DESIGN OF IRRIGATION LINED CHANNELS

CANAL LINING AND WASTELAND

Introduction

- **Earthen Irrigation Canal while conveying water to field from Headworks, undergoes two types of losses.**

  i. ***Losses due to Evaporation***

  ii. ***Losses due to Seepage which is control by Lining***

Necessity of Lining

- **Although lining result a heavy initial cost bust in spite of that it has its multi dimensional benefits in the long run as the canal becomes permanent due to lining. *Lined canal is stable, watertight and Hydraulically more efficient. Problems like silting, erosion, scouring are practically Nil in lined canal.***

CANAL LINING AND WASTELAND

Advantages of Lining

- ***To reduce the Seepage Loss***

  Seepage loss in an earthen canal is maximum which decreases the duty of water. To maintain the required duty of the crop, storage of water is to be enhanced which increases the cost of the project. *To reduce this loss, lining of canal bed and sides is necessary.*

- ***To prevent Water Logging in the area near the canal***

  From canal Headworks to cropland, near the canal there may be low lying areas. Due to seepage, these low lying areas may be converted into marshy lands. *These waterlogged areas become alkaline which is not desirable for crop growth*.

CANAL LINING AND WASTELAND

- ***To increase the Discharge by increasing velocity***

To avoid silting and scouring velocity of flow in earthen canal is fixed. In practical field, this velocity is kept below 1m/sec. Discharge in earthen canal is less due to this low velocity.

If the Discharge is required to increase in earthen channel, cross-sectional area is to be increased which involves extra cost and land area. If the canal is lined, velocity can be increased which increase the Discharge.

- ***To Decrease Canal Fall***

Number of canal falls could be reduced as the steeper slope is possible in lined channel.

CANAL LINING AND WASTELAND

- ***To Increase Command Area***

  Lining saves the losses, which increases the command area of the project.

- ***To Protect Canal from Damage by Flood***

  During rainy season, flood is likely to occur, more water flows through canal increasing the velocity. *Increased velocity damages the canal by erosion and scouring. Therefore, to protect the canal, lining is essential.*

- ***To Control Growth of Weeds***

  The growth of weeds along the banks of earthen canal is a common problem. *Weed growth decreases the velocity due to resistance*. Thus earthen canal requires constant maintenance to maintain the design Discharge. *If lining is provided, weed growth is controlled, Discharge can be increased with increased velocity*.

CANAL LINING AND WASTELAND

- ***To reduce Excavation Cost***

  Lined canal cross-section may be much smaller for same Discharge as the velocity may be increased 2 to 3 times of earthen canal. *Reduction in cross-section reduces the cost of excavation*.

- ***To use as Power Canal***

  If the same canal is used for power generation along with irrigation, Head and Discharge both may be increased to generate more power.

- ***To reduce Evaporation***

  ***When the canal is lined, velocity of flow increases which directly decreases the loss due to evaporation*. Again lined canal exposes less area for same Discharge. The loss the exposed area, the less is the evaporation**

- ***To increase life of Canal***

  Life of canal increases with lining as it becomes strong, stable and durable.

CANAL LINING AND WASTELAND

- ***To reduce misuse of Water by Cultivators***

  Lining prevents cultivators from making cuts just like earthen canals. Misuse of water by cutting is prevented.

- ***To Reduce Silt Problem***

  No silt is deposited in lined canal due to increased velocity.

- ***To Control Harmful Salt***

  Water in lined can cannot pick up harmful salts from the soil through which it passes.

- ***To reduce Maintenance Cost***

  It reduces the maintenance cost.

CANAL LINING AND WASTELAND

Disadvantages of Lining

Although lining has a lot of necessities and advantages, it has the following drawbacks or disadvantages or ill effects;

- ***Lining requires a heavy initial cost.***
- ***Shifting of outlet if required becomes difficult as lined canal is a permanent structure.***
- ***Once the lining is damaged, it is difficult to repair.***
- ***Safety berms, dowels are not constructed in lined canals, so moving vehicles, pedestrians, animals are likely to fall in canal.***
- ***Joins in lining may often create troubles.***
- ***Lining increases the time of completion of the project.***

CANAL LINING AND WASTELAND

Lining Materials

Common materials of lining are;

i. Cement Concrete

ii. Brick

iii. Stone blocks

iv. Bitumen

v. Asphalt

vi. Clay Puddle

CANAL LINING AND WASTELAND

Types of Lining

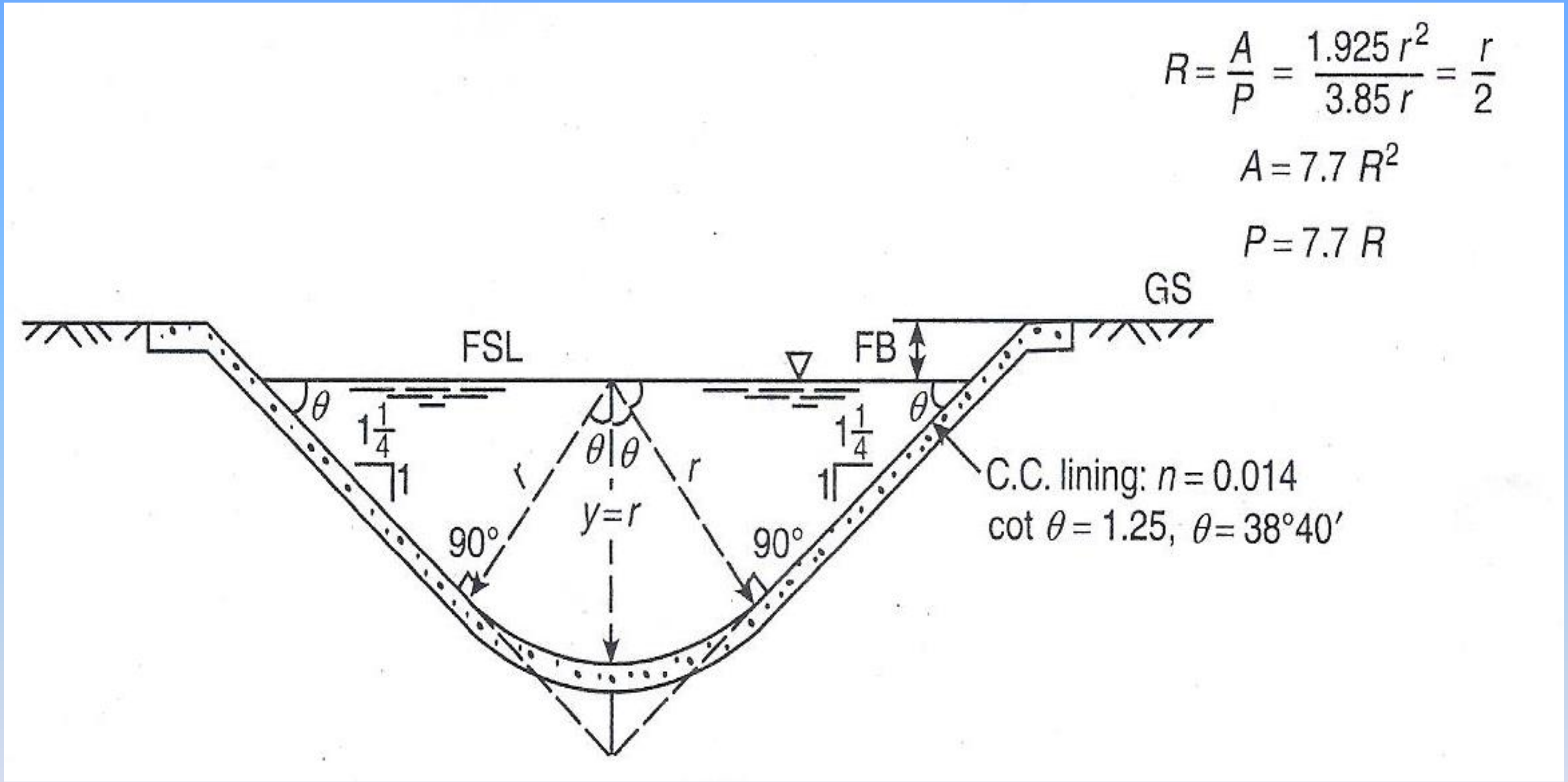
Cement Concrete Lining

- **It has excellent Hydraulic prosperities, but has found only a limited use in our country due to high initial cost.**

