Classification o f Water in the Soil according to the Plants' Usage:

1- Excess Water.

2- Total Available Water.

3- Ready Available Water.

4- Unavailable Water.

1- Excess Water:

- It is the moisture content more than the field capacity of the soil.
- This water percolates to the deep layers of the soil where the plant can't use.

2- Total Available Water:

- It is the moisture content in the range between the field capacity and the permanent wilting point.
- The plant can use this water in general.

3- Readily Available Water:

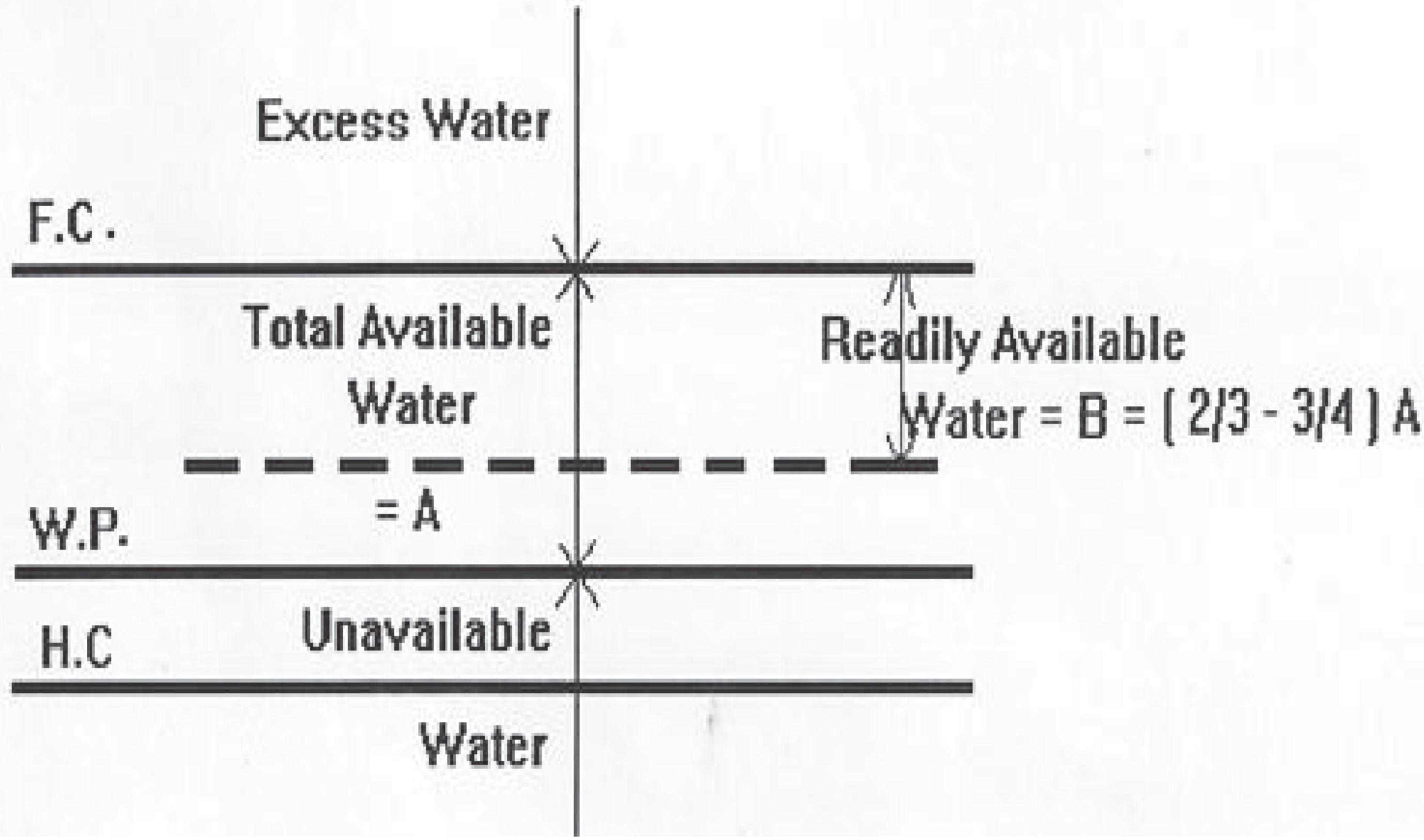
- So, the readily available water is equal to 2/3 - 3/4 of the total available water.

4- Unavailable Water:

It is the moisture content less than the permanent wilting point.

It is obvious that it is impossible that the plant can use this water as it already died.

<u>Classification o f Water in the Soil according to the Plants' Usage</u>



The Consumptive Use C_U:

- It is the quantity of water required, in a certain period, for the plant' s growth in addition to the losses due to the transpiration and evaporation processes.
- quantities of water are expressed as either volumes or equivalent depths.

Example:

- The rainfall, in an area is 1.5 mm/day.

For an area of one feddan,

The quantity of water from the rainfall=

$$(1.5/1000) \times 4200 = 6.3\ m^3/\text{Fed./day}$$

$$\mathbf{C_u = 4200 \times R_{de} \times \frac{\gamma_s}{\gamma_w} \times R.A.W.}$$

C_u: The consumptive use, (m^3/Fed)

1 Feddan = 4200 m^2

R_{de}: Effective root depth, m

γ_s: Specific weight of the soil, t/m^3.

γ_w: Specific weight of the water, =1 t/m^3.

R.A.W. : Readily available water.

The field irrigation requirements F_r:

- Is the quantity of water required daily for both the plant's growth and the field losses per feddan (unit area).
- The field losses include the water lost due to surface run-off and deep percolation.

$$F_r = \frac{D_c - r_e}{1 - L_f}$$

F_r: The field irrigation requirements, (m^3/Fed/day)

D_c: The daily consumptive use, (m^3/Fed/day)

L_f: The field losses (%).

r_e: The quantity of effective rainfall, (m^3/Fed/day)

note

- For arid regions, there is no rainfall.
- For semi-arid regions, the quantity of rainfall is small.
- However, the quantity of effective rainfall is assumed to be zero if it is not given in the problems.

The maximum period, in days, between irrigation processes ($P_{max.}$) can then be calculated as follows:

$$P_{max} = \frac{C_u}{F_r} \text{ days}$$

The field water duty (F.W.D.)

is the quantity of water applied to the field and it is expressed as (m^3/Fed/day)

