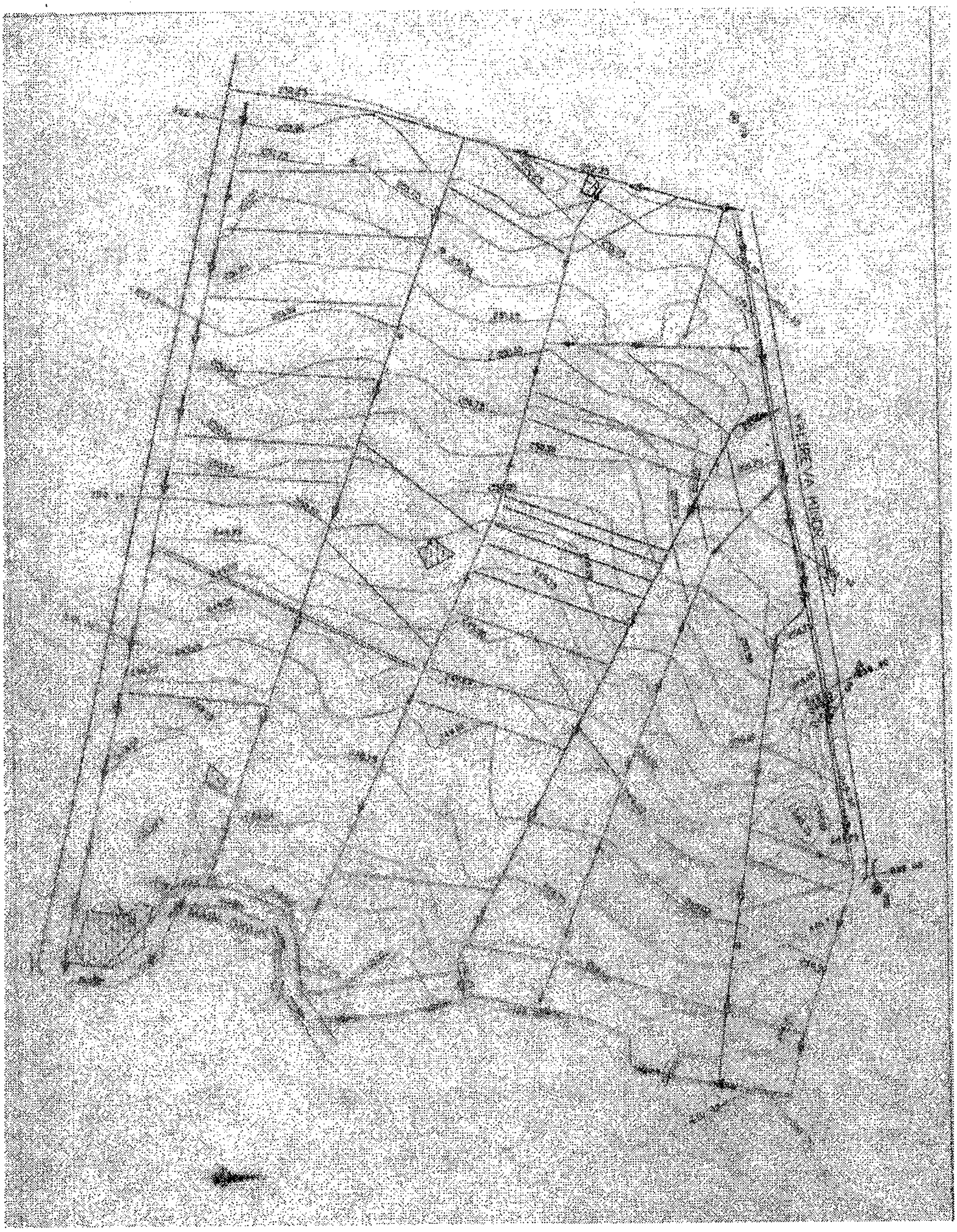

Figure 2: A Sample of Irrinage Planning.

The irrinage planning, traditionally considered a very simple one, is not really so simple, as number of variables involved are too many. Each portion or part of area under planning can be approached in different ways. The planner must therefore consider various alternatives first and then choose the one layout most suitable under the given situation, as it may cause the success or failure of the entire project.

12.3 Preparation of L-Sections of Water Courses

Following steps may be used for the preparation of L-section of a watercourse:

1. Mark the position of watercourses and drains from final planning map on the grid map.
2. Mark point at 30 m interval on each watercourse and drain.