- **To prepare cement concrete lining, sub grade is prepared first by ramming the surface properly using the sand. Then cement slurry (1:3) is spread over the bed. The concrete of cement of grade M15 is spread uniformly according to derived thickness.**

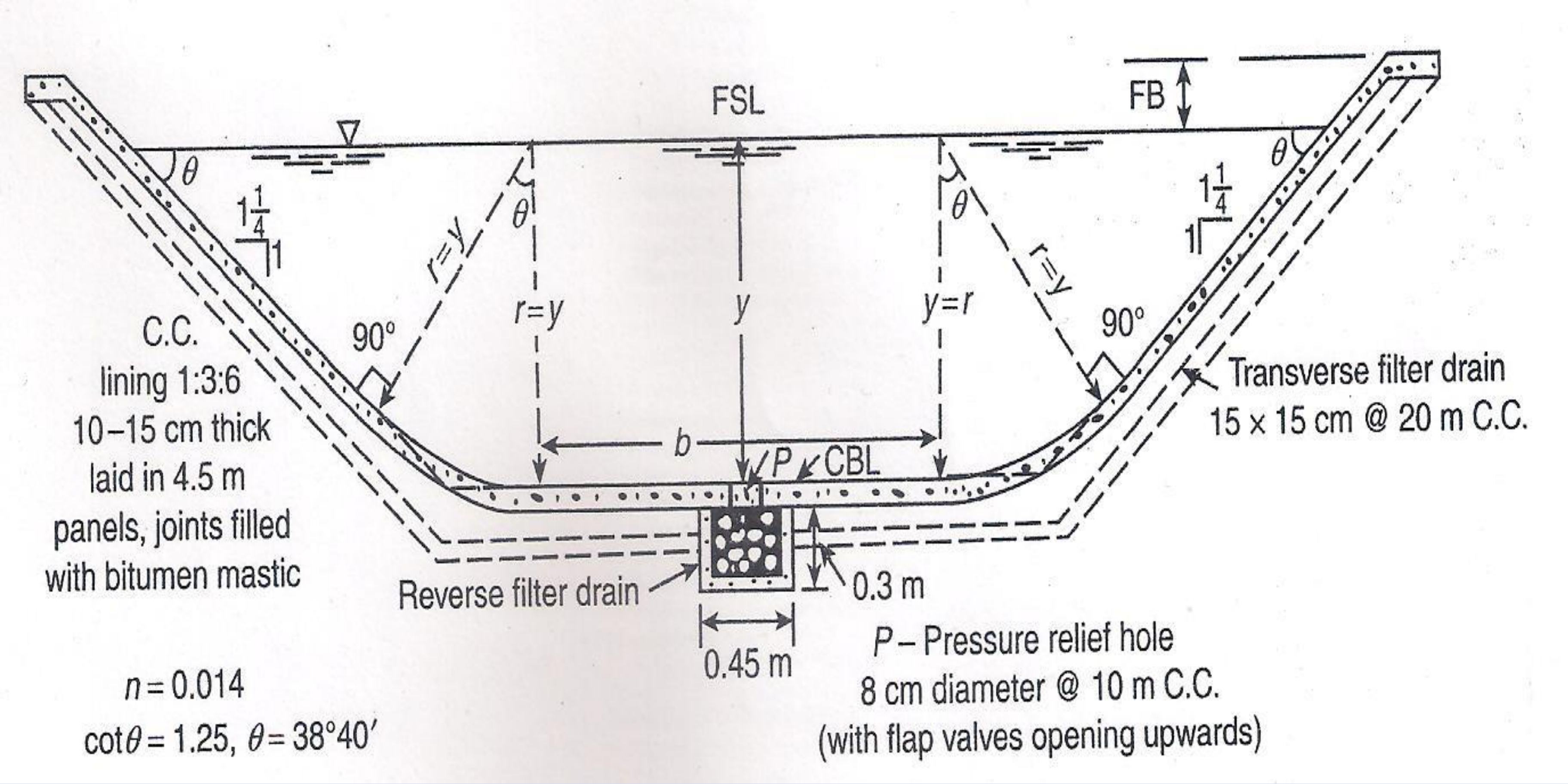
- ***The thickness varies from 5 cm to 15 cm depending on size of canal. Curing is to be done for minimum 1 days. Sometimes reinforcement is required for bigger channel. Expansion joint may also be provided (figure enclosed)***

Lined Canal (Q < 50 Cumec)



IRRIGATION CANALS

Lined Canal (Q > 50 Cumec)



DESIGN OF UN-ERODIBLE CHANNELS

Concrete Lining

CANAL LINING AND WASTELAND

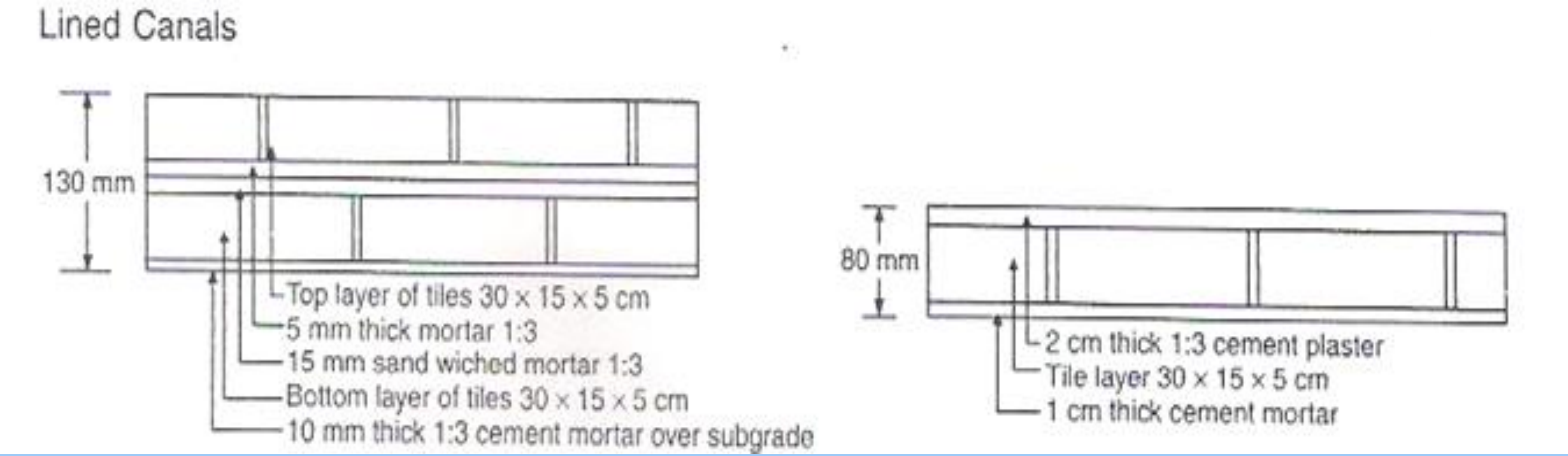
Brick Lining

- ***It is normally done by a double layer bricks. A flat soling with 1:6 cement mortar is done over the compacted sub grade. Then bricks are laid as shown in enclosed figure.***
- **The surface of the bricks is cement mortar of 1:3. This lining is preferred due to the following reasons;**

  i. **This Lining is Economical.**
  ii. **This can be done Quickly.**
  iii. **No Expansion joint is Required.**
  iv. **Repairing is easy.**
  v. **Bricks are not completely impervious, but mortar lining helps to become impervious.**
  vi. **Erosion is rare and resistance is less.**