$$F.W.D. = \frac{F_r * P_{max}}{On - interval}$$

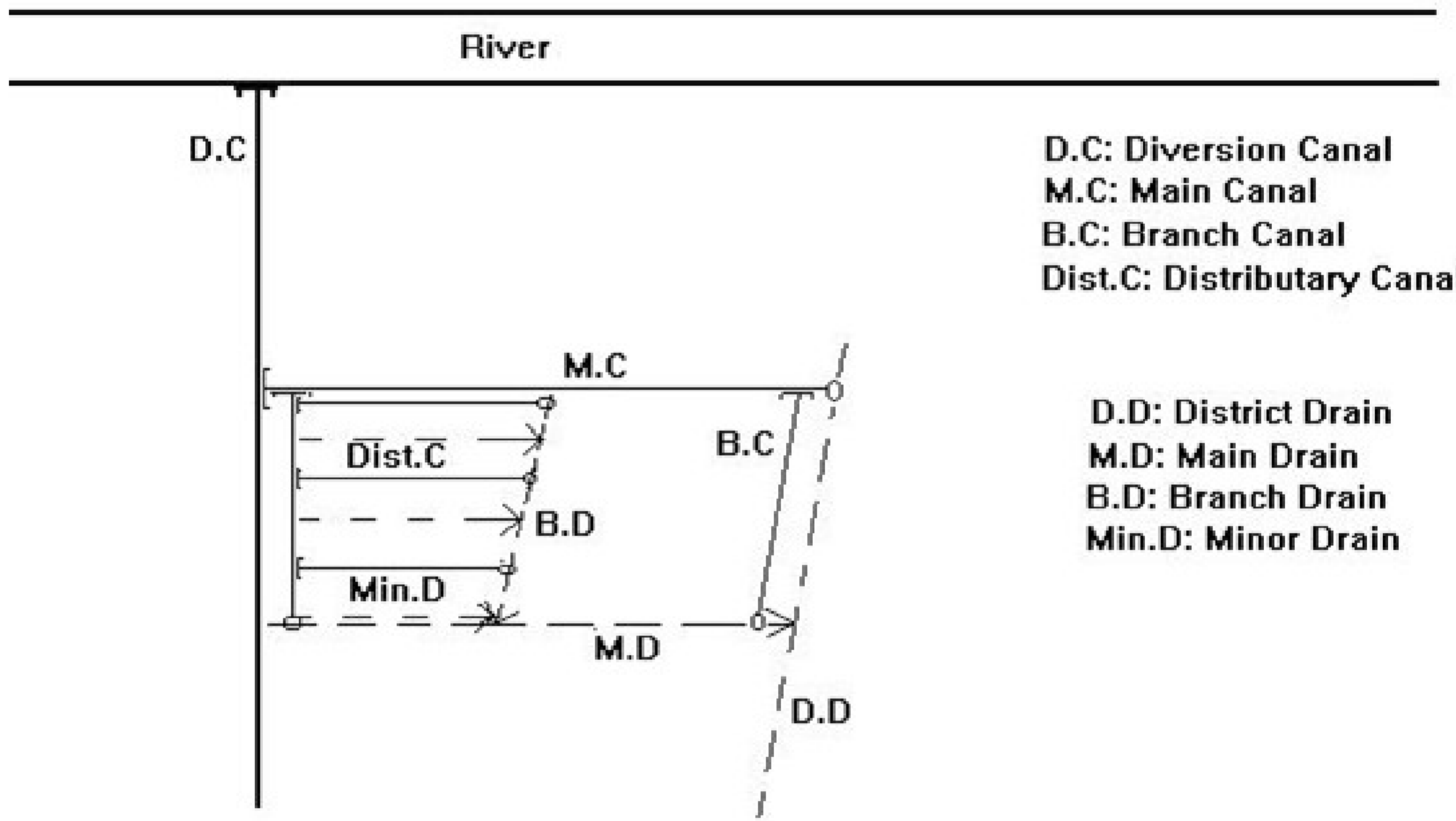
On-interval is the number of days in which irrigation is permitted by the water existed in the canals.

On-interval (Opening period)

is the number of days in which irrigation is permitted by the water existed in the canals.

Off-interval (Closing period)

is the number of days in which irrigation is prevented in the canals.



Irrigation and Drainage Networks

The conveyance losses due to:

1. include seepage of water from the bed and the sides of the canals.
2. evaporation of water from the surfaces of the canals.
3. transpiration by plants and weeds along the canals.

These losses are considered when calculating the water duty for the canals as follows:

D.C.W.D. = F.W.D. x 1.10

B.C.W.D. = F.W.D. x 1.15

M.C.W.D. = F.W.D. x 1.20

Where, D.C.W.D.: Distributor canal water duty.

B.C.W.D.: Branch canal water duty.

M.C.W.D.: Main canal water duty.

Example 1:

An area of clayey soil has a specific weight of 1.2 t/m^3,a field capacity of 36% and a wilting point of 20 %. This area is cultivated by cotton that requires a quantity of water of 24 m^3/day for each feddan in July when its effective root depth is 90 cm.

- If the field losses are 40%, determine the field irrigation requirements?
- Calculate the maximum period between irrigation processes?
- If the on-interval is 5 days, determine the water duties for the field and the distributor canal?
- Explain in detail how to increase the efficiency of the irrigation process?

The Solution

Given:

γ_s = 1.2 t/m^3

F.C. = 36%

W.P. = 20%

D_c = 24 m^3/fed./day

R_{de} = 90 cm = 0.9 m

r_e = 0 (as it is not given)

L_f = 0.40

On-interval = 5 days

Required:

F_r, $P_{max.}$, F.W.D. & D.C.W.D.?

$$F_r = \frac{D_C - r_e}{1 - L_f} = \frac{24 - 0}{1 - 0.4} = 40\, m^3/fed./day$$

$$P_{max} = \frac{C_u}{F_r}$$

$$C_u = 4200 \text{ x } R_{de} \text{ x } \frac{\gamma_s}{\gamma_w} \text{ x R.A.W.}$$

$$\text{R.A.W.} = (\frac{2}{3} : \frac{3}{4}) \text{ x (F.C. - W.P.)}$$

$$= (\frac{3}{4}) \text{ x } (0.36 - 0.20) = 0.12$$

Assume γ_w = 1 t/m^3

Then $C_u = 4200 * 0.90 * \frac{1.2}{1} * 0.12 = 544.32\, m^3/fed.$

Thus $P_{max} = \frac{544.32}{40} = 13.6 = 13 days$

$$F.W.D = \frac{F_r * P_{max}}{On - interval} = \frac{40 * 13}{5} = 104\, m^3/fed./day$$

$$D.C.W.D = F.W.D.* 1.10 = 104 * 1.1$$

$$= 114.4\, m^3/fed./day$$

Irrigation efficiency

تعتمد كفاءة عملية الري علي عدة عوامل مثل :

1- نوع التربة ونسبة الأملاح بها ونوع النبات نفسه.

2- منسوب المياه الجوفية.

3- درجة تجهيز الأرض.

4- طريقة الري.

5- فواقد نقل المياه خلال شبكة الري.

(1) Water conveyance efficiency (E_c):

كفاءة نقل وتوصيل المياه

$$E_c = \frac{w_f}{w_r} * 100$$

W_f = water delivered to the farm.

كمية المياه التي تصل الحقل

W_r = water delivered from the source.

كمية المياة الخارجة من المصدر " نهر أو خزان "

(2) Water application efficiency (E_a): كفاءة الري

$$E_a = \frac{w_s}{w_f} * 100$$

W_s = water stored in the root zone of the plants.

كمية المياه المختزنة في منطقة جذور النبات

W_f = water delivered to the farm.

كمية المياه التي تصل الى الحقل

(3) Water use efficiency (E_U): كفاءة استخدام مياه الري

$$E_U = \frac{w_u}{w_f} * 100$$

W_U = water beneficially used on the farm.

كمية المياة المستعملة فعلا في الحقل.

W_f = water delivered to the farm.

كمية المياه التي تصل الى الحقل

(4) Water storage efficiency (E_s):

كفاءة تخزين المياه في منطقة الجذور

$$E_s = \frac{w_s}{w_n} * 100$$

W_s = water stored in the root zone of the plants.

كمية المياه المختزنة في منطقة جذور النبات اثناء عملية الري

W_n = water needed in the root zone.

كمية المياه الواجب توفيرها في منطقة الجذور

(5) Water distribution efficiency (E_d):

كفاءة توزيع المياه علي الحقل

$$E_d = (1 - \frac{y}{d}) * 100$$

d = average depth of stored along the run during the irrigation.