3. Mark the terrace lines from cadastel map.
4. Mark the highest terrace level value.
5. Mark chainage, natural surface level and highest terrace level value at every 30 m on graph sheet.
6. Draw NSL line and terrace level line on graph sheet.
7. For plotting purposes horizontal scale and vertical scale be taken 1 : 3000 and 1 : 10 respectively. In case ground level is steeper i.e. more than 1 : 300 slope, the vertical scale may be taken 1:20.
8. Show off taking position, required value of FSL in watercourse, designed & available FSL in canal as well as working head at off taking point.
9. FSL line be drawn, keeping in mind the following points:
   - If the Terrace level is less than NSL, then FSL should be minimum 10 cm more than terrace level.
   - If the terrace level is more than NSL, then FSL should be minimum 10 cm more than average of NSL and terrace level.
   - Grade should not be changed from steeper to flatter. If it is necessary, then a fall should be proposed before changing the grade. The grade can be changed from flatter to steeper by providing a grade change structure.
   - Slope should never be provided steeper than 1:300. In case ground is very steep, fall structures should be proposed.
   - Slope should not be proposed flatter than 1: 2500 in earthen water courses except in exceptional cases.
   - After a fall structure, we can go in cutting upto 1 to 2 chain distance. If a field starts just after fall structure then its outlet should be fixed at upstream of fall structure.
   - If there is any non- irrigating reach in beginning then FSL should be kept below NSL as far as possible.
10. Draw bed level line.
11. Get the L-section approved by higher authorities.
12. If there is any change proposed, then incorporate it and change all concerned values accordingly.
13. Write discharge, slope, bed width, and velocity.
14. Write FSL and Bed level values at every 30 m
15. Calculate cut and fill at every 30 m and write it on sheet.
16. Draw cross section of watercourse, at a particular chainage.

Details to be provided on a L-section are shown in Figure 3.

12.4 Preparation of L-Section of Field Drain

Following steps may be used for the preparation of L-section of a field drain:

1. Mark the points at every 30 m interval on drain line.
2. Write the chainage and value of NSL at every 30 m. on GRAPH SHEET.
3. Draw the NSL line.
4. Draw the proposed bed level line keeping in mind that difference of NSL and bed level should not be more than 1.5 m, and less than 0.6 m. On an average, difference should be 1.1 to 1.2 m so that sufficient quantity of soil is available for construction of service road along both sides of field drain.
5. No fall structure should be proposed, as far as possible.
6. The bed line should be drawn in such a way that out fall is available at out fall point. Maximum it can be flushed with the bed of carrier drain at outfall point but if there is main drain at outfall point than a minimum of 30 cm. Difference should be kept between bed level of the main drain and field drain at junction point.
7. If outfall is not available then a note of same should be given for deepening of carrier/ main/ sub main drain.
8. Outfall level should be shown at outfall point.
9. Bed slope of drain should normally be the same as ground slope. However it should not be flatter than 1:1500 and steeper than 1:500 as far as possible.
10. Get the L-section approved by higher authorities.
11. If there is any change then incorporate the same.
12. Write the bed level values at every 30 m. Calculate the cutting and write the values at every 30m
13. Write the values of discharge, velocity, bed width, side slope, bed slope etc.
14. Draw typical cross section of drain at a particular chainage.

12.5 Summary

Good planning calls for maximum coverage of the irrigable lands at minimum construction cost, operation and maintenance expenses. The degree of açcuracy of the topographic survey and mapping directly affects the efficiency of irrinage layout hence survey must be done with due care. A chak should be designed so that equitable distribution of water to individual fields in the command, improved water management, improved irrigation efficiency, by minimizing operational losses and increased potential and agriculture production can be achieved. Easy steps have been described in the chapter for designing and planning of irrinage system.

12.6 Self-Assessment

- Which information/documents should be collected before planning an Irrinage system?
- What precaution should taken for the topographical survey & mapping?
- Define contour line and explain its characteristics?

- What are objectives of good chak design?
- What are the steps for better Irrinage planning?
- What are the steps for the preparation of L-section of a watercourse.

12.7 Key Words

- **Irrinage:** Planning and execution of irrigation & drainage system simultaneously.
- **Contour line:** An imaginary line of constant elevation on the surface of the ground.
- **Ridgeline:** Line joining higher elevation points.
- **CCA:** Culturable Command Area.

12.8 Suggested Readings

- Bharathi V.K., 1979. Hand Book of Applied Water Courses. Alok Technical Publishers, Jaipur (Raj.).
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