DESIGN OF UN-ERODIBLE CHANNELS

Brick Lining



Concrete Lining

Table 6.6 Thickness of cement concrete lining

Canal discharge (cumecs)	*Water depth (m)*	*Lining thickness (cm)*	
up to 5	up to 1.0	5	Tolerance in thickness is ± 10 mm
5 – 50	1.0 – 2.5	6 – 7.5	
50 – 200	2.5 – 4.5	7.5 – 10	
200 – 300	4.5 – 6.5	9 – 10	
300 – 700	6.5 – 9.0	12 – 15	

CANAL LINING AND WASTELAND

Pre-Cast Concrete Lining

- **It is made of precast concrete slabs of 60 cm x 60 cm x 5 cm which are set along the well prepared and compacted sub grade. A network of 6 mm diameter rod is provided at 10 mm centre.**

- ***The proportion of concrete is 1 : 2 : 4. The joints of the slab are finished with 1 : 3 cement mortar. Expansion joints are also placed at suitable points. Curing is done for two weeks figure enclosed.***

CANAL LINING AND WASTELAND

Cement Mortar Lining

- **This type of lining is recommended for canal in full cutting where hard soil or clayey soil is available. *The thickness of cement mortar varies from 1.5 cm to 3.5 cm. Sub grade is prepared by ramming and cement mortar is laid uniformly*.**

- **Curing is necessary for two weeks. Surface is finished with cement polish. Lining is purely impervious, but is not durable figure enclosed.**

CANAL LINING AND WASTELAND

Soil Cement Lining

- **Soil and cement is mixed in ratio of 10 percent of cement with dry soil. They are thoroughly mixed. The mixture is laid on the sub grade and compacted.**

- ***This lining controls Seepage of water but growth cannot be controlled. It is recommended for small canal. It is less expensive and can be constructed rapidly.***

CANAL LINING AND WASTELAND

Clay Puddle Lining

- ***Clay Puddle which is fairly impervious is used for this Lining. It prevents 80 percent of seepage. It's very economical and easy to construct.***

Stone or Boulder Lining

- **In hilly areas, boulders are locally available. In such areas, it is recommended to use this lining. Boulders are laid on sides and bed. The joints of boulders are grouted by cement mortar (1:6). Surface is finished by mortar 1:3 to minimize the resistance.**
- ***This lining is durable and impervious, but transporting cost of boulders to the canal site is costly figure enclosed.***

CANAL LINING AND WASTELAND

Selection Criteria of Lining

The following are some factors that govern the selection of type of lining.

Size and Use of Canal

- **If the size of canal is small and is used intermittently, *lining material which can be laid easily at low cost and labour may be used.***

Importance of Canal

- **Larger canal may be used for continuous supply and operation. *Hence, for such canals stronger lining like concrete, brick linings are selected*.**

Canal Slopes

- **If the slopes are more, velocity flow is more. *To resist against action of water with higher velocity better lining like concrete, boulder, precast concrete lining are essential*.**

CANAL LINING AND WASTELAND

Durability

- **It is another criterion to select the type of lining. To make the canal durable most strong and impervious linings are selected.**

Economy

- ***Economy of lining is measured by benefit-cost ratio*. Economical linings are those which yield maximum benefit-cost ratio. Although initial cost of some of the linings are high, but eventually benefit-cost ratio with time is more.**

Life of the Project

- **Most of the projects have life span of forty to fifty years, accordingly type of lining should be recommended keeping in mind the life of the project.**

Availability of Construction Materials

- ***The expenditure of lining depends on availability of construction materials, carriage charge, etc.* To reduce the expenditure of lining, locally available materials of the project should be utilized.**

IRRIGATION CANALS

Open Channel Flow (Lined Channels)

Manning's Formula;

$$V = 1/n\ R^{2/3}\ S^{1/2} \quad \text{for MKS}$$

$$V = \frac{1.486}{n} R^{2/3}\ S^{1/2}$$

R = Hydraulic Mean Radius = A/P

S = Longitudinal Water Surface Slope

n = Manning's Constants

The value of n depends upon the surface resistance. It is more for the rough surface and laser impermeable friction less surface. The value generally various from 0.14 to 0.4

IRRIGATION CANALS

Open Channel Flow (Lined Channels)

The **CHEZY FORMULA** for *steady, uniform flow*, developed in Problem 1, is

$$V = C\sqrt{RS} \qquad (1)$$

where V = average velocity in ft/sec, C = coefficient,

R = hydraulic radius, S = slope of water surface or of the energy gradient or of the channel bottom; these lines are parallel for steady, uniform flow.

COEFFICIENT C can be obtained by using one of the following expressions.

$$C = \sqrt{\frac{8g}{f}} \qquad (2)$$

$$C = \frac{41.65 + \frac{.00281}{S} + \frac{1.811}{n}}{1 + \frac{n}{\sqrt{R}}\left(41.65 + \frac{.00281}{S}\right)} \qquad \text{(Kutter)} \qquad (3)$$

Calculation of Manning's Constant (n)

Manning' formula (1889):

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

S = slope of energy line (for a uniform flow conditions, it is equal to slope of water surface and channel bed slope)

n = Manning's roughness coefficient, also called as resistance to flow, different for different ,materials, tables are available for n value, difficult to determine for channels, concept of composite roughness for natural channels may have to be considered, it can greatly affect the computational results

Chezy's formula (1775):

$$Q = AC\sqrt{RS}$$

Relationship between 'n' & 'c':

$$C = R^{1/6}/n$$

Calculation of Manning's Constant (n)

Procedure:

1. Set a particular slope of the flume
2. Start the pump; allow the flow in the flume to be stabilized.
3. Determine the flow rate in the flume
4. Take three readings of depth of flow in flume at different points and average it for a particular flow rate in the flume.
5. Change the flow rate through the flume.
6. Again allow the flow in the flume to be stabilized.
7. Again take three readings of depth of flow in flume at different points and average it.
8. Repeat the whole procedure (at least 6 readings) for different discharges in the flume

Specific Energy

Basic Terminology:

Critical flow:

It is the flow that occurs when the specific energy is minimal for a given discharge.

It can be seen in Fig. that a point will be reached where the specific energy is minimum and only a single depth occurs. At this point, the flow is termed as critical flow.

Super Critical flow:

The flow for which the depth is less than critical is (velocity is greater than critical) is termed as supercritical flow.