متوسط سمك طبقة المياه المخزنة في منطقة الجذور خلال فترة الري

y= average numerical deviation in depth of water stored from average depth stored.

متوسط تغير سمك طبقة المياه المختزنة في منطقة الجذور في أول الحقل وآخره

Example 2:

A stream of 135 lit/s was delivered from a canal and 100 lit/s were delivered to the field. An area of 1.6 hectares was irrigated in 8 hours. The effective depth of root zone was 1.8m. The water required for the root zone was 2880m^3. The runoff loss in the field was 432m^3. The depth of water penetration varied linearly from 1.8m at the head end of the field to 1.2m at the tail end.

Available moisture holding capacity of the soil is 20cm per meter depth of soil. If the irrigation starts when moisture level reaches 40% of the available moisture, determine:

a- Water conveyance efficiency.

b- Water application efficiency.

c- Water storage efficiency.

d- Water distribution efficiency.

Water conveyance efficiency (E_c):

كفاءة نقل وتوصيل المياه

$$E_c = \frac{w_f}{w_r} * 100$$

W_f = water delivered to the farm.

كمية المياه التي تصل الحقل

W_r = water delivered from the source.

كمية المياة الخارجة من المصدر " نهر أو خزان "

Solution

(a) Water conveyance efficiency:

$$E_C = \frac{w_f}{w_r} * 100 = \frac{100}{135} *100 = 74\%$$

Water application efficiency (E_a): كفاءة الري

$$E_a = \frac{w_s}{w_f} * 100$$

W_s = water stored in the root zone of the plants.

كمية المياه المختزنة في منطقة جذور النبات

W_f = water delivered to the farm.

كمية المياه التي تصل الى الحقل

(b) Water application efficiency:

$E_a = \frac{w_s}{w_f} * 100$

W_s = water stored in the root zone = 2880 – 432 (الفواقد) = 2448 m^3

W_f = water delivered to the farm = $\frac{100*8*60*60}{1000}$ = 2880m^3

$E_a = \frac{2448}{2880} * 100 = 85\%$

Water storage efficiency (E_s):

كفاءة تخزين المياه في منطقة الجذور

$$E_s = \frac{w_s}{w_n} * 100$$

W_s = water stored in the root zone of the plants.

كمية المياه المختزنة في منطقة جذور النبات اثناء عملية الري

W_n = water needed in the root zone.

كمية المياه الواجب توفيرها في منطقة الجذور

(c) Water storage efficiency:

$E_s = \frac{w_s}{w_n} * 100$

1م ← 20 سم

1.8م ← y سم

Moisture holding capacity of the root zone $y = \frac{1.8*20}{1}$

$= 36cm$ عمق الماء في منطقة الجذور

تبدأ عملية الري عندما يقل المحتوي الرطوبي ويصل 40% من المحتوي الرطوبي المتاح. ولذلك فإن احتياج النبات يساوي 60%

Moisture needed = 36* (1-0.4) = 21.6cm = 0.22m

Note: 1 hectare= 10,000m^2

= 0.22* 1.6 * 10000 = 3520 m^3

Water storage efficiency = $\frac{2448}{3520}$ * 100 = 69.5%

<u>**Water distribution efficiency (E_d):**</u>

كفاءة توزيع المياه علي الحقل

$E_d = (1 - \frac{y}{d}) * 100$

d = average depth of stored along the run during the irrigation.

متوسط سمك طبقة المياه المخزنة في منطقة الجذور خلال فترة الري

y= average numerical deviation in depth of water stored from average depth stored.

متوسط تغير سمك طبقة المياه المختزنة في منطقة الجذور في أول الحقل وآخره

(d) Water distribution efficiency:

$E_d = (1- \frac{y}{d}) * 100$

d= average depth of water stored = $\frac{1.8+1.2}{2}$ = 1.5m

$y_1 = |1.8 - 1.5| = 0.3m$ $y_2 = |1.2 - 1.5| = 0.3m$

y = average deviation = $\frac{0.3+0.3}{2}$ = 0.3

$E_d = (1- \frac{0.3}{1.5}) * 100 = 80\%$

CHAPTER (4)
Irrigation and crop rotation

The Crop Rotation :

Is the sequence of different crops cultivated in the land during a specific period.

The objectives of the crop rotation:

1) Maintaining the land suitable for being cultivated. That is by keeping a balance between the different food elements in the soil.

2) Optimum usage of the soil and the subsoil. That is by cultivating the crops of short roots after the crops of tall roots, and so on.
3) Giving a sufficient time for land service.
4) Rehabilitating some lands by leaching them from salts. That is by cultivating these lands with rice.

5) Improving the properties of some lands and providing them by natural organic fertilizers. That is by cultivating these lands with clover.

The kinds of the crop rotation:

a) Two turn rotation, where the crop is cultivated each two years.

b) Three turn rotation, where the crop is cultivated each three years.

c) Special rotation, where the main objective is to leach and improve the properties of the lands required to be reclaimed.

The Irrigation Rotation:

Water is discharged in the distributary canals for a specific period called “working period” or “on - interval”.

Then, water is prevented from being discharged in these canals for other period called “closing period” or “off -interval”. The sum of the two periods is called “the length of the irrigation rotation”.

<u>The objectives of the irrigation rotation:</u>

1) Protecting the lands beside the distributary canals from continuous seepage of water.

That is because the distributary canals in the off-intervals act as drains that collect the excess water percolated to these lands during the on- intervals.

2) Helping the irrigation engineer to supervise different areas in sequent periods, which leads to achieving the required distribution of water among the different canals.

3) Helping the farmer to irrigate the land in the on-interval, and to do the required agricultural processes in the off-interval.

4) Decreasing the dimensions required for the sections of the canals. So, the cost is decreased.

5) Decreasing the losses, where the water does not exist in the canals for long periods.

The irrigation rotation can be classified according to:

1) Period of the year.
2) Number of turns.

<u>Period of the year at which the irrigation rotation is executed:</u>

1. Summer irrigation rotation.

- From half of April to the half of August if three turn rotation [6+12]
- From half of April to the half of September if two turn rotation [4+4]

2. Nile irrigation rotation.

From half of August till the end of November.

3. Winter irrigation rotation.

- From the end of November till the half of March.
- It includes the period of January where no water for irrigation is discharged.
- The required irrigation constructions, repairs and cleaning of the canals are well executed during this month.

4. Spring irrigation rotation

- It is done from the half of March till the half of April.

The irrigation rotation according to Number of turns:

1. Two turn irrigation rotation [4+4]

- The distributary canals are divided into two groups A and B of almost equal area served.
- One partial (or intermediate) regulator (P.R.) is constructed on the branch canal at the location that divides the total area served into the two groups A and B.

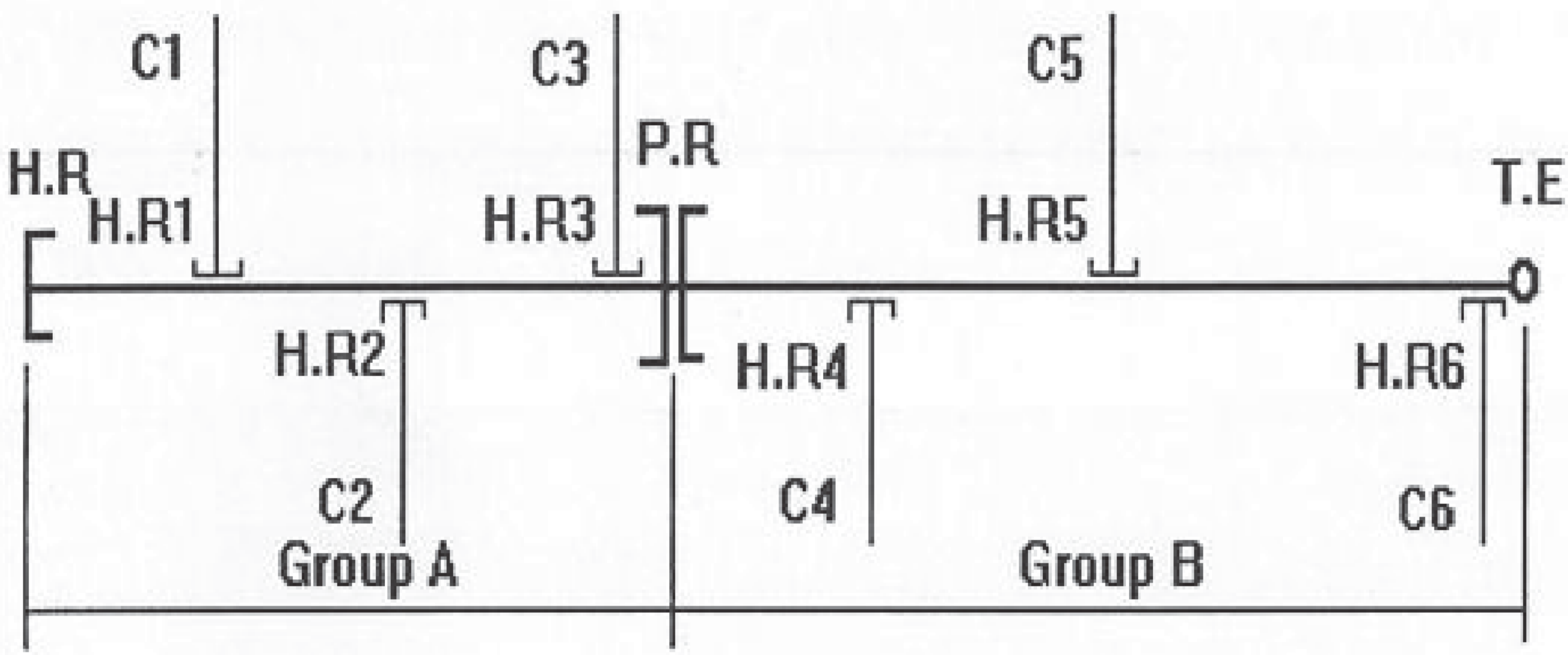
1. Two turn irrigation rotation [4+4]

- At the beginning of the two turn rotation, the P.R. is closed to keep the water required for the group A.
- It has to be noted that the two turn rotation is composed of two equal intervals.

1. Two turn irrigation rotation [4+4]

- The first interval is on-interval for the distributary canals of group A, and also it is off-interval for the distributor canals of group B.
- Similarly, the second interval is off-interval for the distributary canals of group A, and also it is on-interval for the distributor canals of group B.

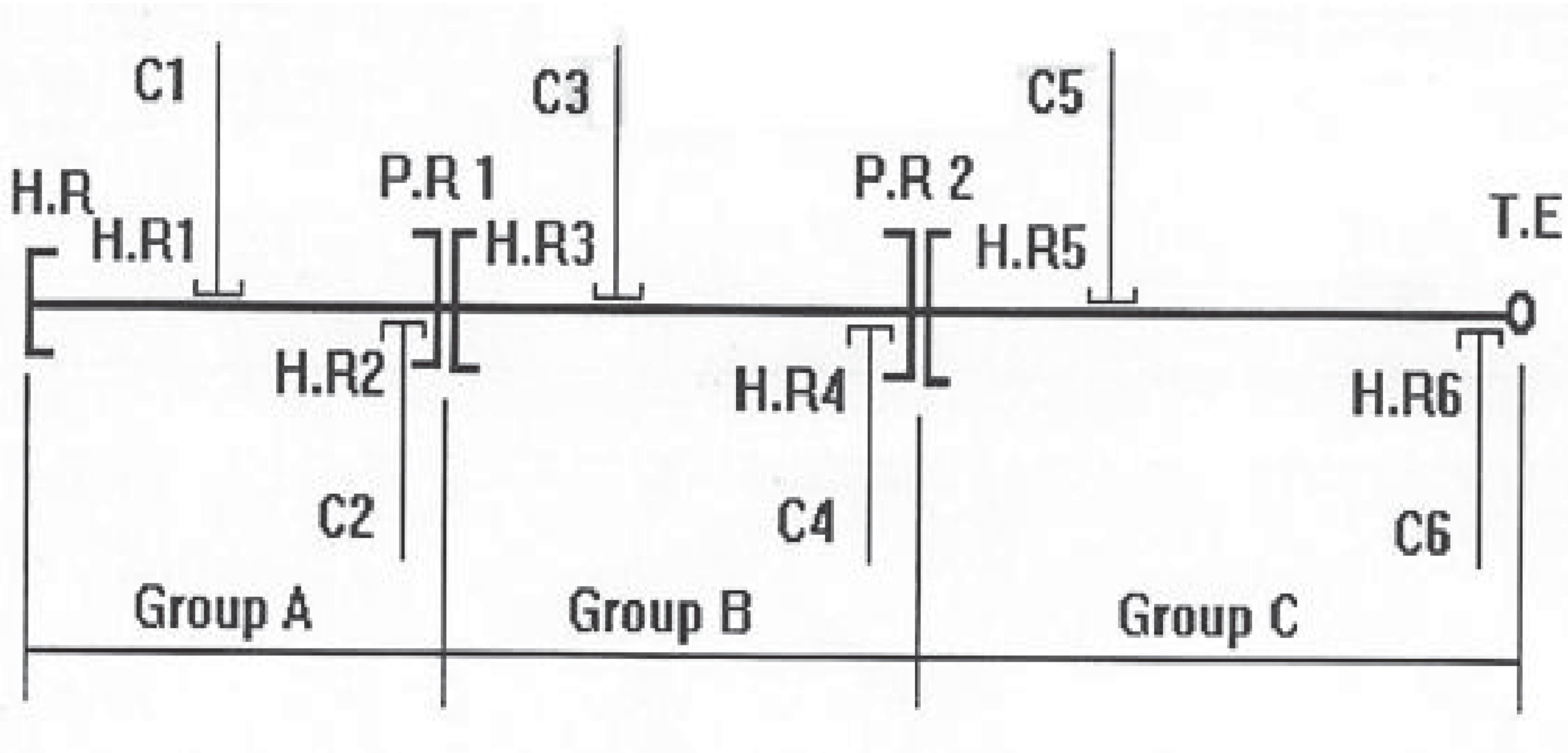
1. **Two turn irrigation rotation [4+4]**



2. Three turn irrigation rotation [6+12]:

- The distributor canals are divided into three groups A, B and C of almost equal area served.
- Two partial regulators (P.R.1 and P.R.2) are constructed on the branch canal at the two locations that divide the total area served into the three groups A, B and C

2. Three turn irrigation rotation [6+12]:



Example (4-1):

A branch canal of 25 km length serves an area of 48,400 feddans and has 6 distributor canals as follows:

Distributary Canal	Location (km)	Area Served (Feddan)
C1	10,L	5,400
C2	10,R	11,100
C3	15,L	10,000
C4	15,R	6,010
C5	21,L	5,900
C6	21,R	8,000

The canal is used for direct irrigation after the km 21.00 to serve the rest of the area served.