Sub Critical flow:

Flow with low velocity and larger depth. (Froude No. < 1)

Critical Depth:

The depth of flow of water at which the specific energy is a minimum is called critical depth.

$$d_c = [q2/g]^{1/3}$$

Critical Velocity:

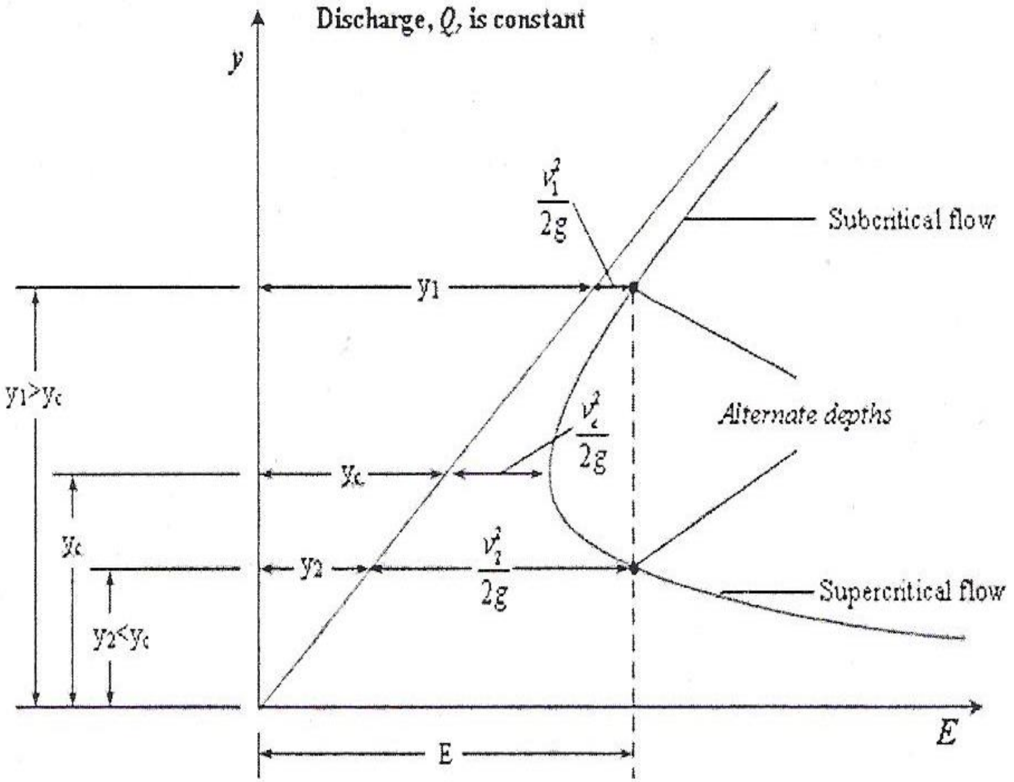
The velocity of flow at the critical depth is known as critical velocity.

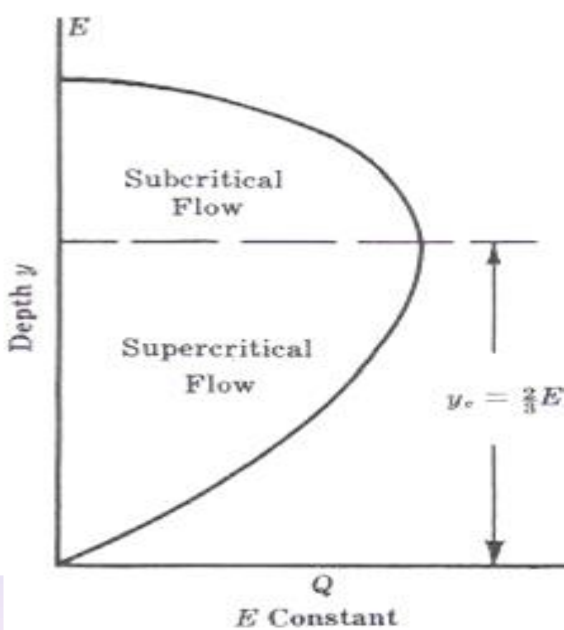
Alternate Depths:

For any value of the specific energy other than critical one, there are two depths, one greater than the critical depth and other smaller than the critical depth. These two depths for a given specific energy are called alternate depths.

Specific Energy Diagram

It is a plot between specific energy as a function of depth of flow.





Procedure:

1. Start the pump to maintain a constant discharge in hydraulic flume apparatus.
2. Allow the flow in the flume to be stabilized.
3. Take three readings of depth of flow in the flume at different points and average it.
4. Change the slope of the flume by automatic system attached to the apparatus.
5. Again allow the flow in the flume to be stabilized.
6. Again take three readings of depth of flow in flume at different points and average it.
7. Repeat the whole procedure by changing the slope of the flume.
8. Develop a specific energy curve from observed data & calculations.

DESIGN OF UN-ERODIBLE CHANNELS

A) Economical Rectangular Channel

Consider Figure 10.3.

$$A = \text{Area of the channel} = By$$

$$\therefore \quad B = \frac{A}{y}$$

$$P = B + 2y = \frac{A}{y} + 2y$$

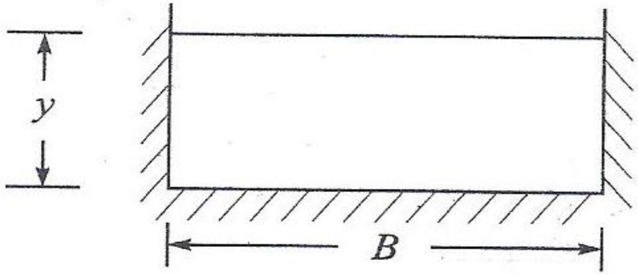


Figure 10.3 Economic rectangular channel, $B = 2y$, $R = \frac{y}{2}$

Taking the derivative of P with respect to y and equating to zero for minimum,

$$\frac{dP}{dy} = A(-1)\frac{1}{y^2} + 2 = 0$$

DESIGN OF UN-ERODIBLE CHANNELS

$$\frac{-A}{y^2} + 2 = 0$$

$\therefore$
$$\frac{A}{y^2} = 2$$

or
$$A = 2y^2$$

or
$$By = 2y^2$$

$\therefore$
$$B = 2y \quad \text{or} \quad y = \frac{B}{2} \tag{10.9}$$

Equation (10.9) is the relation between B and y for economic section.

Again
$$R = \frac{A}{P} = \frac{B \cdot y}{B + 2y} = \frac{2y \cdot y}{2y + 2y} = \frac{2y^2}{4y} = \frac{y}{2}$$

$\therefore$
$$R = \frac{y}{2} \tag{10.10}$$

DESIGN OF UN-ERODIBLE CHANNELS

B) Trapezoidal Section

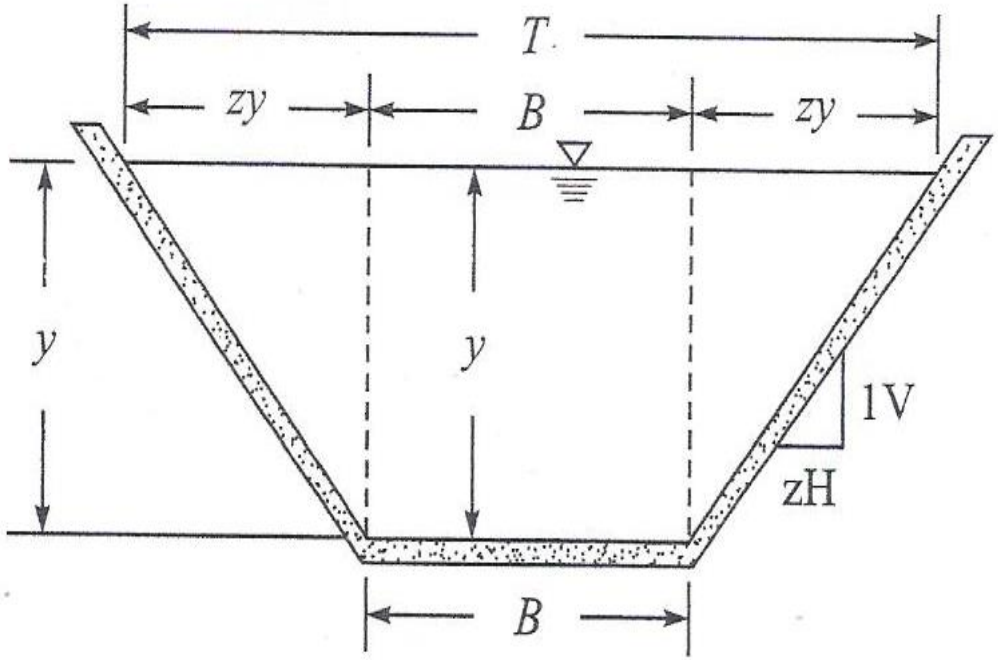


Figure 10.1 Trapezoidal section.