It is required to draw a diagram for the branch canal with its distributaries indicating the locations of suggested constructions and showing the area served for each turn in the cases of:

(1) Two turn irrigation rotation?
(2) Three turn irrigation rotation?

The Solution

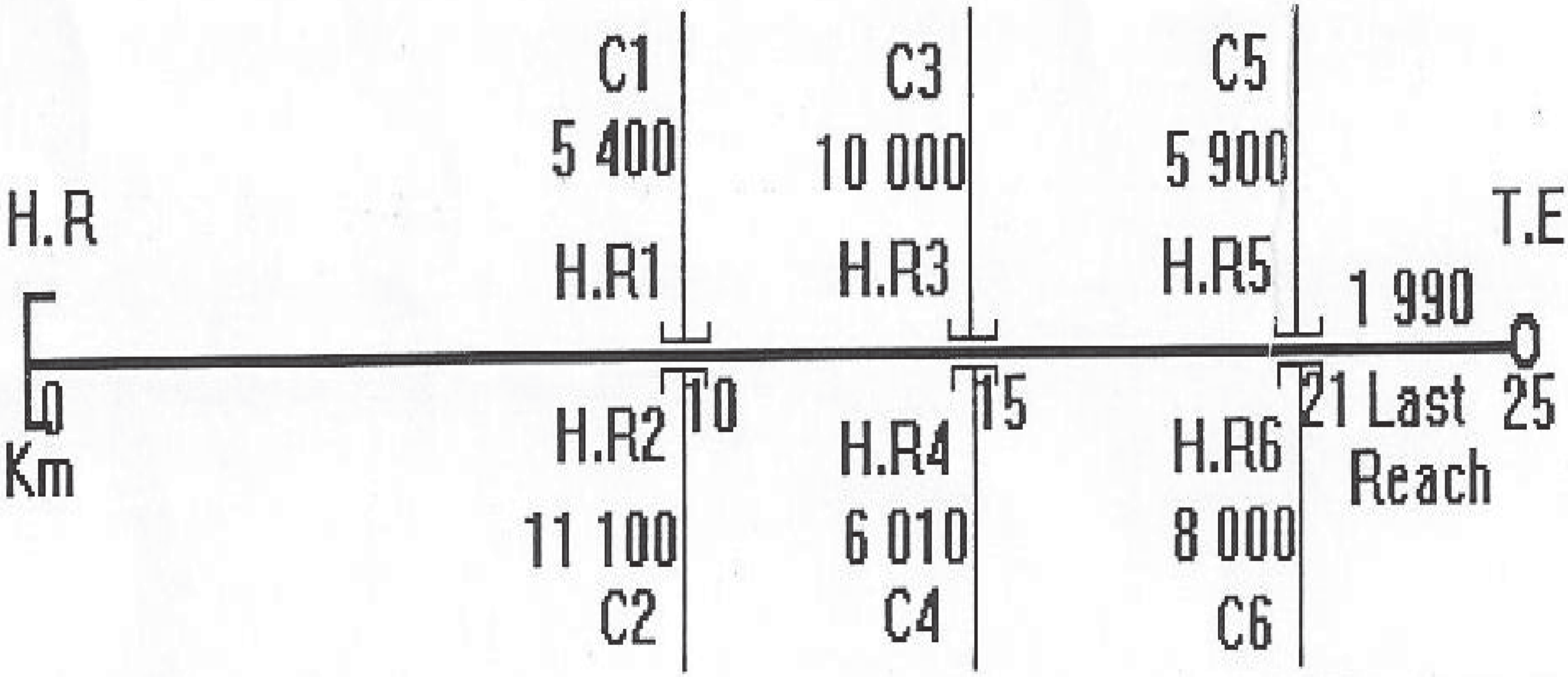
The sum of area served for the 6 distributaries =

5,400 + 11,100 + 10,000 + 6,010 + 5,900 + 8,000 =

46,410 Fed

∴The area served by direct irrigation after km 21.00 =

48,400 – 46,410 = 1,990 Fed

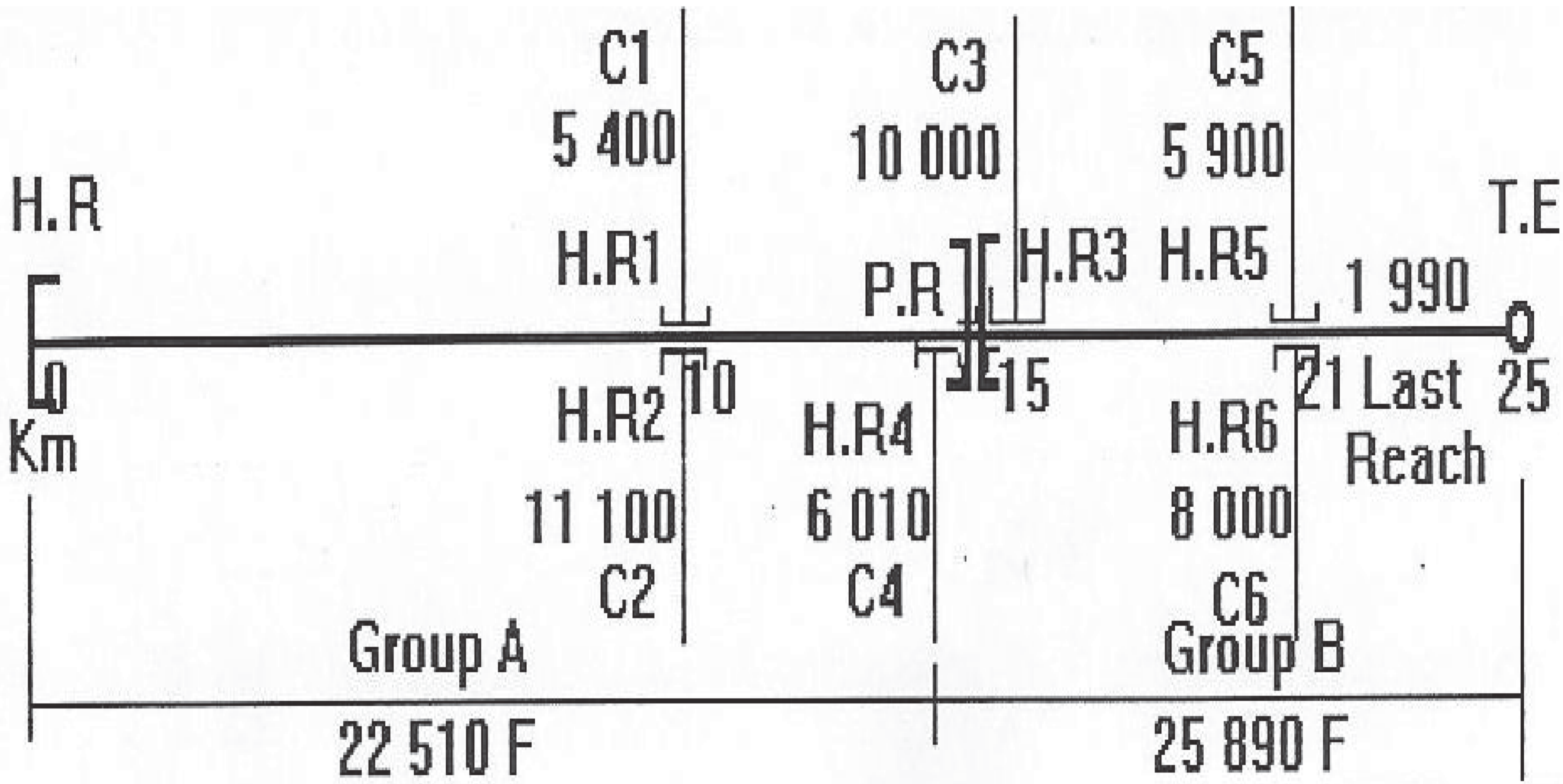

H.R
0
Km
C1
5 400
H.R1
H.R2
10
11 100
C2
C3
10 000
H.R3
15
H.R4
6 010
C4
C5
5 900
H.R5
21 Last Reach
H.R6
8 000
C6
1 990
T.E
25

Two turn irrigation rotation:

Average required area served for each turn = $\frac{48,400}{2}$ = 24,200 Fed.