$$A = (B + zy)\, y = By + zy^2$$

$$\therefore \quad B = \frac{A}{y} - zy \qquad (10.5)$$

DESIGN OF UN-ERODIBLE CHANNELS

Top width $$T = B + 2zy$$

$$P = B + 2y\sqrt{1+z^2}$$

or $$P = \frac{A}{y} - zy + 2y\sqrt{1+z^2}$$

Assuming A and z to be constant, P is differentiated with respect to y and equated to zero for minimum.

i.e., $$\frac{dP}{dy} = -\frac{A}{y^2} - z + 2\sqrt{1+z^2} = 0$$

∴ $$\frac{A}{y^2} + z = 2\sqrt{1+z^2}$$

or $$\frac{By + zy^2}{y^2} + z = 2\sqrt{1+z^2}$$

or $$\frac{B + zy}{y} + z = 2\sqrt{1+z^2}$$

or $$B + zy + zy = 2y\sqrt{1+z^2}$$

∴ $$\left(\frac{B + 2zy}{2}\right) = y\sqrt{1+z^2} \qquad (10.6)$$

i.e., half of top width = length of one slanting side, which is the condition for economic section.

DESIGN OF UN-ERODIBLE CHANNELS

For the economic section, hydraulic radius ($R = A/P$) is obtained as:

$$R = \frac{A}{P} = \frac{(B + zy)y}{B + zy\sqrt{1 + z^2}}$$

Substituting the value of B from Eq. (10.6) and simplifying

$$R = \frac{y}{2} \tag{10.7}$$

Thus, channel section is economic when hydraulic radius is half of the depth.

DESIGN OF UN-ERODIBLE CHANNELS

Example-I

An irrigation canal has a discharge of 10 m^3/sec. Mannings n for the non-erodible surface is 0.025 side slope is taken 2H : 1V. Design the section for economic condition if the bed slope is 0.0016.

Solution:

$$Q = 10 \text{ m}^3/\text{sec}$$

$$n = 0.025$$

$$z : 1 = 2 : 1, \qquad \text{i.e., } z = 2$$

$$s_b = 0.0016$$

From economic condition, $\dfrac{B + 2zy}{2} = y\sqrt{1 + z^2}$

$$\frac{B + 2zy}{2} = y\sqrt{5} \qquad (\because \; z = 2)$$

$$\frac{B}{2} + 2y = y\sqrt{5} \qquad (1)$$

DESIGN OF UN-ERODIBLE CHANNELS

Again $$AR^{2/3} = \frac{Qn}{\sqrt{s_b}} = \frac{10 \times 0.025}{\sqrt{0.0016}} = 6.25$$

or $$(B + zy)y \cdot \left(\frac{(B + zy)y}{B + zy\sqrt{1 + z^2}} \right)^{2/3} = 6.25$$

$$\frac{[(B + 2y)y]^{5/3}}{(B + 2y\sqrt{5})^{2/3}} = 6.25 \qquad (2)$$

Now two Eqs. (1) and (2) and two unknowns B and y,

Solving simultaneously,

$$B \simeq 6 \text{ m}$$
$$y = 0.962 \text{ m} \simeq 1 \text{ m}$$

Provide a FB of 20 per cent, Full Supply Depth (FSD) = $0.962 + 0.962 \times 0.2 = 1.15$ m

and $$B = 6 \text{ m}$$ **Ans.**

Example-II

Design a non-erodible boundary irrigation canal laid on a slope of 0.0016 with discharge 9.1 m^3/sec. Assume Mannings $n = 0.015$ with permissible velocity of 1.3 m/sec.

Solution:

$$Q = 9.1 \text{ m}^3/\text{sec}$$
$$s_b = 0.0016$$
$$n = 0.015$$

$V = 1.3$ m/sec. Assume side slope 0.5H : 1V i.e., $z = 0.5$

$$A = \frac{Q}{V} = \frac{9.3}{1.3} = 7 \text{ m}^2 = (B + 0.5y)\, y$$

$$\therefore \qquad By + 0.5y^2 = 7 \qquad (1)$$

$$V = \frac{1}{n}\left(\frac{A}{P}\right)^{2/3} s_b^{1/2} \Rightarrow 1.3 = \frac{1}{0.015}\left(\frac{7}{B + 2y\sqrt{1+0.5^2}}\right)^{2/3} (0.0016)^{1/2}$$

Simplifying $\quad B = 14.359 - 2.36\, y \qquad (2)$

Substituting this value of B in Eq. (1)

$$1.736\, y^2 - 14.359\, y + 7 = 0$$

Solving $\quad y = 0.52$ m and 7.7 m

when $\quad y = 0.52$ m, $\quad B = 13.2$ m

when $\quad y = 7.7$ m, $\quad B = -$ve so this y is neglected.

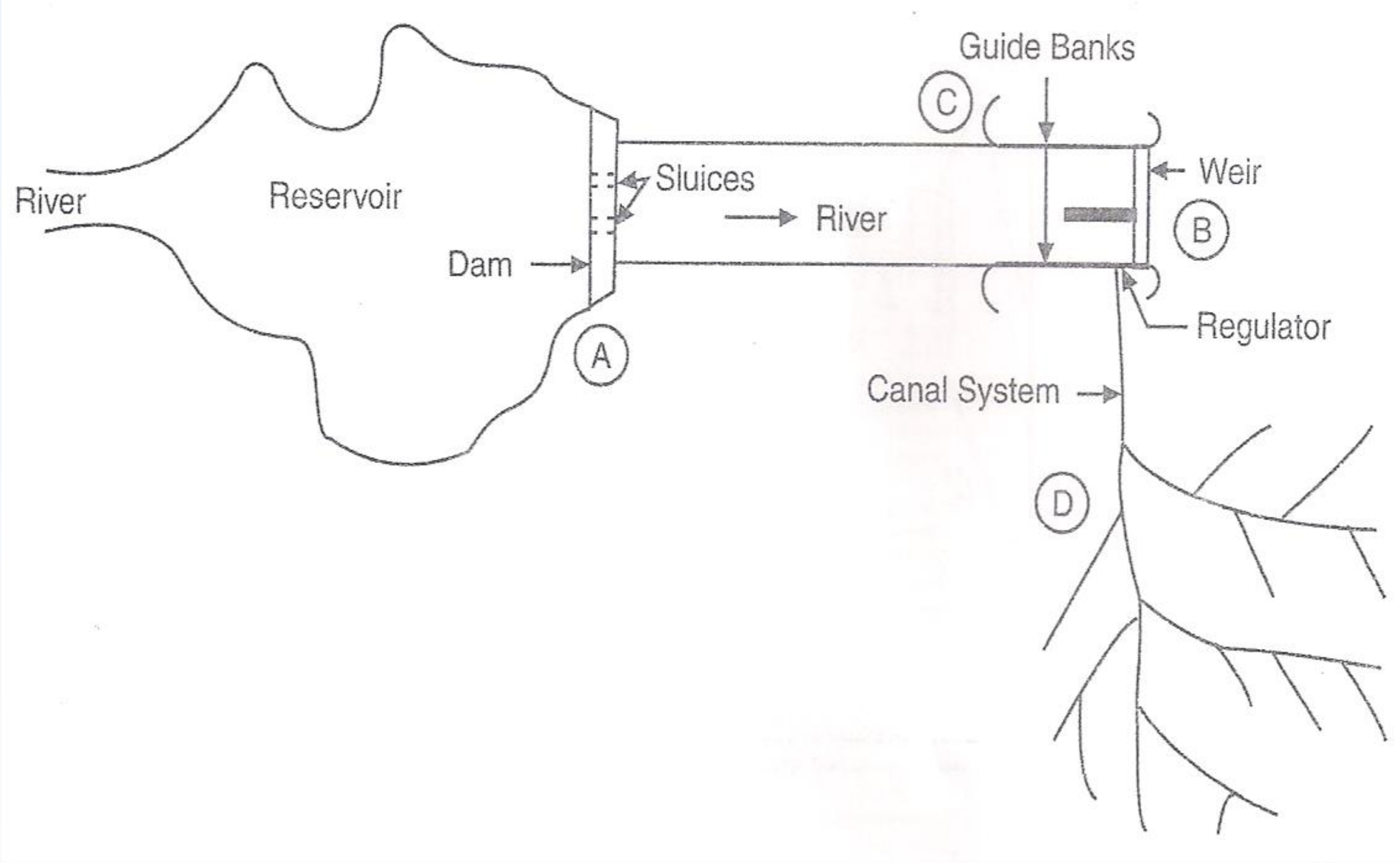
Assuming a 25 per cent FB, $y = (0.52 + 0.13)$ m

$$y = 0.65 \text{ m}$$
$$B = 13.2 \text{ m}$$

Ans.

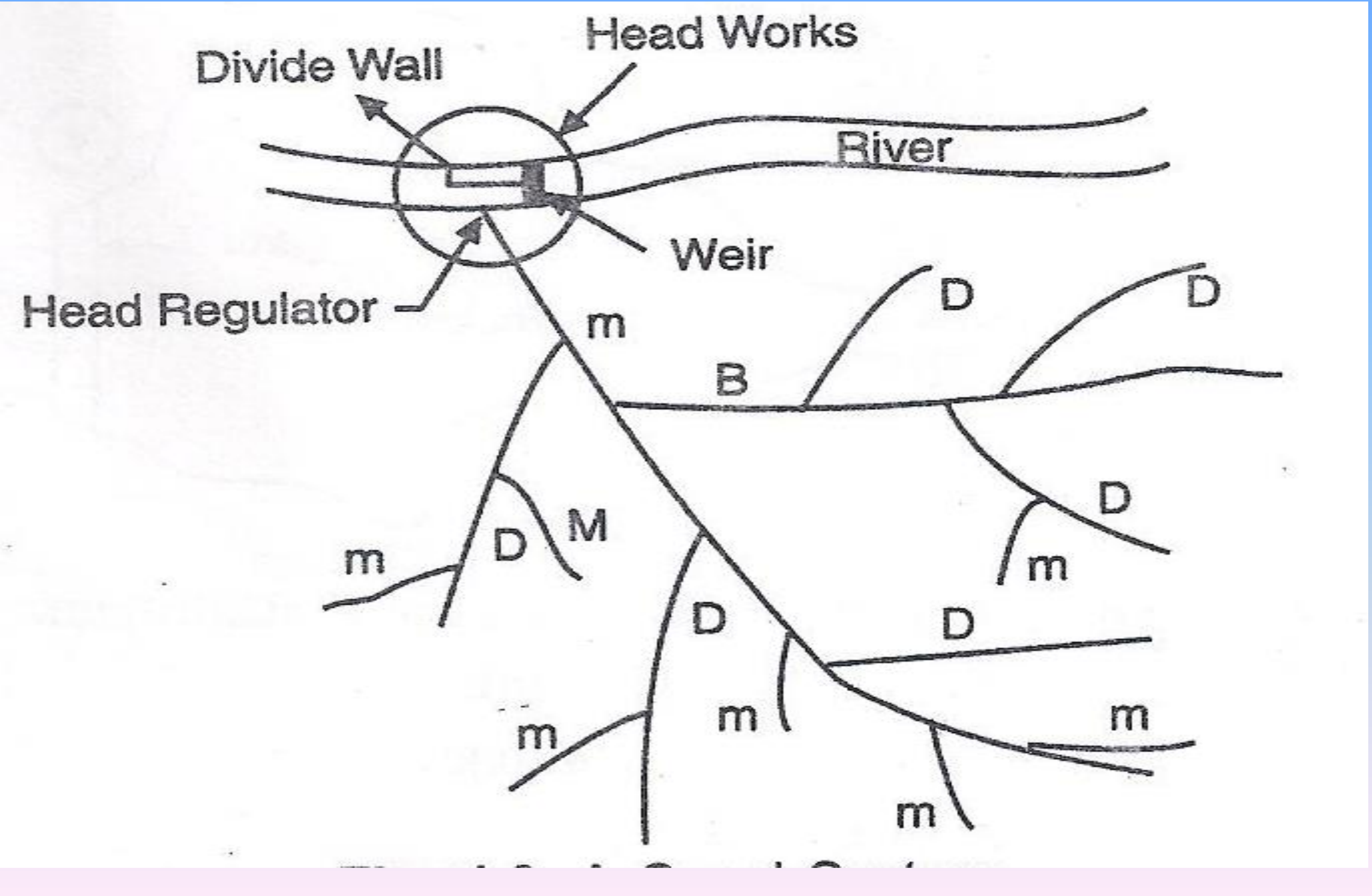
LAYOUT OF IRRIGATION CHANNELS

Layout of a Canal System



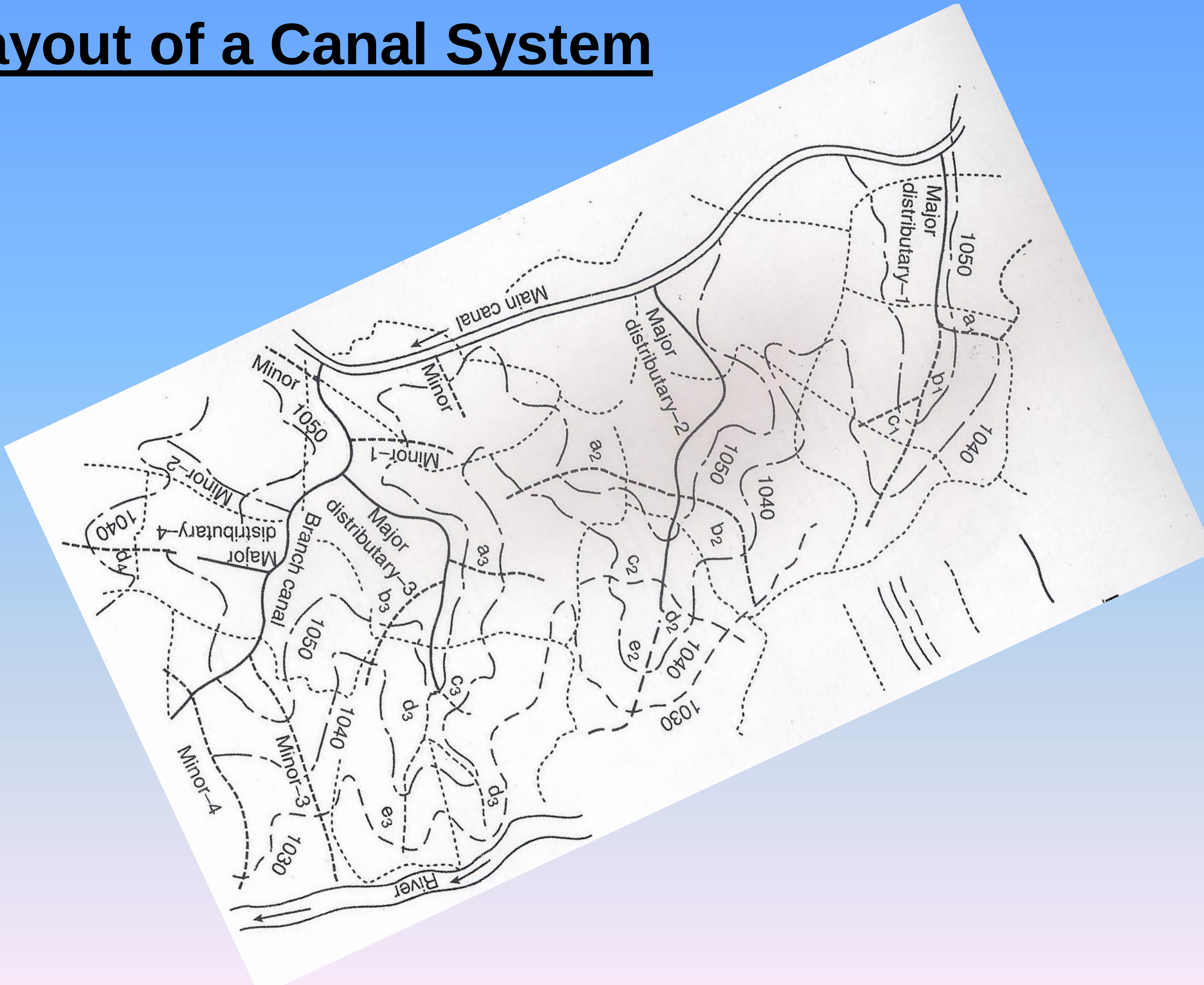
IRRIGATION CANALS

Layout of a Canal System



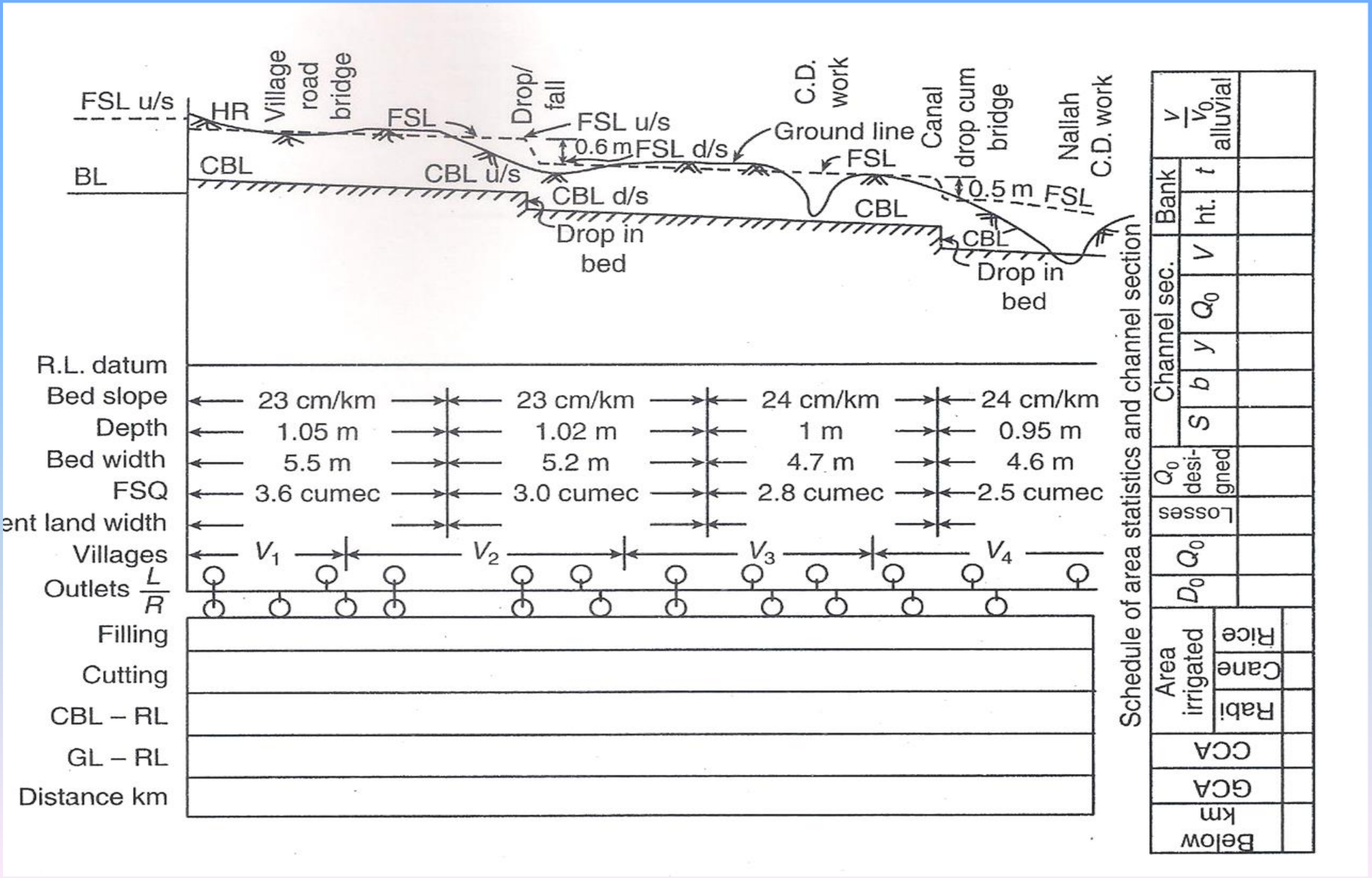
IRRIGATION CANALS

Layout of a Canal System



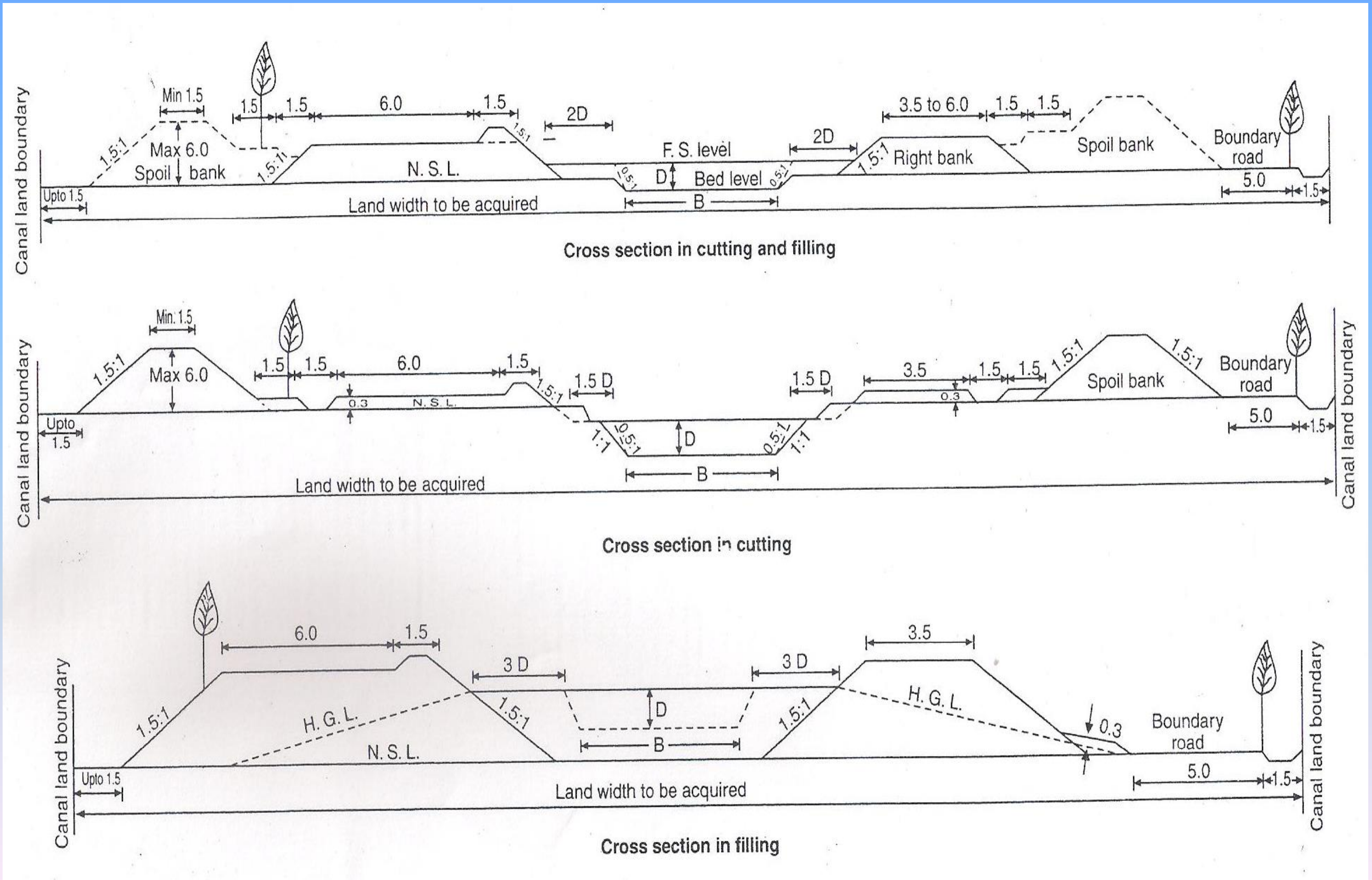
IRRIGATION CANALS

L-Section of Canal



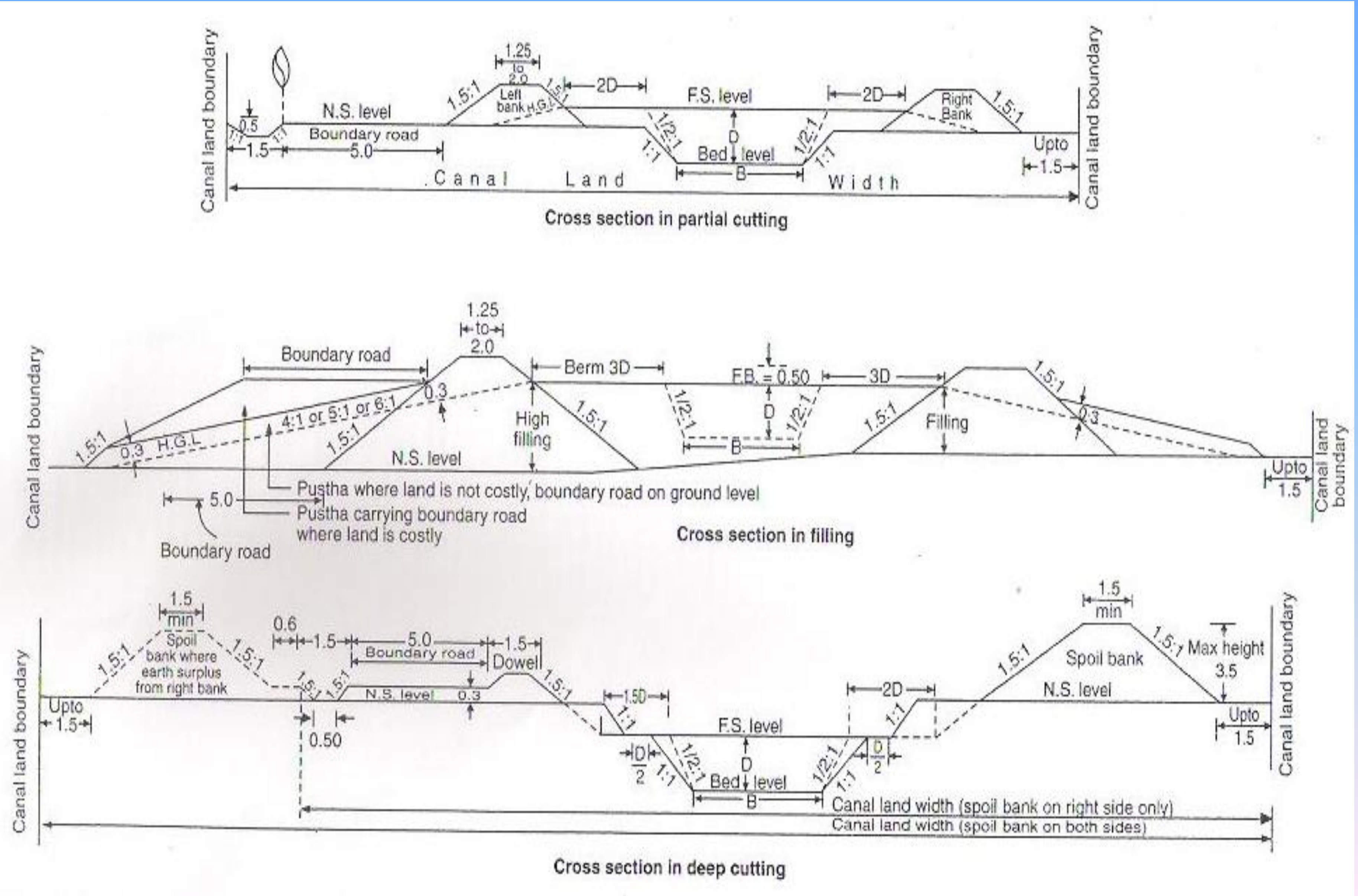
IRRIGATION CANALS

Typical Cross Section of Unlined Main/ Branch Canal



IRRIGATION CANALS

Typical Cross Section of Unlined Disty and Minors



IRRIGATION CANALS

Components of the Canal

i. ***Canal Banks***