For the first turn, take group A = C1 + C2 + C4 = 22,510 Fed.

For the second turn, take group B = C3 + C5 + C6 + Direct Irrigation = 25,890 Fed.



C1
5 400
C3
10 000
C5
5 900
H.R
T.E
H.R1
P.R
H.R3
H.R5
1 990
0
Km
10
15
21 Last Reach
25
H.R2
H.R4
H.R6
11 100
6 010
8 000
C2
C4
C6
Group A
Group B
22 510 F
25 890 F

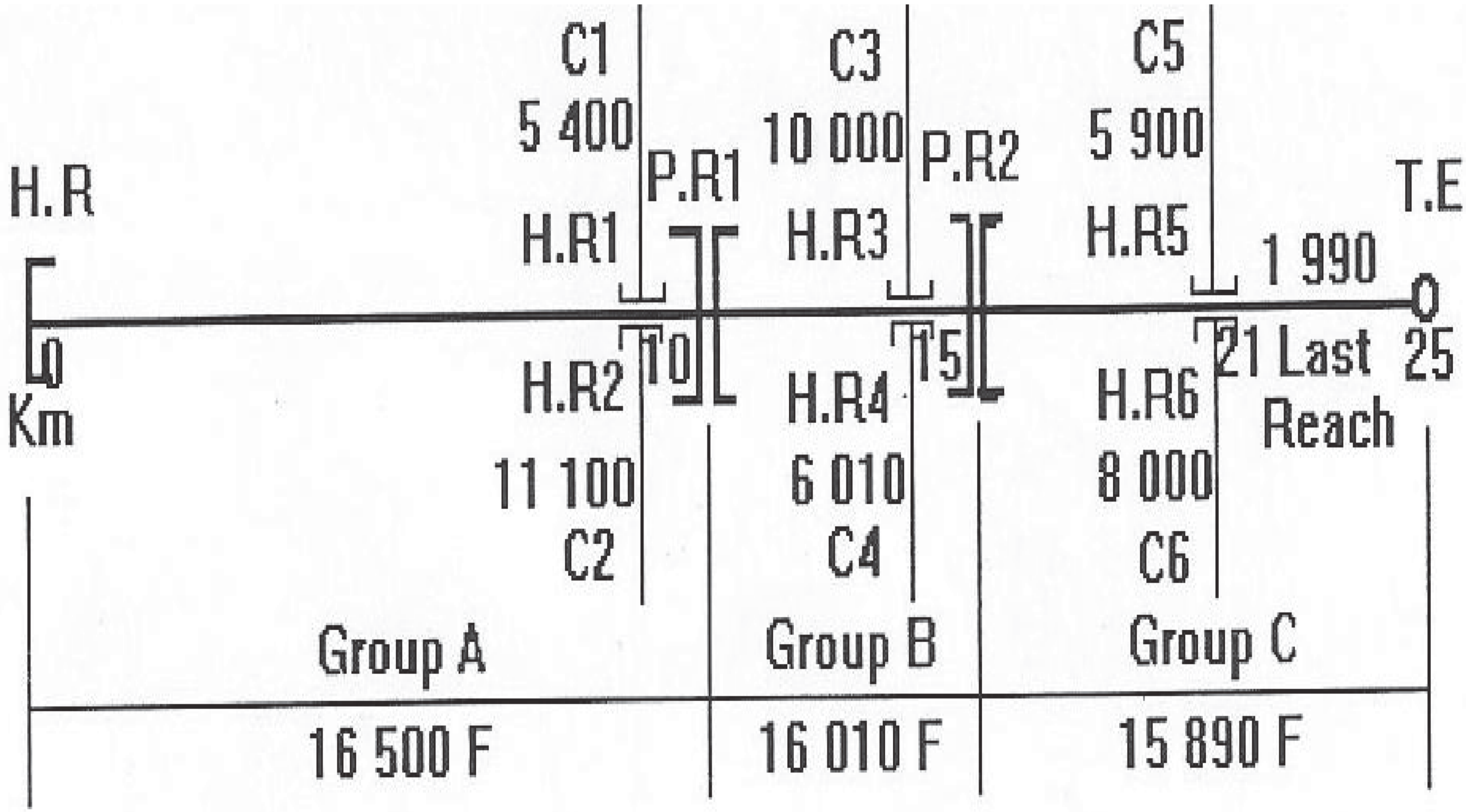
Three turn irrigation rotation:

Average required area served for each turn = $\frac{48,400}{3}$ = 16,133.3 Fed.

For the first turn, take group A = C1 + C2 = 16,500 Fed.

For the second turn, take group B = C3 + C4 = 16,010 Fed.

For the third turn, take group C = C5 + C6 + Direct Irrigation = 15,890 Fed.



C1
5 400
P.R1
C3
10 000
P.R2
C5
5 900
T.E
H.R
H.R1
H.R3
H.R5
1 990
0
10
15
21 Last Reach
25
Km
H.R2
H.R4
H.R6
11 100
6 010
8 000
C2
C4
C6
Group A
Group B
Group C
16 500 F
16 010 F
15 890 F

The Water Duty and the discharge :

Crop	W.D/Irrigation	Irrigated Each	No. of Turns
Rice	$420m^3$/fed	≤8 days	[4+4]
Cotton, Maize, Wheat	$350m^3$/fed	≤18 days	[6+12]
Sharaki	$760m^3$/fed	≤32 days	[4+4]
		≤36 days	[6+12]

The Field Water Duty (F.W.D)=

$\sum$[(% of crop)*($\frac{W.D_{crop}}{On-Interval}$)*(% Irrigated Land)]

The canal discharge (Q)= $\frac{F.W.D*A.S}{24*60*60}$ m^3/s

The Water Duty and the Discharge :

Crop	% Irrigated Land	
	2-Turn [4+4]	3-Turn [6+12]
Rice	All	-----
Cotton, Maize, Wheat	$\frac{1}{2}$	All
Sharaki	$\frac{1}{4}$	$\frac{1}{2}$

Example (4-2):

A diversion canal serves an area of 20km x 21km and feeds two main canals A and B.

The main canal A serves 60 % of the total area, and its area served is cultivated as follows:

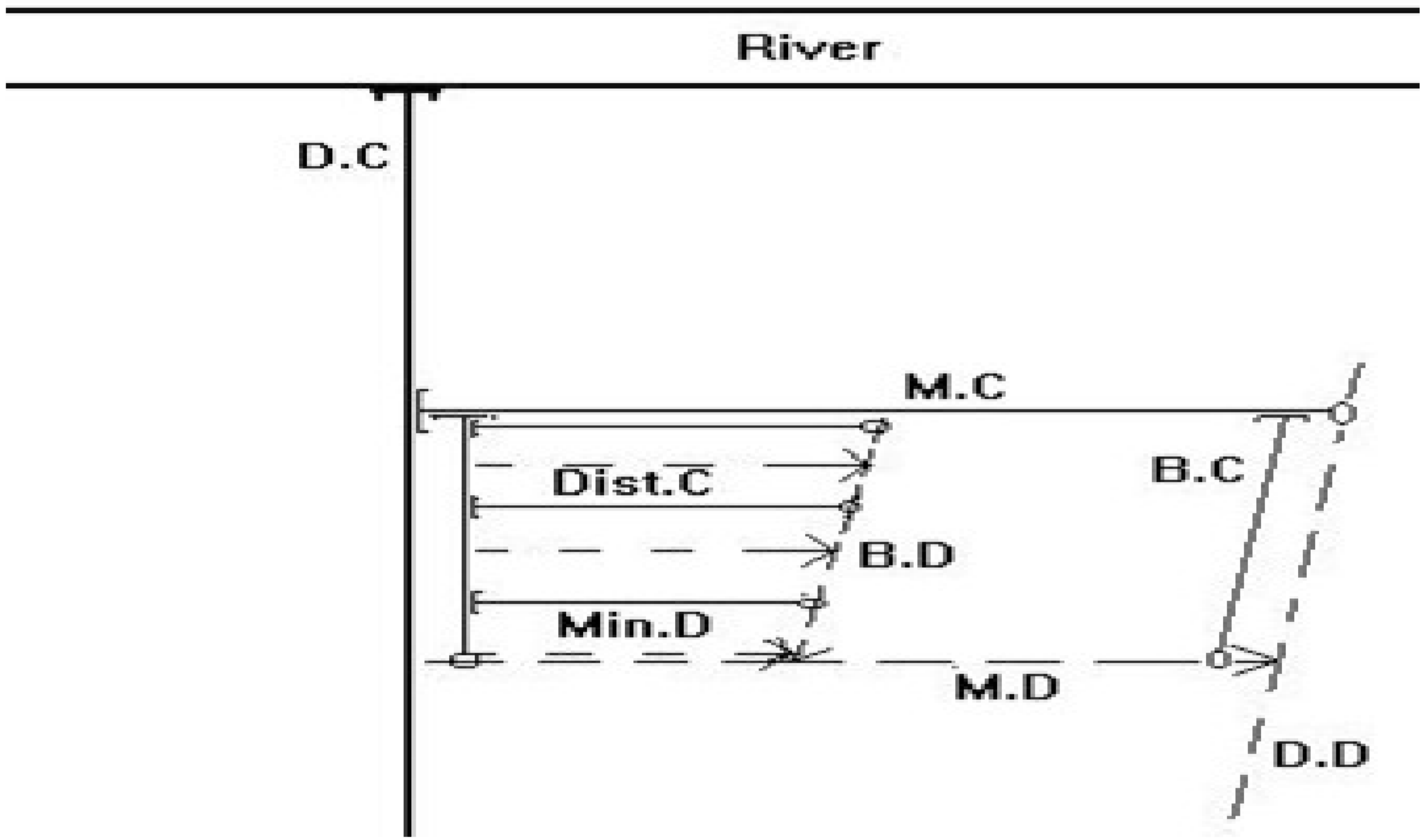
40 % cotton, 50 % sharaki (prepared for cultivating maize), and the rest 10 % is used for the public services.

The main canal B serves 40 % of the total area, and its area served is cultivated as follows:

30 % cotton, 25 % rice, 35 % sharaki (prepared for cultivating maize), and the rest 10 % is used for the public services.

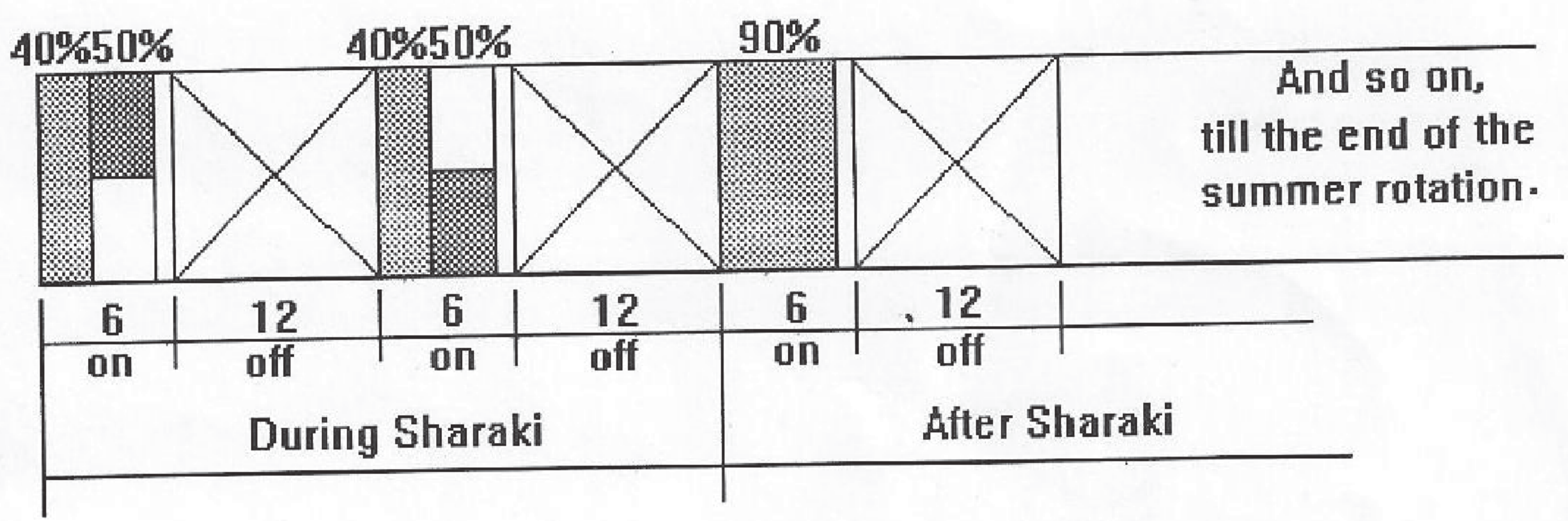
1. Suggest the suitable irrigation rotations for the two main canals A and B?

2. Sketch a diagram for each main canal showing the details of performing the irrigation rotation?
3. Determine the maximum and the minimum discharges passing in the diversion canal?


River
D.C
M.C
Dist.C
B.C
B.D
Min.D
M.D
D.D

The Solution

For the main canal A, use a 3-turn irrigation rotation [6+12].