ii. ***Berm***

iii. ***Free Board (FB)***

iv. ***Side Slope***

v. ***Borrow Pit Area***

vi. ***Land Width***

vii. ***Spoil Bank***

viii. ***Dowel or Dowla***

ix. ***Service Road***

IRRIGATION CANALS

Maintenance of Canal

When irrigation canal system is put into operation after construction, its maintenance is required for proper and efficient functioning. The canals are required to maintained regularly due to following causes;

i) ***Siltation in Canal***

ii) ***Weed growth***

iii) ***Overflowing of Canal Banks***

iv) ***Breaching of Canal Banks***

v) ***Excess Seepage***

vi) ***Evaporation***

IRRIGATION CANALS

Classification of Canals

The canals are classified in the following categories;

A) Based upon source of supply and system of supply

i) ***Permanent Canals***

ii) ***Perennial Canals***

iii) ***Non-Perennial Canals***

iv) ***Inundation Canals***

B) Based upon Financial Aspect

i) ***Productive Canals***

ii) ***Protective Canals***

IRRIGATION CANALS

Classification of Canals

C) Based upon the Function Performed

i) ***Irrigation Canals***
ii) ***Link Canals***
iii) ***Feeder Canals***
iv) ***Navigation Canals***
v) ***Power Canals***

D) Based upon Discharge

i) ***Mian Canals***
ii) ***Branch Canals***
iii) ***Distributaries***
iv) ***Minors***
v) ***Sub Minors***
vi) ***Water Course***