Crop	W.D/Irrigation	% Irrigated Land	
		2-Turn [4+4]	3-Turn [6+12]
Rice	420m³/fed	All	-----
Cotton, Maize, Wheat	350m³/fed	$\frac{1}{2}$	All
Sharaki	760m³/fed	$\frac{1}{4}$	$\frac{1}{2}$

$F.W.D._{\text{During Sharaqi}}$

$$= \left[\left(\frac{40}{100}\right) * \left(\frac{350}{6}\right) * 1\right] + \left[\left(\frac{50}{100}\right) * \left(\frac{760}{6}\right) * \left(\frac{1}{2}\right)\right] = 55 \text{ m}^3/\text{Fed./day}$$

$F.W.D._{\text{After Sharaqi}}$

$$= \left[\left(\frac{40}{100}\right) * \left(\frac{350}{6}\right) * 1\right] + \left[\left(\frac{50}{100}\right) * \left(\frac{350}{6}\right) * (1)\right]$$

$$= 52.5 \text{ m}^3/\text{Fed./day}$$

Max. M.C.W.D.= 55*1.2= 66 m^3/Fed./day

Min. M.C.W.D.= 52.5*1.2= 63 m^3/Fed./day

These losses are considered when calculating the water duty for the canals as follows:

D.C.W.D. = F.W.D. x 1.10

B.C.W.D. = F.W.D. x 1.15

M.C.W.D. = F.W.D. x 1.20

Where, D.C.W.D.: Distributor canal water duty.

B.C.W.D.: Branch canal water duty.

M.C.W.D.: Main canal water duty.

The canal discharge (Q)= $\frac{F.W.D*A.S}{24*60*60}$ m^3/s

Total A.S.= $\frac{20*21*10^6}{4200} = 100{,}000\ Fed$

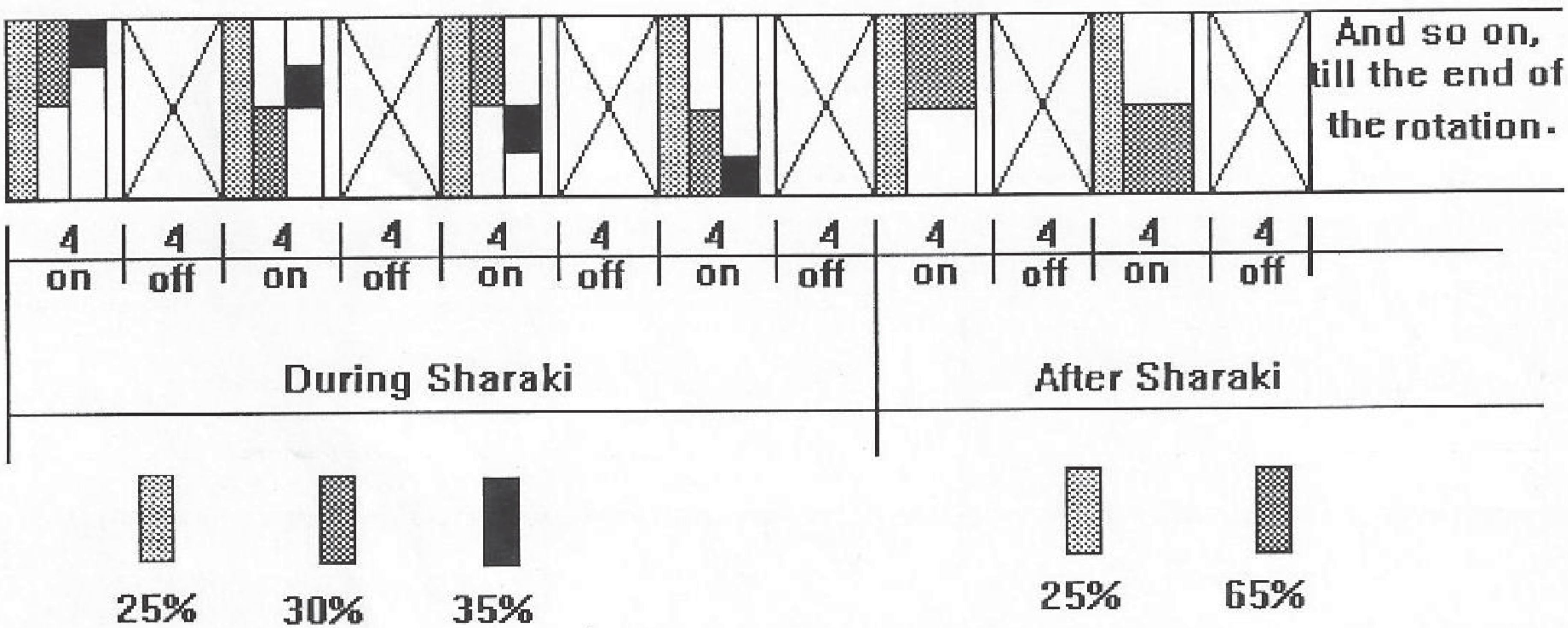
Total A.S. by canal A= $\frac{60}{100} * 100{,}000 = 60{,}000\ Fed$

A.S. by canal A= $\frac{60{,}000}{3} = 20{,}000\ Fed$

$Q_{max.} = \frac{F.W.D_{max}*A.S}{24*60*60} = \frac{66*20{,}000}{24*60*60} = 15.28\ m^3/s$

$Q_{min.} = \frac{F.W.D_{min}*A.S}{24*60*60} = \frac{63*20{,}000}{24*60*60} = 14.58\ m^3/s$

For the main canal B, use a 2-turn irrigation rotation [4+4] due to Rice.



Crop	W.D/Irrigation	% Irrigated Land	
		2-Turn [4+4]	3-Turn [6+12]
Rice	$420m^3$/fed	All	-----
Cotton, Maize, Wheat	$350m^3$/fed	$\frac{1}{2}$	All
Sharaki	$760m^3$/fed	$\frac{1}{4}$	$\frac{1}{2}$

$F.W.D._{\text{During Sharaqi}}$

$$= \left[\left(\frac{25}{100}\right) * \left(\frac{420}{4}\right) * 1\right] + \left[\left(\frac{30}{100}\right) * \left(\frac{350}{4}\right) * \left(\frac{1}{2}\right)\right] + \left[\left(\frac{35}{100}\right) * \left(\frac{760}{4}\right) * \left(\frac{1}{4}\right)\right] = 56 \text{ m}^3/\text{Fed./day}$$

$F.W.D._{\text{After Sharaqi}}$

$$= \left[\left(\frac{25}{100}\right) * \left(\frac{420}{4}\right) * 1\right] + \left[\left(\frac{30}{100}\right) * \left(\frac{350}{4}\right) * \left(\frac{1}{2}\right)\right] + \left[\left(\frac{35}{100}\right) * \left(\frac{350}{4}\right) * \left(\frac{1}{2}\right)\right] = 54.7 \text{ m}^3/\text{Fed./day}$$

Max. M.C.W.D.= 56*1.2= 67.2 m^3/Fed./day

Min. M.C.W.D.= 54.7*1.2= 65.6 m^3/Fed./day

The canal discharge (Q)= $\frac{F.W.D*A.S}{24*60*60}$ m^3/s

Total A.S.= $\frac{20*21*10^6}{4200} = 100{,}000\ Fed$

Total A.S. by canal B= $\frac{40}{100} * 100{,}000 = 40{,}000\ Fed$

A.S. by canal A= $\frac{40{,}000}{2} = 20{,}000\ Fed$

$Q_{max.} = \frac{F.W.D_{max}*A.S}{24*60*60} = \frac{67.2*20{,}000}{24*60*60} = 15.56\ m^3/s$

$Q_{min.} = \frac{F.W.D_{min}*A.S}{24*60*60} = \frac{65.6*20{,}000}{24*60*60} = 15.19\ m^3/s$

For the diversion canal:

$Q_{max} = Q_{Amax} + Q_{Bmax} = 15.28 + 15.56 = 30.84\ m^3/sec.$

$Q_{min} = Q_{Amin} + Q_{Bmin} = 14.58 + 15.19 = 29.77\ m^3/sec.$